ESSAYS ON THE UNITED KINGDOM PHILLIPS CURVE

by

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ESSAYS ON THE UNITED KINDOM PHILLIPS CURVE

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ABSTRACT

This thesis consists of three essays which re-examine some of the issues which were raised by the early research on the Phillips curve from the vantage point of an extended data base and modern computational facilities.

The first essay is primarily a replication of the Lipsey experiment. We ask whether an economist in 1980, presented with the Lipsey regressions and accepting the standard econometric methodology, which emphasises goodness of fit over the estimation period, would have accepted the claim that there exists a stable Phillips curve for the 1851 to 1979 period. Our procedure is to re-estimate the Lipsey equations over the whole period, and various sub-samples, paying particular attention to the need to apply joint significance tests to the excess demand proxies, and to evidence of multicollinearity and serial correlation in the regression residuals. We conclude that our hypothetical economist would have been intrigued by the Phillips-Lipsey equations but highly skeptical about their claim to have unearthed a stable curve.

In the second essay we apply Solow's test of the Acceleration Hypothesis to U. K. data on wage inflation. A variety of formulations of inflationary expectations are explored, both price and wage series being used in order to investigate the Friedman and Phelps approaches to the Acceleration Hypothesis. We conclude that the evidence does not support the adaptive mechanism of expectations formation. The essay also suggests that this type of experiment should be interpreted as testing theories of expectations formation rather than testing "money illusion."

The last essay is concerned with the so-called "alignment problem" which refers to the problem of measuring rates of change so that they are temporally

compatible with the levels variables in the equations. Our approach is primarily empirical and involves comparing estimated Phillips curves using rates of change terms measured in different ways. We conclude that there is sufficient evidence of systematic variation between the various estimates, at least for small samples, to suggest the need for further research on this topic.

FOR JANET AND MARTIN

WITH LOVE

People Who Like This Sort
of Thing Will Find This
The Sort of Thing They Like.

--Abraham Lincoln

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Professor Dennis Maki has the dubious honour of being the longest surviving member of my thesis committee. I wish to thank him for his comments and advice over the years.

Professor Zane Spindler agreed to act as chairperson almost at the last moment and took on the administrative chores associated with seeing the thesis through its final stages. I offer my thanks to him, and to his predecessor Professor Peter Kennedy. I am also most grateful to Professors Archibald, Borcherding and Reed for their parts in the thesis defence.

Journal articles routinely relieve anyone who has commented on the draft manuscript from responsibility for any remaining errors of omission or commission. Theses, for obvious reasons, implicate all concerned as accessories before the fact. I wish, nonetheless, to provide absolution for the above named persons. As Cliff Lloyd would have said, they should not be regarded as responsible people.

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CHAPTER 1

INTRODUCTION AND CONCLUSIONS

"'The errors of great men are venerable because they are more fruitful than the truths of little men.' (Nietzsche, Werke, I, p. 393). For all that, they do not cease to be errors, and one shows little respect for a thinker if one does not take his ideas seriously enough to ask whether they stand up under criticism."

--W. Kaufmann "Discovering the Mind: Goethe, Kant, and Hegel."

INTRODUCTION AND CONCLUSIONS

1. REPLICATION EXPERIMENTS

Professor Thomas Mayer (1980) recently posed the question "Economics as a Hard Science: Realistic Goal or Wishful Thinking?" Presumably all right thinking economists reply "Realistic Goal" since the appellation "soft" scientist would hardly be consonant with our professional dignity. Nonetheless, Mayer, a macroeconomist with an acknowledged expertise in empirical work, plumps for "Wishful Thinking" arguing that the goal is "overly ambitious, premature, and more likely to do harm than good" (Mayer, (1980, p.5)).

Mayer chooses the reliability of their methods for testing hypotheses as his demarcation criterion between the hard and the soft sciences. He characterises the hard sciences as disciplines which utilise the controlled experiment to discriminate between alternative hypotheses, and to decide the truth content of a specific hypothesis. On the other hand the soft sciences, amongst which he includes economics, have little or no recourse to controlled experiment, and they are thus at the mercy of the often poorly designed experiments generated by a capricious, or perhaps, even malicious, Nature. The methodology traditionally adopted by the economist, in her role as applied econometrician, is to use this nonexperimental data to differentiate between rival hypotheses by the goodness of fit of the implied regression equations. Mayer argues that this methodology is inadequate, laying stress on the well known, but almost universally discounted, fact that maximisation of fit over the estimation period in no way guarantees a satisfactory predictive performance outside that sample. The reason, of course, is that apparent improvements in fit are often the consequence of the econometrician erroneously "explaining" part of the stochastic process generating the behavior of the disturbance term rather than "explaining" the systematic part of the population regression. In the limit a "perfect" fit--$R^2=1$--implies that all of the variation of the dependent variable has been accounted for, by the vector of independent variables, which denies one of the basic assumptions underlying the usual statistical model--that the behavior of the dependent variable depends upon an unpredictable stochastic error term.

Further, it is no secret that most empirical workers in economics run many more regressions than they report, and that "fishing" and "mining" are two of the major industries in the economics profession's input-output matrix. However, as Mayer (1980, p. 174) notes "not all data mining is necessarily bad" since economic theory stands mute upon many crucial issues[1]--such as functional specification or the shape of lag distributions--and use of part of the data to provide guidance on these issues is often essential. However, the crucial qualifier in the previous sentence is "part"--we may not use up all of our data for this purpose without simultaneously giving up our ability to utilise a "control data set" which will act as a bench mark for our results. The essence of statistics is comparison, and the essence of scientific objectivity is control. What keeps science honest is the knowledge that someone else can repeat the experiment and expose the cheat. But, in practice, as Mayer stresses, deliberate attempts to mislead are rare.

The trouble lies in our propensity to err, and in the limitations of the frequentist probability theory which is the basis for almost all empirical work in economics.

Let us consider human error first. Anyone who has collected, checked, and processed reasonable sized data sets is aware of how easy it is to transpose, misread, or incorrectly transform figures, misplace decimal points, etc. Thousands of key strokes are involved in the transference to files of the most mundane data sets, and some of these key strokes will be incorrect. Once committed these errors will only come to light if the experiment is repeated by someone else, and in economics replication experiments are rare events. We therefore know that the economic journals contain empirical results which are incorrect because of simple mechanical errors--unfortunately we do not know which of the reported results fall into this category. The only way to find out is to undertake replication experiments. This result is well covered by Mayer.

However Mayer has little to say about our second point--the implications of the frequentist statistical methodology for economic research. Consider a standard hypothesis test. Set up the so-called rejection region corresponding to a one percent significance level, draw a sample and calculate the value of the test statistic. Assume that the sample yields a test statistic several times larger than the approximate "critical value." We are then faced with two choices. Either we assume that we have drawn a "representative" sample from the population, in which case we conclude the null hypothesis is untenable, or, we assume that we have drawn an unrepresentative sample, in which case we conclude that the evidence is not sufficiently reliable for us to reject the null hypothesis. In either case, of course, there is the possibility of making an erroneous inference. With a one percent significance level we will, on average, in a very large number of repetitions of the experiment, reject the null hypothesis when it is in fact true, one time in every one hundred repetitions. But this in no way rules out the possibility that we will make incorrect inferences on the first three repetitions of the experiment, or, for that matter, on the first one hundred repetitions.

In disciplines in which we can conduct controlled experiments this fact is just a nuisance, not a fundamental problem, because ultimately as we increase the number of repetitions of the experiment our run of bad luck will be reversed if the experiment is truly random. But, in a largely non-experimental subject like economics, we are usually given a single sample (to which we add a new observation each year). Phillips, formulating his hypothesis in 1957, might well have been faced with a unique sample consisting only of post-war observations. With a mere twelve annual observations to play with, perhaps even Phillips would have hesitated to estimate a relationship between $\dot{W}$ and U. Admittedly as each year passed the sample size would have increased, but twenty-three years would have had to go by--extending the sample to 1980--before even thirty degrees of freedom would have been achieved. In economics, then, we may be provided with a very atypical sample which we innocently believe at the time to be representative of our population. Believing the sample we erroneously cast out the null hypothesis. Further, in economics a considerable period of time may have to pass before we acquire enough additional observations to recognize the unrepresentativeness of our initial data.[2]

This provides us with another incentive to undertake replication experiments since with a unique sample at our disposal it is important that we make the best use of it we can. Furthermore, if we have committed an error (which is not easily detected) then we may discover this only by repeating the original experiment--hopefully getting it right the second time.

There are, naturally, other reasons why we should undertake replication experiments. Mayer (1980, p. 173) and Lipsey (1979, pp. 283-4) have stressed the need to test hypotheses by repeating experiments with new data sets. These new data may often consist of just a few extra observations which have been generated since the original experiment. Sometimes the new data may refer to a different geographical region or to a different type of data (cross section rather than time series).

Mayer has also stressed (1980, p. 174) "that authors run their regressions in all or many of the numerous and varied forms that are valid. One should then accept only those results that are robust with respect to a wide variety of reasonable techniques." An added incentive to this sort of activity is the generally low esteem attached to replication experiments, which are thought of as "just" being repetitions of the original regression runs using the same data, or an exact reproduction of the original regressions but using a new data set. It is an indication of how few such experiments have actually been undertaken that they can be dismissed so readily. Anyone who has attempted to replicate another economic study need not be reminded how difficult it is to determine which data were used, what transformations were applied to the data, how different series were linked together, which regressions were run, etc. One also has to be an extremely dull person to be satisfied with an exact repetition of a previous experiment. In practice the more one learns about a study the more questions will be raised in one's mind, and the more likely it is that some modification of the original procedure will suggest itself.

In fact, this is a very important and largely neglected issue in applied economics. Although, as we noted above, economists are notorious "data miners" and "regression massagers" surprisngly few economists are aware of the alarming number of alternative regressions which can be run with quite modest data sets, or have considered the implications of this potential plethora of results for research strategy. Consider the following not completely absurd example. Say we have two proxy measures for the nominal price of labour (e.g., weekly earnings and hourly wage rates), three excess demand proxies (e.g., a polynomial in U^{-1}, the difference between measured unemployment and vacancy rates, and an unemployment series "corrected" for demographic shifts), and two proxies for the expected rate of inflation (e.g., current consumer and lagged import prices). Assume that we have three different procedures for estimating rates of change (logarithmic differences, percentage changes, and first centraldifferences), and three time periods available (whole, first half, second half). If we use five different estimation techniques in our study (ordinary least squares, and the Hildreth-Lu grid search and Cochrane-Orcutt interative procedures with, and without, the Prais-Wisten procedure for taking the first observation into account) then we can run 540 regressions which will take about half an hour to set up, but many hours to transcribe, check and write up. Now, in practice, there are usually literally millions of equations which might be estimated in any given situation. The standard procedure in economics is for an economist to choose some combination of the factors we have listed and to run a set of regressions. These regressions are then used to support some hypothesis, and arguments are presented as to why previous researchers' results are incorrect. However, a close examination of a group of such studies usually shows that they possess very little in the way of overlap. One researcher used money wage rates, and annual observations, 1948-1967. The next person moves to quarterly data, but that only exists after 1955 and so the sample also changes--which change is crucial is not made clear. Further research sticks with the quarterly data, but new observations are available and a new estimation technique has recently been introduced. And so on. What we end up with is not a careful accumulation of results, with each new experiment carefully related to previous research so that the reasons why different results are obtained is clear, but often a process of development which looks more like a decision tree than a broad, but coherent, advance along a common line.

It is also true that very little comparative work seems to be undertaken.[3] Hypotheses are often tried out against naive alternatives, but there are few real horse races. Consider, for example, the absence of any studies before about 1976 (for the U.K. economy) of the relative merits of the Phillips curve and the Quantity Theory.

Our final point concerning replication studies is that we should avoid temporal parochialism. A well known U.K. forecaster once commented--and only partly in jest--that "the world is quarterly and life began in 1963." Now, from a forecasting point of view, there may indeed be great advantages to concentrating on the most up-to-date sample available. However, that sample may be very atypical of the overall behavior of the economy, e.g., in the U.K. between 1947 and 1966 the unemployment rate fluctuated over a very restricted range (unemployment only exceeded 3 percent in one quarter). One consequence was that linear Phillips curves seemed to fit the data satisfactorily, but that that linear curve may actually represent a linear approximation (for a restricted data set close to the origin) to the highly non-linear curve which Phillips hypothesised on the basis of his analysis of some ninety years of data where the unemployment level varied between 0.95 and 22.1 percent.

On the other hand, it could be argued that in order to get a reasonable size sample with annual data you are forced to treat periods of time with quite different characteristics as if they were homogeneous. Further it seems likely that, at least since World War II, the year is too long an interval to capture the cyclical behavior of excess demand. However, economic hypotheses are supposed to be universally valid--not just true for some recent period, and, although the point about the shorter period of the cycle is well taken, what that really implies is that we should attempt to use the largest quarterly series available (which in the U.K. is from about 1919 to the present). If we are unable to explain why our hypotheses fail to fit the facts in some historical episode then we must be skeptical about the claims of these hypotheses. In any event in the work we have undertaken we have endeavored to use as long a time series as possible, even though we are far from satisfied with the quality of some of the data.

2. CONCLUSIONS

We will now outline the major conclusions of the three essays.

(1) Chapter 2: The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1851-1979

This essay falls into two parts. The first section provides a commentary on the early interpetations of the Phillips curve and their origins. We observe that Phillips introduced his relation in his 1954 article in terms of a mapping from aggregate capacity utilisation to the rate of price inflation. We argue that Phillips, and Lipsey in his 1960 paper, did not interpret the Phillips curve as a trade-off between inflation and unemployment, but rather as a model of disequilibrium adjustment in the aggregate labor market, and we trace the trade-off interpretation to the Samuelson and Solow A.E.A. conference paper. We then review the controversy between Desai and Gilbert concerning Desai's contention that Phillips interpreted his curve as a phase relation. We conclude, on the basis of the evidence in Phillips' neglected 1959 paper, that both Desai and Gilbert are incorrect, and that the only reason Phillips adopted his unusual estimation technique was because he had not yet realised that the polynomial in U^{-1} provided an adequate approximation to his non-linear equation.

The second part of the essay presents the results of a replication experiment in which we use annual U.K. data for the 1851-1979 period (and various sub-periods) to attempt to answer two questions: if the Phillips curve is dead, was it ever alive? and, if the Phillips curve was once alive, when did it die? We conclude that there was a Phillips curve for th U.K. before World War I but that that relationship does not hold for the periods after 1918. If a replication experiment for the Lipsey study had been conducted in the early nineteen-sixties this would have revealed the break-down of the Phillips relationship after the First World War.

(2) Chapter 3: Expectations, Money Illusion and the Acceleration Hypothesis: United Kingdom, 1851-1979

This essay is concerned with early attempts to test the Acceleration Hypothesis using U.K. data. The first part of the essay argues that the standard test of the Acceleration Hypothesis needs to be reinterpreted. The usual interpretation of the test requires that we assume that we have evidence for money illusion in labor market transactions if the so-called alpha coefficient (the coefficient of the expected inflation term) is estimated to be less than unity. This requires us to assume that we have modelled the expectations mechanism correctly. We suggest re-interpreting such results as indicating an incorrectly modelled expectations formation hypothesis on the grounds that the absence of money illusion is a much better founded hypothesis than any of the currently existing theories of expectations formation.

The second part of the essay describes the result of an experiment using the adaptive expectations mechanism to generate a number of proxies for the expected rate of inflation, and to incorprate them, using the Cagan and Solow techniques, in a so-called augmented Phillips curve equation. We ran many regressions for the whole 1851-1979 period and sub-periods, evaluating the equations by goodness of fit and the closeness of alpha to unity. We also used the actual rate of inflation, the rate of inflation of food prices, and the rate of wage change as proxies. We conclude that our experiment offers no support for the adaptive expectations approach and that the formulations utilising the actual rate of inflation are superior.

(3) Chapter 4: Rates of Change and Phillips Curve Estimates: United Kingdom, 1922-1978

In the final essay we turn our attention to the so-called alignment problem--the problem of measuring the rates of change of the variables so that they are correctly aligned with the levels variables in the Phillips curve equation--and the general issue of how to measure the dependent variable in Phillips curve regressions. We ran a number of regressions using different rates measures and conclude that, as has been long suspected, the traditional first central difference measure introduces a second-order moving average process into the equation residuals. The last part of the paper reports some attempts to incorporate this error formulation into the estimation process. We conclude that such a procedure does lead to improved results.

FOOTNOTES

[1]In this respect there is no difference between economic theory and theoretical physics, although some economists seem to believe that "theory" in economics is qualitative whereas "theory" in physics is quantitative. This is, of course, not the case. All theory is qualitative. The differences between physics and economics are: physicists have been doing physics for longer than economists have been doing economics; physical systems and interactions are generally much less complicated, and much better behaved, than are economic systems; and, the physicist's ability to undertake controlled experiments ensures that physical measurements are known with far greater precision than are any comparable economic relationships. As a consequence of these differences the physicist is able to enter well defined, and accurately measured, quantities into her equations, while the economist cannot.

[2]Of course, if we act on our inference--initiate some policy--then this activity, and its repercussions, may generate additional information (not necessarily of the same type as we started with) which may act as a check on our inference.

[3]Henry, Sawyer, and Smith (1976), and some of the work by Cross and Laidler (e.g., 1975) are notable exceptions.

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CHAPTER 2

THE RELATION BETWEEN UNEMPLOYMENT AND THE RATE OF CHANGE OF MONEY WAGE RATES IN THE UNITED KINGDOM, 1851-1979

"Economists love to draw curves."

--Martin Gardner

THE RELATION BETWEEN UNEMPLOYMENT AND THE RATE OF CHANGE OF MONEY WAGE RATES IN THE UNITED KINGDOM, 1851-1979

I. INTRODUCTION

Almost a quarter of a century has passed since the New Zealand economist, A. W. Phillips,[1] published his celebrated Economica[2] article on the U.K. Phillips curve. As is well known, in that paper Phillips attempted to show that the curve which he had estimated (using annual data from 1861-1913) adequately explained the behaviour of wage inflation in the U.K. between 1948 and 1957. Phillips' paper quickly attracted critical notice in the U.K. from Routh, and Knowles and Winsten. Then, in February 1960, Phillips' colleague, R. G. Lipsey, (1960) presented a reformulation of Phillips' equation which was susceptible to estimation by the familiar multiple regression technique. In addition to re-estimating Phillips' equation, Lipsey formalised and elaborated Phillips' theory, and subjected his model to a number of statistical tests. Meanwhile, at the December 1959 meeting of the American Economic Association, Samuelson and Solow[3] had (implicitly) re-interpreted Phillips' work, arguing that Phillips had discovered that there was a trade-off between inflation and unemployment, and presenting the first empirical analysis of such a trade-off using U.S. data. Samuelson (1961) incorporated the Phillips curve (in its trade-off guise) into the fifth edition of his undergraduate textbook,[4] after which the Phillips curve was rapidly absorbed into mainstream macroeconomics.

By 1962 the standing of the Phillips curve in the economics profession could be roughly characterised as follows. The Phillips curve was conceived as a (univerally valid) trade-off between inflation and unemployment defining the locus of combinations of these two objectives which were empirically attainable by economic policy. Further, it was believed that Phillips had demonstrated that the trade-off was remarkably stable over the ninety-seven years of British data which he analysed.

The subsequent history of the Phillips curve falls into two phases. The first phase lasted until about 1969. During the 1960s the idea of a trade-off between inflation and unemployment became widely accepted by policy makers and economic commentators as well as by academic economists. Although little theoretical development occurred during these years there was extensive empirical research (aided by the rapid advances in computer technology which were occurring simultaneously), and Phillips curves were estimated for most developed countries (almost always, because of data limitations, for some subset of the post-Second World War period).[5]

The second phase was ushered in by two developments. On the empirical level trouble developed for the U.K. Phillips curve about 1967 and soon there were reports from other countries that high (and even increasing) levels of unemployment were no longer being accompanied by falling rates of wage and price inflation. The Phillips curve appeared to have become positively sloped and the era of "stagflation" had begun. Then, in 1967 and 1968, important theoretical papers were published by Friedman and Phelps[6] who argued that the original of the Phillips curve involved a major misspecification, and e absence of that misspecification, we would expect the :ve to become vertical in the "long run." In particular, that the apparent short-run trade-off would disappear if attempted to exploit it. During the second phase, which loosely to the decade of the 1970s, the economics profession llusioned with the Phillips curve. Most economists now seem that there is no exploitable long-run trade-off between and unemployment,[7] and that the short-run Phillips curve is . steeply sloped and temporally unstable.[8] Like Algernon Moncrieff's Bunbury, the Phillips curve is "quite exploded."

In terms of frequency of citation and the quality of the theoretical and empirical research it engendered, Phillips' paper was one of the most successful articles ever published in economics.[9] Yet, it would seem that Phillips' idea was a failure.[10] Indeed, some economists have argued that the Phillips curve concept was a major social disaster since it persuaded policymakers that they could buy lower unemployment levels by accepting higher levels of inflation.[11]

The primary objective of this paper is to re-examine the empirical evidence which was used to establish the claim that there existed a stable empirical Phillips curve for the U.K. economy before 1957. We will attempt to answer (in the context of the British economy) two questions. First: if, as has sometimes been claimed,[12] the Phillips curve is dead, was it ever alive? Second: if the Phillips curve was once alive, when did it die? Our procedure is to estimate Phillips curves using sub-sets of our data base.[13] We evaluate the regression results using the conventional criteria which have dominated research in applied econometrics during the last quarter of a century.[14] In particular we concentrate on the overall fit of the equations (as measured by the coefficient of determination and F statistics), how well determined are the estimated coefficients (are they statistically significant according to the usual t-test? Do they have expected signs and plausible magnitudes?), and whether there is evidence of first-order serial correlation among the equation residuals. We are also concerned with problems of multicollinearity and with the temporal stability of the estimated equation.

Before proceeding to our experiment (which is the subject of the third section of the paper), we devote section 2 of the paper to a discussion of the various interpretations which have appeared in the literature of Phillips' 1958 article and examine Phillips' unjustly neglected paper written in Australia in 1959. Section 4 of the paper concentrates on the question of the stability of the estimated Phillips curves. The final section provides conclusions and suggestions for further research.

2. INTERPRETATIONS OF PHILLIPS 1958 ARTICLE

The conventional economic wisdom concerning the Phillips curve might be characterised as follows:

1. Phillips introduced the Phillips curve in his 1958 paper.

2. The Phillips curve defines the economy's empirical trade-off between inflation and unemployment.

3. Phillips failed to provide a theoretical rationale for his hypothesis. The theory had to be provided by Lipsey in his 1960 paper.

4. Phillips discovered a remarkably stable empirical relationship which accounted for over ninety years of British economic history.

5. Lipsey's replication experiment confirmed Phillips' findings. Lipsey's major empirical contribution was to show how to estimate the curve using conventional statistical techniques.

6. The Phillips curve for the U.K. (and most other countries) was stable until 1966 after which the relationship broke down.

In this section we will examine the validity of points 1-3 (and 5), and in section 3 below we will take up the status of points 4-6.

It is by now reasonably well established[15] that Phillips introduced the Phillips curve into modern macroeconomics in Section II.1 ("The Relationship between Prices and Production") of his 1954 paper concerned with the application of closed-loop control techniques to the problems of optimal stabilisation policy. This initial formulation by Phillips is worth quoting at length. He writes:

> "If changes in the quality and productivity of the factors of production are ignored, the change in the average level of product prices which results from a given change in the aggregate level of production will be the sum of two components. First, if the prices of the services of the factors of production (which will be referred to for brevity as factor prices) are absolutely rigid, product prices, tending to move with marginal costs, will vary directly with the level of production. This component of the change in product prices is probably not very large, and will be neglected in the following analysis.

Second, if factor prices have some degree of flexibility, there will be changes in product prices resulting from the changes which take place in factor prices. Even with flexible factor prices, there will be some level of production and employment which, given the bargaining powers of the different groups in the economy, will just result in the average level of factor prices remaining constant, this level of production being lower the stronger and more aggressive the organisation of the factors of production. If aggregate real demand is high enough to make a higher level of production than this profitable, entrepreneurs will be more anxious to obtain (and to retain) the services of labour and other factors of production and no less inclined to resist demands for higher wages and other factor rewards. Factor prices will therefore rise. The level of demand being high, the rising costs will be passed on in the form of higher product prices. Factor and product prices will continue to rise in this way so long as the high level of demand and production is maintained, the rate at which they rise being greater, the higher the level of demand and production" (Phillips (1954, p. 307)).

He continues

"We may therefore postulate a relationship between the level of production and the rate of change of factor prices, which is probably of the form shown in Fig. 11 (see our Figure 1 below), the fairly sharp bend in the curve where it passes through zero (sic) rate of change of prices being the result of the greater rigidity of factor prices in the downward than in the upward direction. The relationship between the level of production and the rate of change of product prices will be a similar shape if productivity is constant" (Phillips (1954, p. 308)).

A number of points are worthy of comment. First, Phillips' formulation of his famous relation treats inflation as a disequilibrium adjustment process. Second, and related to the previous point, Phillips' analytical structure is a standard aggregative general equilibrium system with a number of interrelated markets, each of which behaves like the familiar competitive supply and demand model.[16] Third, Phillips has a well defined transmission mechanism generating his inflationary processes. Exogenous changes in the aggregate demand for goods and services (perhaps initiated by monetary or fiscal policy) lead to induced changes in the derived demand for factors of production (especially labour), which, in turn, bring about changes in factor prices, which cause changes in the prices of final goods and services. Fourthly, observe that, although Phillips' name has often been linked with the so-called cost-push approach to inflation, he in fact lays stress upon the competitive bidding of employers as being the prime mover of factor prices. Finally, it is clear that Phillips' exposition does not even hint at a trade-off interpretation of his curve linking inflation and excess demand for output.

Of course, as Lipsey (1979, p. 50) has observed, "The articles on stabilization policy attracted significant attention among specialists,

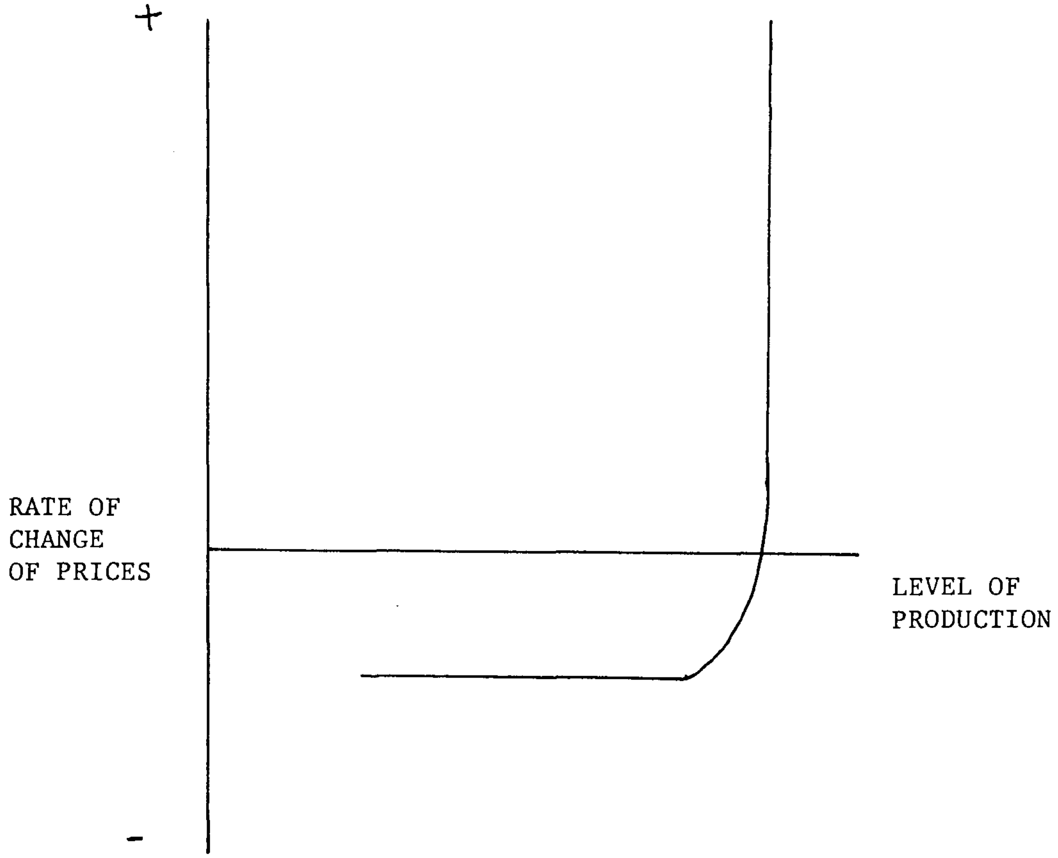


Figure 2.1 (This corresponds to Phillips' Fig. 11 (Phillips (1954, p. 308)).)

but the particular Phillips curve relation went largely unremarked in the literature until the now-famous 1958 article." Phillips' rationale for his curve is set out in that article quite explicitly although in a purely verbal form. He writes, in the often quoted first paragraph:

> "When the demand for a commodity or service is high relatively to the supply of it we expect the price to rise, the rate of rise being greater the greater the excess demand. Conversely when the demand is low relatively to the supply we expect the price to fall, the rate of fall being greater the greater the deficiency of demand. It seems plausible that this principle should operate as one of the factors determining the rate of change of money wage rates, which are the price of labour services. When the demand for labour is high and there are very few unemployed we should expect employers to bid wage rates up quite rapidly....On the other hand it appears that workers are reluctant to offer their services at less than the prevailing rates when the demand for labour is low and unemployment is high so that wages fall only very slowly" (Phillips (1958, p. 283)).

Here we have a clear statement of the traditional excess demand mechanism which has been used to explain the disequilibrium behaviour of competitive markets since Marshall. Admittedly Phillips seems to have confused the <u>nominal</u> wage with the price of laborr (the <u>real</u> wage), but this probably reflects his interest in describing the <u>actual</u> process of adjustment in labour markets which, of course, involves negotiations concerning the <u>money</u> wage rate not the real rate.[17] Notice that

Phillips seems to be arguing, as an empirical generalisation, that the reaction function is non-linear,[18] and hence the Phillips curve is non-linear, rather than deriving the non-linearity of the Phillips curve from the non-linearity of the transformation function linking employment and excess demand.[19] Also notice that Phillips does not invoke the trade-off interpretation of his curve in this passage, nor, as far as we can determine, anywhere else in his paper.

Although Phillips' 1958 paper does not contain an algebraic formulation of his model, the basic structure of his theory is clearly explained in the first two pages of exposition. His neglect of formal mathematics obviously did not stem from any technical limitations on his part (as is clear from a perusal of his papers on stabilisation policy), the most likely explanation for this omission, is that Phillips felt that the exercise was too trivial to be worth the effort, and that he believed that his readers would already be familiar with his earlier work--especially the 1954 paper.[20]

Lipsey's 1960 paper does contain a long theoretical section[21] (Lipsey (1960, pp. 12-23)). Most of this theoretical development, however, is devoted to an elaborate explanation of Phillips' famous "loops," and the only attempt to elaborate the basic labour market model is relegated to a footnote (Lipsey (1960, n. 1, p. 15)). The relationship between the Phillips curve as an adjustment mechanism for a labour market embedded in a fully articulated macroeconomic model--which is essentially the role Phillips assigned his curve--is not pursued in Lipsey's paper.[22]

A careful reading of Lipsey's article also fails to turn up any explicit trade-off interpretation of the Phillips curve. Indeed, Lipsey's strictures against policies designed to keep unemployment constant (Lipsey (1960, pp. 31-32 and 1979, p. 56)) suggest that such an interpretation was far from his mind.[23] We believe that the first appearance of the trade-off interpretation occurs in the paper by Samuelson and Solow where they say: "In order to achieve the nonperfectionist's goal of high enough output to give us no more than 3 percent unemployment, the price index might have to rise by as much as 4 to 5 percent per year. That much price rise would seem to be the <u>necessary cost</u> of high employment and production..." (1960, p. 192, emphasis added). Also the legend to their Fig. 2 (1960, p. 192) reads: "Modified Phillips Curve for U.S. This shows the <u>menu</u> of <u>choice</u> between different degrees of unemployment and price stability as roughly estimated from (sic) last twenty-five years of American data" (1960, p. 192, emphasis added).[24] We conclude that, contrary to popular belief, Phillips introduced his curve into economics in 1954, not 1958, that he provided a brief but adequate theoretical rationale for the relationship, that neither he nor Lipsey interpreted the curve in terms of a policy trade-off, and that the trade-off interpretation and the term Phillips curve both originate with the Samuelson and Solow article. We now turn our attention to Desai's attempt to reinterpret Phillips' work and to distinguish between what he calls the Phillips curve and the Lipsey curve.[25]

Phillips had argued that $\dot{W} = f(U, \dot{U}, \dot{P})$ where $\dot{W}$ is the rate of change of money wage rates, U is the unemployment percentage (acting as a proxy for the excess demand for labour), $\dot{U}$ is the rate of change of unemployment (introduced to improve the ability of U to proxy excess demand (see below)), and where $\dot{P}$ is a proxy for the cost of living (either a consumer price index or an index of import prices). Phillips plotted his data on $\dot{W}$ and U for the period 1861 to 1913, and then plotted the average values of these variables for six unemployment intervals. On the basis of his inspection of the scatter diagrams Phillips decided to estimate the highly non-linear equation

(1) $\dot{W} + a = bU^c$

which is equivalent to

(2) $\log (\dot{W} + a) = \log b + c \log U$.

Unfortunately, since $\dot{W}$ takes non-positive values in the sample a conventional logarithmic regression was not appropriate. Therefore Phillips estimated the coefficient a by eye (using the crosses in the two right hand unemployment intervals: 5-7% and 7-11%), and then used the remaining four average observations to estimate the coefficients b and c by least squares.[26] The equation he obtained was

$$\dot{W} = -0.9 + 9.638\ U^{-1.394}$$

which is plotted on his scatter diagram.[27]

When Lipsey undertook his replication experiment he replaced the difficult nonlinear form of the equation adopted by Phillips[28] by the linear (in coefficients) equation:[29]

(3) $\dot{W} = a + bU^{-1} + cU^{-2}$.

Thus Lipsey opened the floodgate of Phillips curve estimation which has kept the wolf from the door of many a fledgling economist during the last twenty years.

Apart from its attractive simplicity, Lipsey's approach has the advantage that it makes conventional hypothesis testing possible. Phillips' procedure had quite unknown statistical properties and the only way of evaluating the curve seemed to be in terms of its forecasting abilities.[30] However the major limitations of Phillips' approach is its essentially bivariate nature which is associated with the need to estimate the a coefficient by eye. It will have been observed that Phillips started with a four dimensional surface which he reduced to a two dimensional curve, by first dropping the $\dot{P}$ variable (without any attempt to justify doing so), and then using his averaging procedure to eliminate $\dot{U}$.[31]

Recently Desai (1975)[32] has sought to reinterpret Phillips, laying stress on Phillips' averaging procedure, and, as we have already seen, drawing a distinction between the Phillips curve and the Lipsey curve. Desai's main point is that the Phillips curve should be thought of as a phase equation ("...an equilibrium solution of a (non-linear) differential equation" Desai (1975, p. 5)), while Phillips' averaging procedure should be thought of as a transformation designed to remove "the problem from the time domain altogether" (Desai (1975, p. 7)).[33]

Gilbert argues that, not only did Desai misunderstand the procedure used by Phillips to estimate his curve,[34] but he also misunderstood Phillips' reason for adopting that procedure. Gilbert refers to Phillips' characterisation of his curve as "likely to be highly non-linear" (Gilbert (1976, p. 52) and Phillips (1958, p. 283)), and notes that Phillips (1958, n. 3, pp. 290-1) proposed a specific functional form for his curve:

$$(4)\ \dot{W}_t + a = bU_t^c + k(1/U_t^m DU_t)$$

where a, b, c, k and m are constants and $DU_t = dU/dt$. Gilbert observes that Phillips' problem was to obtain a linear approximation to this equation--which he achieved in two steps. "The first was to argue that since U_t is a trend-free variable, U_t^c will be uncorrelated with U_t^{-m} DU_t. This implies that if one is prepared to regard c and m as known, the regressors U_t^c and U_t^{-m} DU_t will be orthogonal and hence the latter term may be omitted from the regression without biasing the estimated coefficient ($\hat{b}$) of the former" (Gilbert (1976, p. 52)). Phillips, according to Gilbert, was therefore able to drop the $\dot{U}$ term from his equation and to concentrate on the relationship between $\dot{W}$ and U. (Note that all these authors conveniently disregard $\dot{P}$ in their discussions.) Further, the Phillips curve equation (1)

$$\dot{W}_t + a = bU_t^c$$

could, as we have seen, be estimated by least squares if an estimate of a, $\hat{a}$, could be found such that

$$(5)\quad \dot{W}_t + \hat{a} > 0.$$

Gilbert points out that the estimation procedure requires that (1) has a multiplicative error term, and he argues that the omissions of the kU_t^{-m} DU_t term, which enables us to go from (4) to (1), implies an error term which "must be at least in part additive" (Gilbert (1976, p. 53)). Gilbert then asserts that the true significance of Phillips' averaging procedure, and his emphasis that that procedure guaranteed that $\dot{U}$ would be approximately zero, is that it removes the difficult additive error term. Gilbert argues that Phillips preferred to obtain (using (1)) an approximation to the "true relation (4) rather than getting an accurate estimate of the approximate equation (3).

At this point we must turn our attention to the curiously neglected paper which Phillips wrote during his visit to Australia in 1959, and which was published, by the New South Wales and Victorian branches of the Economic Society of Australia and New Zealand, in August 1959 (Phillips (1959)).[35] There are a number of features of this paper which are worth discussing, one of which--the treatment of prices in the Phillips curve equation--we will return to below:

1. This paper, like that written at London School of Economics, contains no trace of the trade-off interpretation of the Phillips curve, if, by this terminology, we mean an advocacy of exploiting the Phillips curve to achieve lower unemployment levels at the cost of higher inflation, and vice versa. Section 3 (Statistical Estimation) contains a number of calculations, similar to those in the 1958 paper, by which Phillips sought to explore different combinations of inflation and unemployment which were compatible with his estimated relationship. Section 4 (Policy Implications) begins with the observation that the estimated relationship indicates the incompatibility of full employment and price stability for the Australian economy.

2. This paper seems to be the first article to use quarterly data to estimate a Phillips curve.[36]

3. Phillips enters the excess demand proxies (the unemployment terms), import and export prices, and (in the equation in footnote 2, p. 5) the rate of change of money wages, with lags of up to three periods.[37] Phillips also introduced distributed lags into the Phillips curve estimation process (Phillips (1959, p. 5)).

4. Phillips drops the $\dot{U}$ term from his equation.

5. Phillips uses two sorts of transformation of the unemployment variable to improve the ability of unemployment to proxy the excess demand for labour.[38]

From our perspective it is this last point which is most important. It would seem that Phillips was the first person to publish an estimated "Lipsey curve." The famous Lipsey device of estimating a polynomial in U^{-1} seems to have been first developed by Phillips in his Australian research. Further, Phillips' formulation of the equation, with its complex dynamics, pushed the analysis to a point which the better known literature does not reach for another five to ten years. Observe, however, that Phillips does not report any of the standard statistics which we have come to expect to be attached to regression results in applied econometrics.

Lipsey was presumably unaware of Phillips' Australian research at the time he was doing his own analysis with Phillips' U.K. data. Strangely, Phillips never seems to have brought his work to Lipsey's notice, although he did discuss it in his macroeconomics lectures to the L.S.E. M.Sc. Econ. programme in the early 1960s.[39] We have not been able to find any reference by Lipsey to Phillips' 1959 article--it does not appear, for example, in Lipsey's list of references attached to his 1979 memorial paper[40]--nor does Phillips refer to the paper himself in those of his later publications which deal with macroeconomic policy.[41] Phillips' 1959 paper, as a consequence of its relatively obscure place of publication and its author's reticence, has therefore gone largely unnoticed until Perry's recent unearthing. In particular it does not seem to have come to the notice of either Desai[42] or Gilbert, although its relevance to their debate is obvious. If Desai's interpretation of Phillips is correct, we would expect Phillips to have continued to use his averaging "transformation" in any subsequent empirical work he undertook on the Phillips curve.[43] But in the Australian study, completed within a year of his Economica paper, he introduced the standard estimation procedure which is usually associated with Lipsey's work.[44] We conclude that Desai's argument is unfounded and agree with Gilbert (1976, p. 57) that "Phillips' averaging procedure...was merely a computational device...so there is no distinction between the Phillips and Lipsey curves." However, we note that Phillips' 1959 paper also throws doubt upon Gilbert's ingenious argument that Phillips adopted his approach in order to achieve the "log-linearization of an equation with an additive error term."

In our opinion Phillips' averaging procedure served two purposes: it enabled him to eliminate $\dot{U}$ from $\dot{W} = f(U, \dot{U})$ so that he could estimate a by eye, and it enabled him to estimate a "long run" curve. "Long run" referring not to the accelerationists' expectational usage but to a secular average, or trend relationship. As we have already observed above Phillips seems to have thought of the economy as moving along a cyclical path around a long-run trend. His careful analysis of the cyclical behaviour of his $\dot{W}$ and U series is well known, and it seems likely that, when he writes of each of his average points being associated with $\dot{U} = 0$, what he had in mind was that the corresponding points on the Phillips curve were in some sense equilibrium points associated with the long run behaviour of the system. The Phillips curve, on this interpretation represents the "normal" or average response of the labour market to excess demand conditions--abstracting from cyclical fluctuations (which include the effects of random events).[45] The actual path of the economy in any historical cycle corresponds to a specific loop around the curve.[46] The full Lipsey equation, including the U term, is then attempting to detect the average cycle (or loop) over the data set.

We now turn our attention to reporting the results of our empirical work.

3. THE EXPERIMENT[47]

In the next three sub-sections of the paper we report the pre-World War One, Interwar, and post-Second World War results. The final sub-section provides an overall evaluation of the empirical research and attempts to answer the two questions posed in the general introduction to the paper.

(1) THE PRE-WORLD WAR ONE PERIOD[48]

Phillips claimed to have discovered a stable empirical relationship between the rate of change of money wage rates, the level of unemployment and the rate of change of unemployment. "...except in or immediately after those years in which there was a very rapid rise in import prices" (Phillips (1958, p. 184)). In particular he claimed that the relationship between the variables that held during the period 1861-1913 could be used to explain the rate of change of money wage rates in the period after the Second World War. In fact, as we have already noted, Phillips estimated his curve only for the 1861-1913 period and only for the relationship between the rate of change of money wage rates and the level of unemployment (i.e. he did not include the rates of change of unemployment and import prices in his estimating equations.)

Lipsey reformulated Phillips curve and estimated the following equation:[49]

$$\dot{W} = -0.94 + 4.92\ U^{-1} + 3.66\ U^{-2} - 0.016\ \dot{U} + 0.20\ \dot{P}.$$

We re-estimated Lipsey's equation[50] and obtained:

$$\underset{(-2.08)}{\dot{W} = -0.94} + \underset{(2.15)}{4.92\ U^{-1}} + \underset{(1.60)}{3.67\ U^{-2}} - \underset{(-4.24)}{0.016\ \dot{U}} + \underset{(2.68)}{0.20\ \dot{P}}.$$

$R^2 = .82$ $\bar{R}^2 = 0.80$ $F(4,47) = 52.2$ $DW = 1.12$

The overall fit is good with the equation accounting for about 80% of the variation in the dependent variable. The t statistics are given in parentheses below each coefficient. Only the t-value for the coefficient on U^{-2} is statistically non-significant (the 5% critical value for a one-tail test is approximately 1.68). However, we are really maintaining the hypothesis that $\dot{W} = f(U)$ rather than the hypothesis that $\dot{W} = g(U^{-1}, U^{-2})$ where the U^{-i}s are treated independently. Therefore we should be concerned with the joint significance of the U terms, and, hence an F test is appropriate. Since $F(2,47) = 67.2$ and the critical value of F, at the 1% level, is less than 7.20, we reject the hypothesis that both of the coefficients on U^{-1} and U^{-2} are zero. However the relatively low value of the t statistic for U^{-2} raises the possibility that the U^{-i}s may be collinear. The simple correlation coefficient between U^{-1} and U^{-2}, which is 0.95, indicates that this is indeed a problem.

The coefficient on $\dot{P}$ is significantly different from zero at the 1% level, but it is not clear what $\dot{P}$ is doing in the regression. Phillips had originally argued rather loosely[51] for cost-of-living effects being important in the wage determination process. However, as Archibald was to point out in 1969, since the unemployment variables are acting as proxies for the excess demand for labour, any variable that alters either the demand or the supply of labour will have been taken into account already, and hence, changes in these variables will cause movements along, not shifts of, the Phillips curve. Further Phillips formulated his model in terms of changes in import prices, whereas Lipsey incorporated changes in retail prices in his equation. Prima facie $\dot{P}$ appears to be what Archibald calls an "intruder" variable, but there is one obvious (with hindsight!, see Lipsey (1979)) interpretation that would justify its inclusion, which is to assume that $\dot{P}$ is a proxy for the expected rate of change of consumer prices over the next year. Notice, however, that the coefficient on $\dot{P}$ is significantly less than one, and so the equation appears to provide no support for the Acceleration Hypothesis.

On conventional criteria $\ddot{U}$ is significantly different from zero at the 1% level, but it is again not clear why it should appear in the equation. Phillips introduced $\dot{U}$ to take account of the famous loops that he discovered around his fitted curve in each of the pre-World War One cycles. Phillips (1958, p. 283) justified the inclusion of $\dot{U}$ on the grounds that it acted as a proxy for expected unemployment. Lipsey (1960, p. 20) argues that if $\dot{U}$ is a proxy for expected unemployment then the Phillips curve would become steeper but there would be no loop.[52] Essentially this argument makes the assumption that firms adjust their labour force instantaneously, which seems implausible in a world of uncertainty. Furthermore, the firm's demand for labour is a demand for a stock of labour to hold. Consequently the $\dot{U}$ term may be picking up stock adjustment effects.

Finally we should observe that the Durbin-Watson statistic is well below the two-tail, 5%, lower significance point for the lower bound (1.39). It therefore seems appropriate, given the conventinal 1960s practice, to adjust for possible positive serial correlation via the Cochrane-Orcutt procedure. When an ordinary least squares (OLS) Cochrane-Orcutt (CORC) transformatin is applied to the 1861 to 1913 regression, with unemployment entering as U^{-1} and U^{-2}, the following results are obtained:

$$\dot{W} = \underset{(-1.72)}{-0.86} + \underset{(2.49)}{5.45U^{-1}} + \underset{(0.99)}{2.09U^{-2}} - \underset{(-2.94)}{0.011\dot{U}} + \underset{(2.85)}{0.21\,\dot{P}}$$

$R^2 = 0.70$ $\quad R^2 = 0.68$ $\quad DW = 1.75$ $\quad RHO = 0.55$

The Durbin-Watson is now just slightly bigger than the upper critical level at the 2-1/2% level of significance for a one-tail test.

Some 70% of the variation of $\dot{W}$ is explainable by the right-hand side variables. A joint F test for U^{-1} and U^{-2} allows us to reject the null hypothesis, that they are simultaneously zero, at the 1% level. For the pre-World War One period then, according to conventional econometric criteria, we would still have accepted the proposition that there was a reasonably well behaved relationship between the rate of change of money wage rates and unemployment, the rate of change of unemployment, and the rate of inflation. Before leaving this period, however, there are two loose ends to be tied off.[53]

First, from Lipsey's article we know that his preferred functional form for unemployment in the post-Second World War period involved not U^{-1} and U^{-2} but U^{-1} and U^{-4}. Neither of these forms has any particular theoretical justification. However, Lipsey (1960, n. 1, p. 15) provides a brief sketch of a theoretical macro labour market model that involves aggregate flows of quits and hires, etc., and relies on the basic hypothesis, formulated by Dicks-Mireaux and Dow on the basis of their studies of the U.K. economy, that vacancies and unemployment are hyperbolically related. It is easy to show[54] that this relationship implies that the theoretical proxy for excess demand for labour should be of the form $E^D = f(U, U^{-1})$ and more specifically that $\dot{W}$ may be predicted from an equation of the form

$$\dot{W} = a + bU + cU^{-1} + d\dot{U} + e\dot{P}^e.$$

Secondly, it would have been possible in 1960 to extend the data set back to 1850 and hence to run pre-World War One regressions for the period 1851 to 1913.[55]

Table 2.1 contains the OLS and CORC results for all three functional forms and for both time periods.[56] For each equation we report the estimated coefficients, their t-values, the coefficient of determination (R^2 --unadjusted, $\bar{R}^2$ -- adjusted), the F-statistic (with k-1 and N-k degrees of freedom) for testing the joint significance of all of the independent variables, the Durbin-Watson statistic (DW) for testing for the presence of first-order serial correlation in the equation residuals, and the F-statistic (with 2 and N-k degrees of freedom) for testing the joint significance of the coefficients of the U (excess demand proxy) terms.

This table includes results for both the ordinary least squares (OLS) and Cochrane-Orcutt (CORC) estimating procedures.[57] We observe that there is little significant variation between the results for the

Table 2.1

Pre-World War One Regressions*

1862-1913: OLS

$W = = -0.94 + 4.92\ U^{-1} + 3.67\ U^{-2} - 0.016\ U + 0.20\ P$

(-2.08) (2.15) (1.60) (-4.24) (2.68)

$R^2 = 0.82$ $R^2 = 0.80$ $F(4,47) = 52.2$ $DW = 1.11$

$F(2,47) = 67.2$

$W = -1.27 + 7.30\ U^{-1} + 1.46\ U^{-4} - 0.016\ U + 0.18\ P$

(-3.78) (2.20) (1.24) (-4.30) (2.49)

$R^2 = 0.81$ $\bar{R}^2 = 0.80$ $F(4,47) = 50.9$ $DW = 1.11$

$F(2,47) = 65.4$

$W = -2.92 + 0.19\ U + 10.20\ U^{-1} - 0.016\ U + 0.22\ P$

(-3.68) (1.87) (8.43) (-4.17) (2.94)

$R^2 = 0.82$ $\bar{R}^2 = 0.80$ $F(4,47) = 53.4$ $DW = 1.14$

$F_1(2,47) = 68.9$

1851-1913: OLS

$W = -0.35 + 1.51\ U^{-1} + 6.53\ U^{-2} - 0.011\ U + 0.28\ P$

(-0.68)*(0.57) (2.40) (-2.88) (4.02)

$R^2 = 0.74$ $\bar{R}^2 = 0.72$ $F(4,58) = 40.6$ $DW = 1.34$

$F(2,58) = 42.1$

$W = -0.93 + 5.70\ U^{-1} + 2.64\ U^{-4} - 0.012\ U + 0.26\ P$

(-2.42) (4.33) (1.90) (-2.97) (3.77)

Table 2.1--continued

$R^2 = 0.73 \quad \bar{R}^2 = 0.71 \quad F(4,58) = 38.7 \quad DW = 1.34$

$F(2,58) = 39.7$

$$W = -3.58 + 0.30\ U + 10.46\ U^{-1} - 0.011\ U + 0.29\ P$$
$$(-3.84)\ (2.50)\quad (7.29)\quad (-2.71)\quad (4.21)$$

$R^2 = 0.74 \quad \bar{R}^2 = 0.72 \quad F(4,58) = 41.0 \quad DW = 1.38$

$F(2,58) = 42.7$

<u>1862-1913: CORC</u>

$$W = -0.87 + 5.45\ U^{-1} + 2.09\ U^{-2} - 0.011\ U + 0.21\ P$$
$$(-1.72)^{*}(2.49)\quad (0.99)\quad (-2.94)\quad (2.85)$$

$R^2 = 0.70 \quad \bar{R}^2 = 0.68 \quad RHO = 0.55 \quad DW = 1.75$

(4.75)

$F(2,47) = 35.0$

$$W = -1.08 + 6.91\ U^{-1} + 0.65\ U^{-4} - 0.011\ U + 0.20\ P$$
$$(-2.55)\ (5.86)\quad (0.65)\quad (-2.92)\quad (2.78)$$

$R^2 = 0.70 \quad \bar{R}^2 = 0.67 \quad RHO = 0.56 \quad DW = 1.74$

(4.84)

$F(2,47) = 34.1$

$$W = -2.05 + 0.11\ U + 8.54\ U^{-1} - 0.010\ U + 0.22\ P$$
$$(-2.57)\ (1.20)\quad (6.67)\quad (-2.91)\quad (2.98)$$

$R^2 = 0.71 \quad \bar{R}^2 = 0.68 \quad RHO = 0.54 \quad DW = 1.75$

(4.69)

$F(2,47) = 35.8$

Table 2.1--continued

<u>1851-1913: CORC</u>

$$W = 0.05 + 0.54\ U^{-1} + 5.67\ U^{-2} - 0.008\ U + 0.23\ P$$

(0.09)*(0.21) (2.21) (-2.09) (3.18)

$R^2 = 0.58$ $\bar{R}^2 = 0.55$ RHO = 0.52 DW = 1.80

(4.83)

F(2,58) = 18.0

F(2,58) = 18.0

$$W = -0.47 + 4.30\ U^{-1} + 2.03\ U^{-4} - 0.008\ U + 0.22\ P$$

(-1.01) (3.27) (1.66) (-2.15) (2.98)

$R^2 = 0.57$ $\bar{R}^2 = 0.54$ RHO = 0.52 DW = 1.82

(4.86)

F(2,58) = 16.4

$$W = -2.63 + 0.25\ U + 8.11\ U^{-1} - 0.007\ U + 0.24\ P$$

(-2.77) (2.16) (5.30) (-1.88) (3.29)

$R^2 = 0.58$ $\bar{R}^2 = 0.55$ RHO = 0.52 DW = 1.80

(4.89)

F(2,58) = 17.7

*T-Ratios in parentheses. Asymptotic T-Ratios for the estimate of rho.

Figure 2.2 1862-1913 Phillips' (6 Average Points) Equation

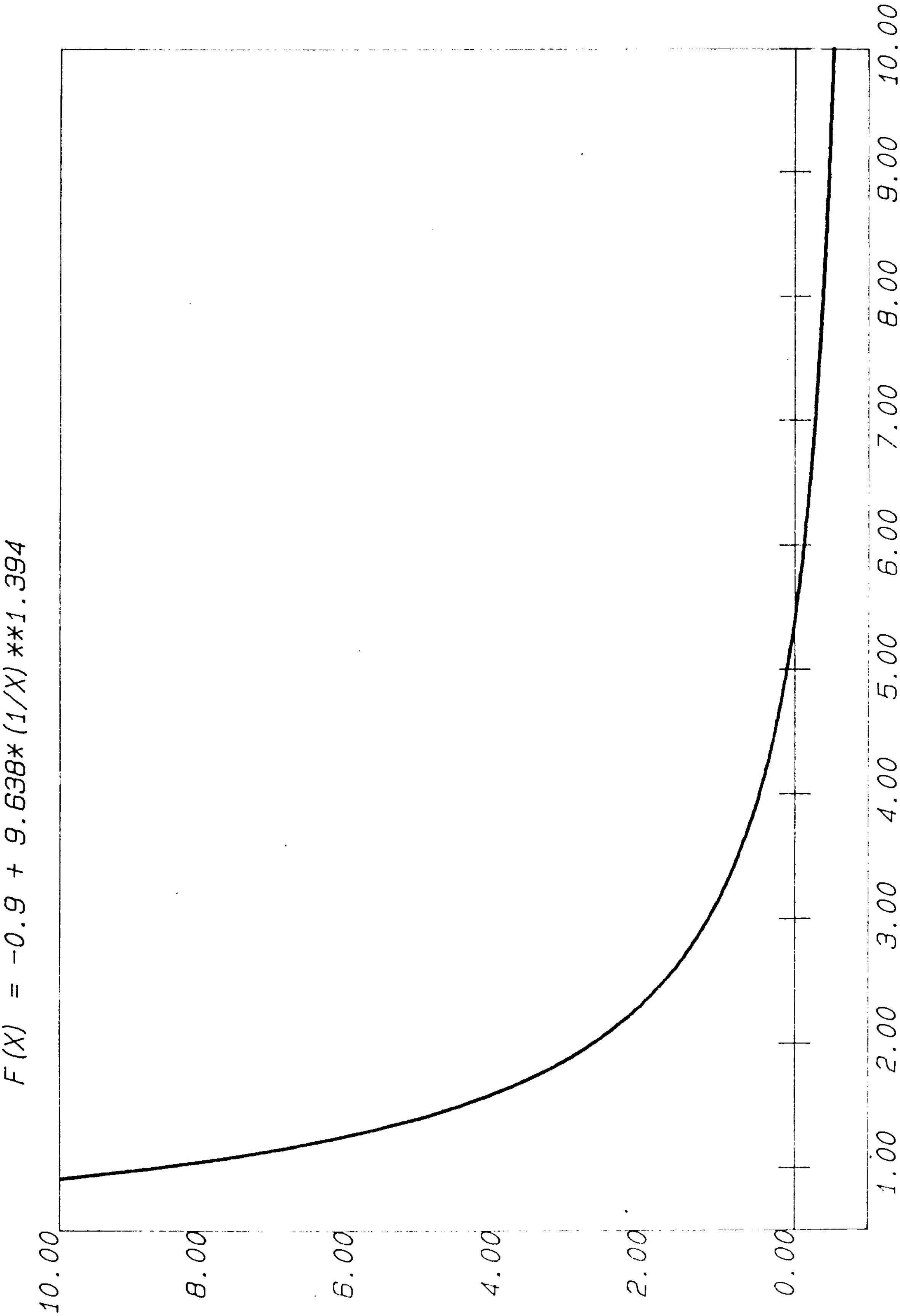


Figure 2.3 1862-1913 Lipsey's (6 Average Points) Equation

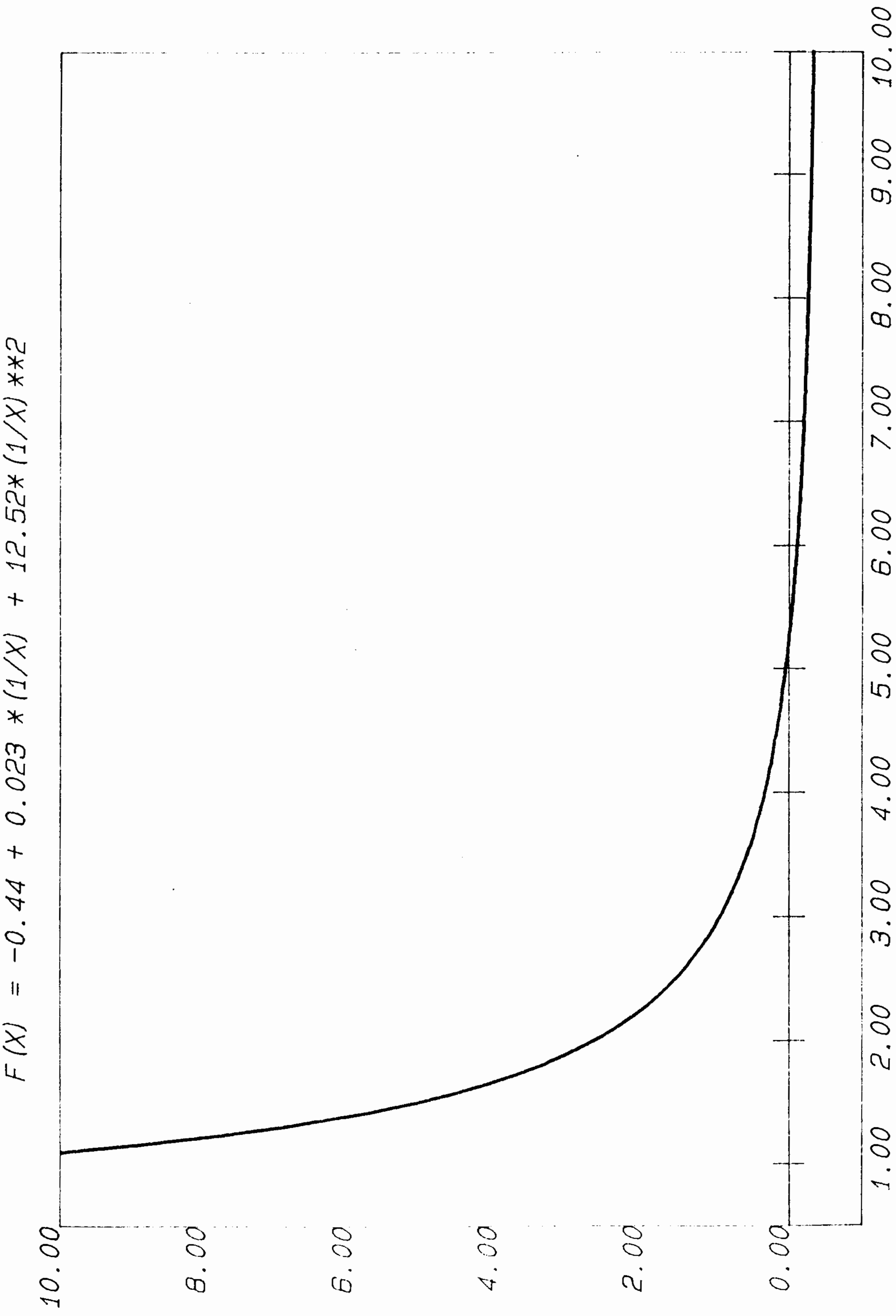


Figure 2.4 1862-1913 Lipsey's (52 Observation) Equation

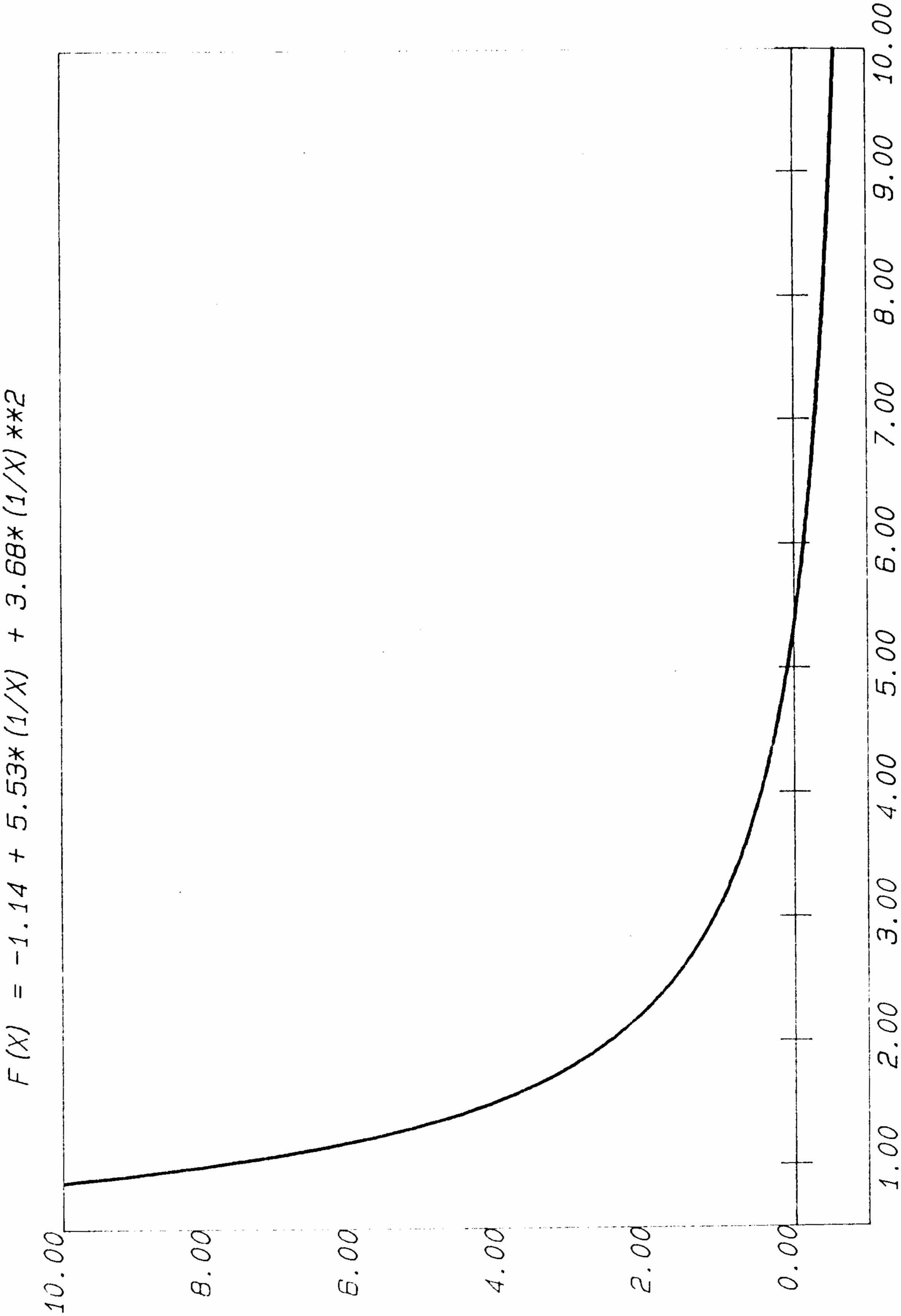


Figure 2.5 1862-1913 OLS, UU^{-1} Equation

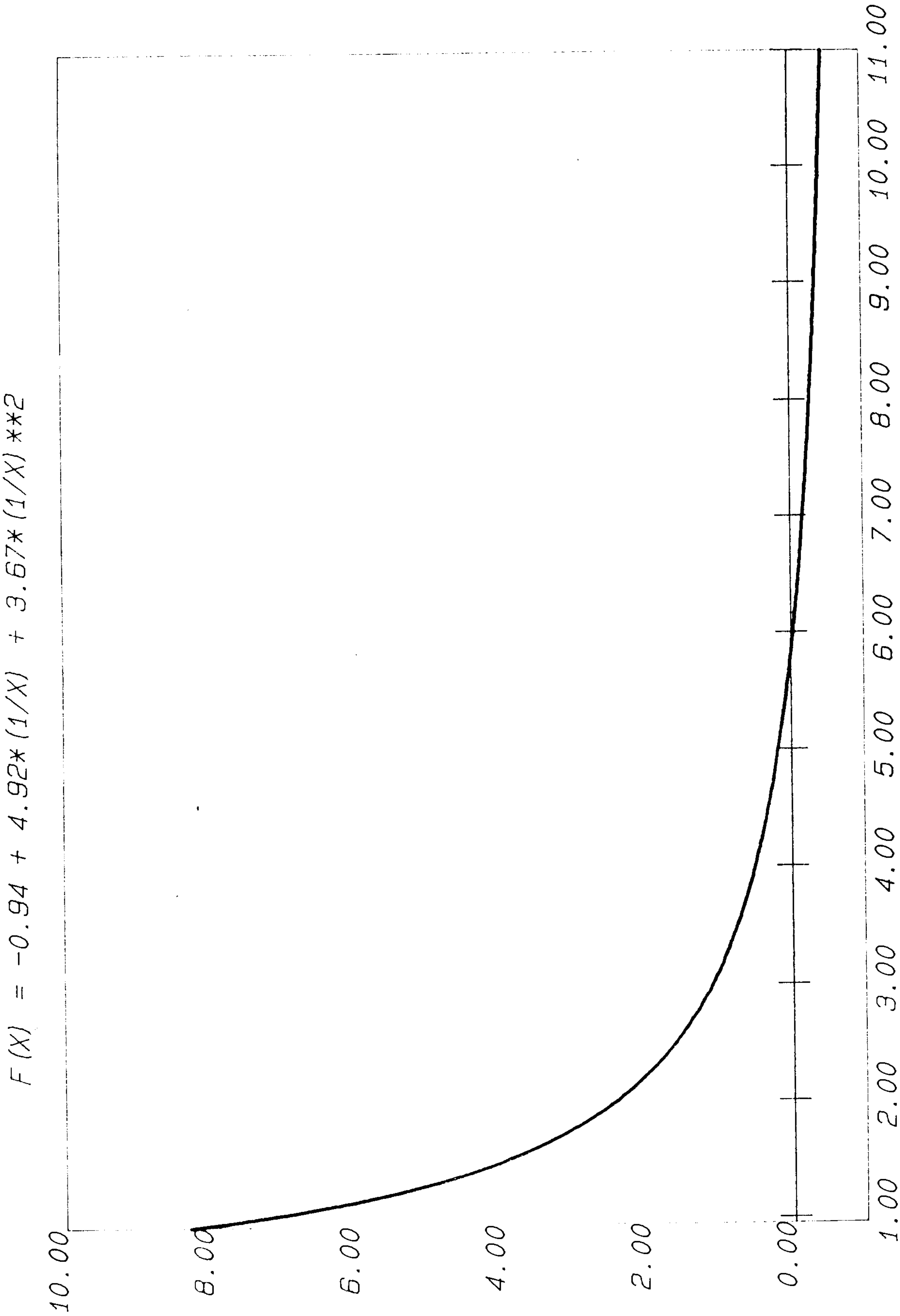


Figure 2.6 1862-1913 OLS $U^{-1}U^{-4}$ Equation

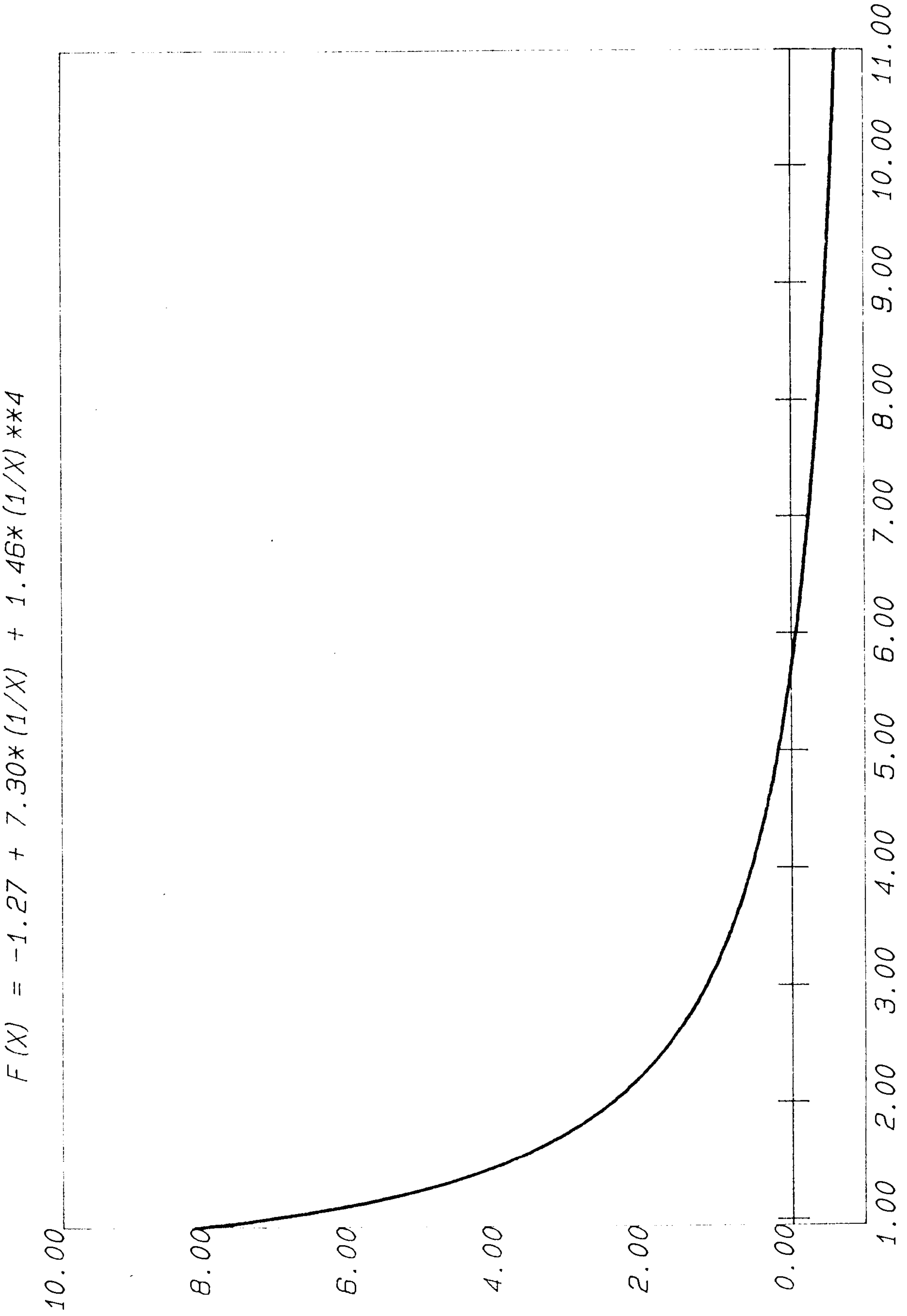


Figure 2.7 1862-1913 OLS UU^{-1} Equation

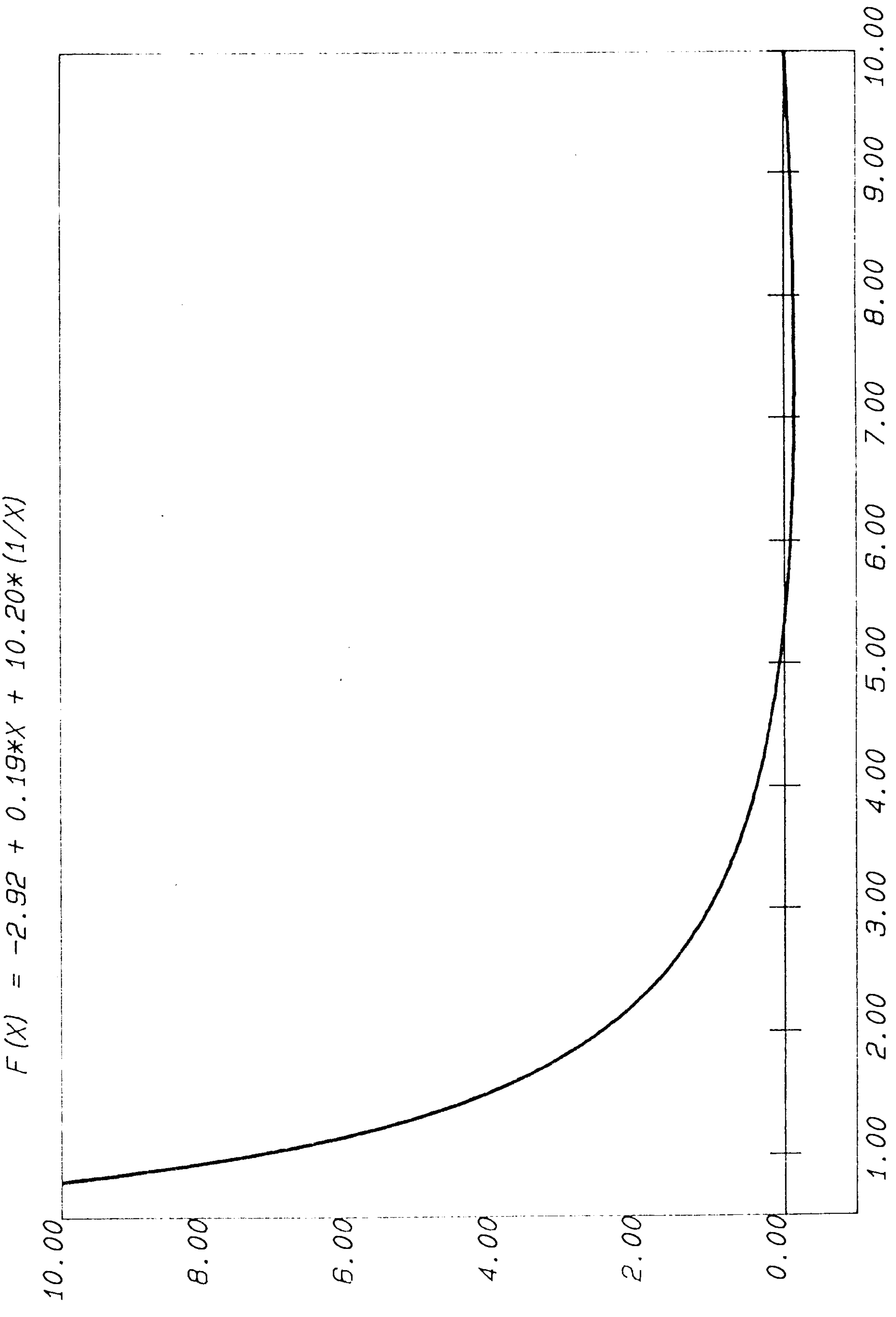


Figure 2.8 1851-1913 OLS $U^{-1}U^{-2}$ Equation

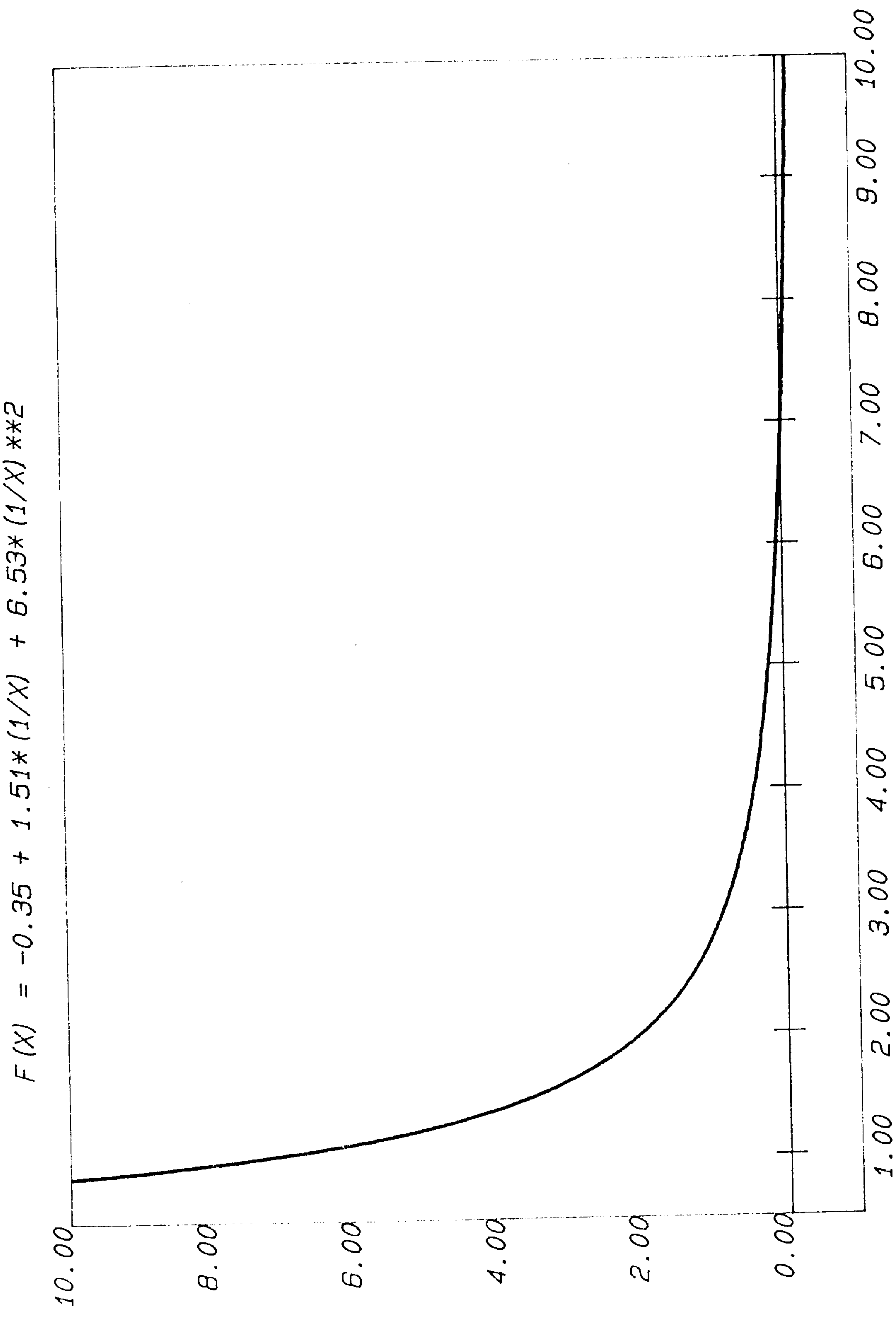


Figure 2.9 1851-1913 OLS $U^{-1}U^{-4}$ Equation

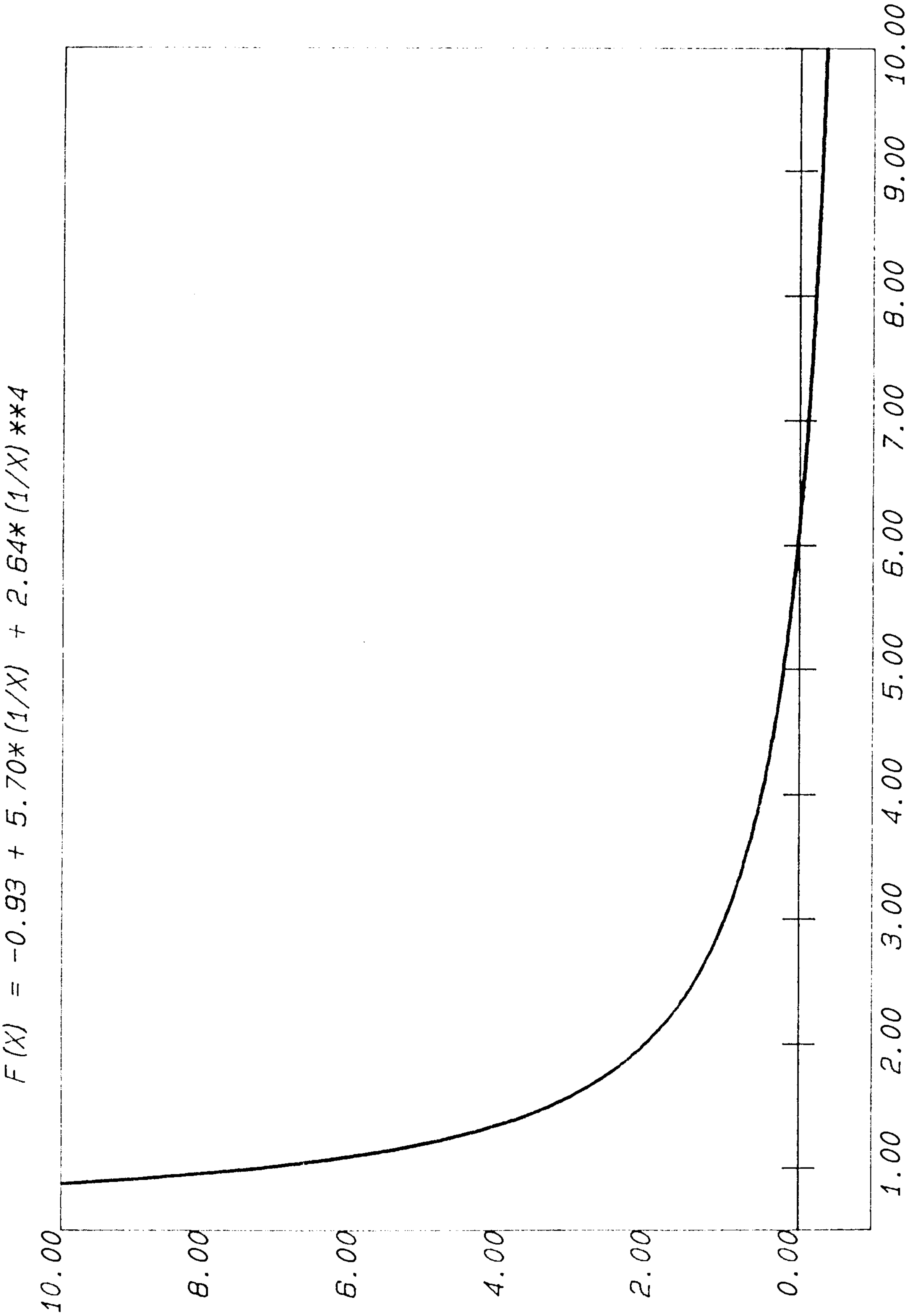
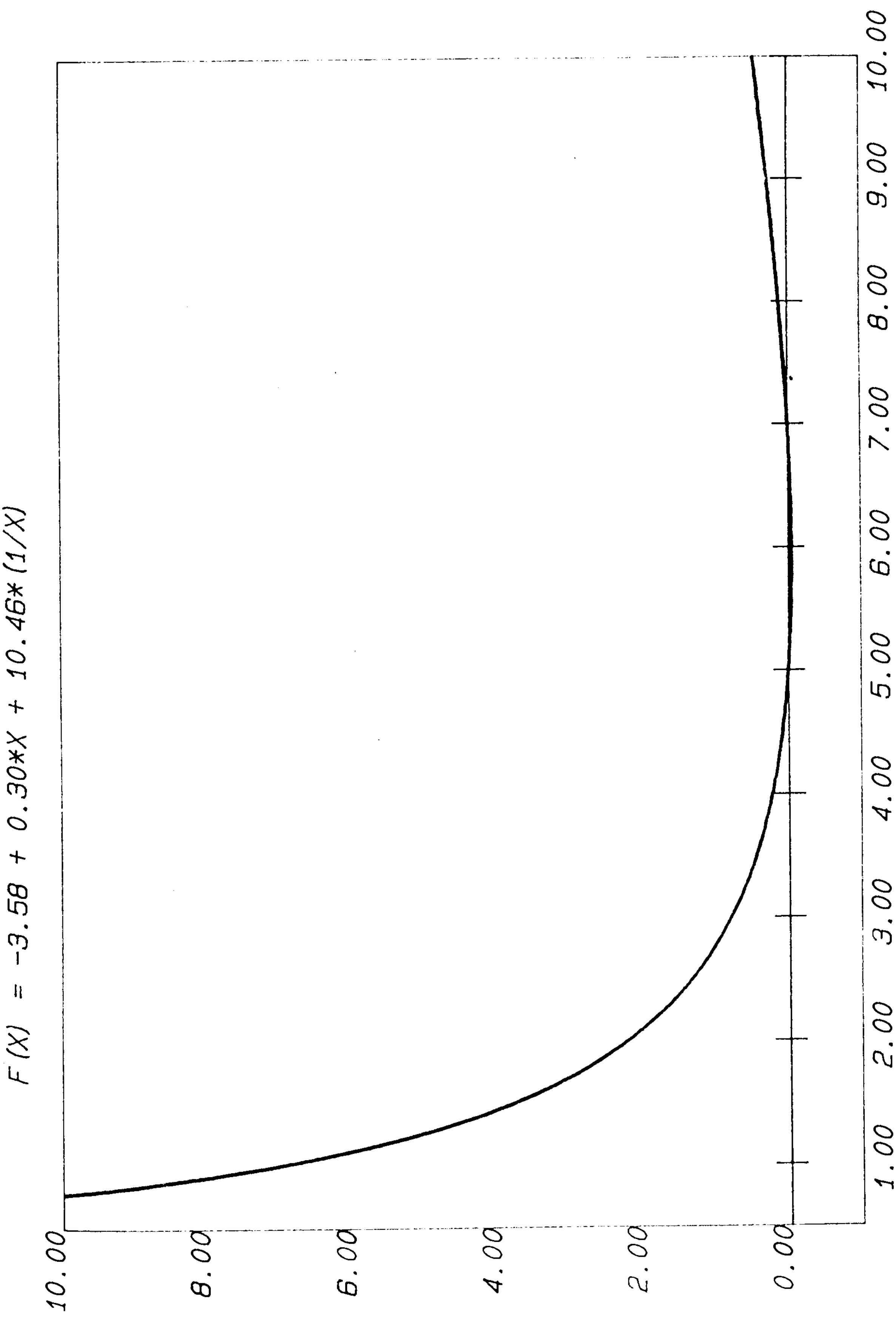


Figure 2.10 1851-1913 OLS UU^{-1} Equation



different functional forms. The overall fits of the OLS equations are good (with the Lipsey period giving generally better results than the whole pre-World War One sample), but the low DWs, which signal the presence of first-order serial correlation, give rise to skepticism about the reliability of the R^2 and t-values. On the whole the coefficients seem to be acceptable (with correct signs and plausible magnitudes), and apparently statistically significant either individually or jointly. All of the intercept terms are non-positive, all of the $\dot{U}$ terms are small and negative (consistent with tight counter-clockwise loops), and all of the $\dot{P}$ coefficients are significantly different from unity.

Figures 2.5-2.10 contain plots of our regression results, which may be compared with Figures 2.2-2.4. which plot the original Phillips (6 average points) and Lipsey (6 average points and 52 individual observations) curves. These graphs show the familiar (negatively sloped, convex to the origin) Phillips curve shape, but notice that the UU^{-1} "theoretical" specification exhibits a positive slope for both periods for large values of U.[58]

After applying the CORC transformation we observe a universal sharp increase in the DWs. Once again the 1862-1913 period yields slightly superior fits. These equations are graphed in Figures 1.11-1.16 where again we see that the theoretical form generates a positively sloped, and hence unacceptable, Phillips curve for large values of U.

In Table 2.2 we list the values of U,(which we symbolise as U*), which correspond to $\dot{W} = 0$. We see that the original Phillips and Lipsey equations give values of U* of about 5.4 percent. We also note that the

Figure 2.11 1862-1913 CORC $U^{-1}U^{-2}$ Equation

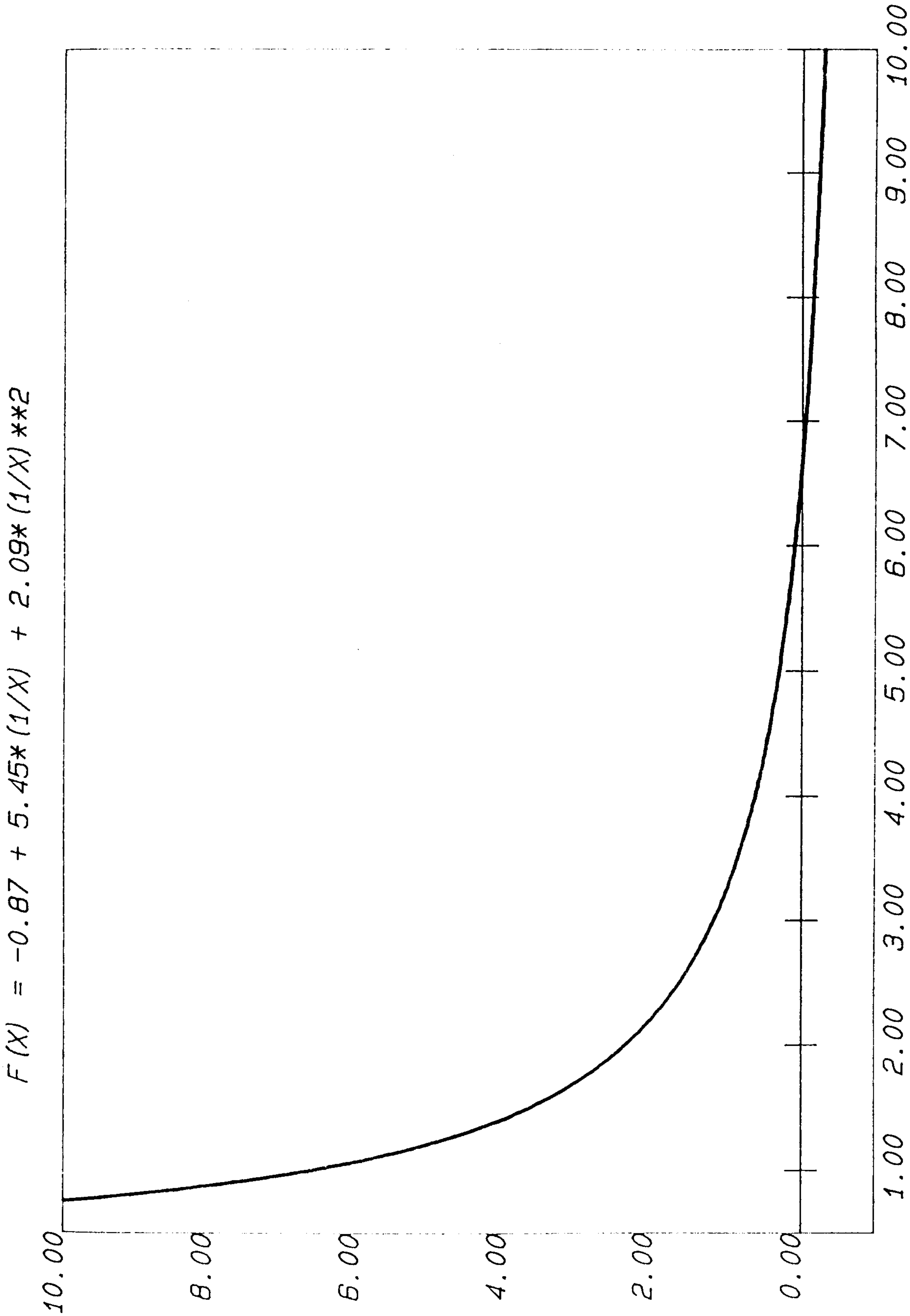


Figure 2.12 1862-1913 CORC $U^{-1}U^{-4}$ Equation

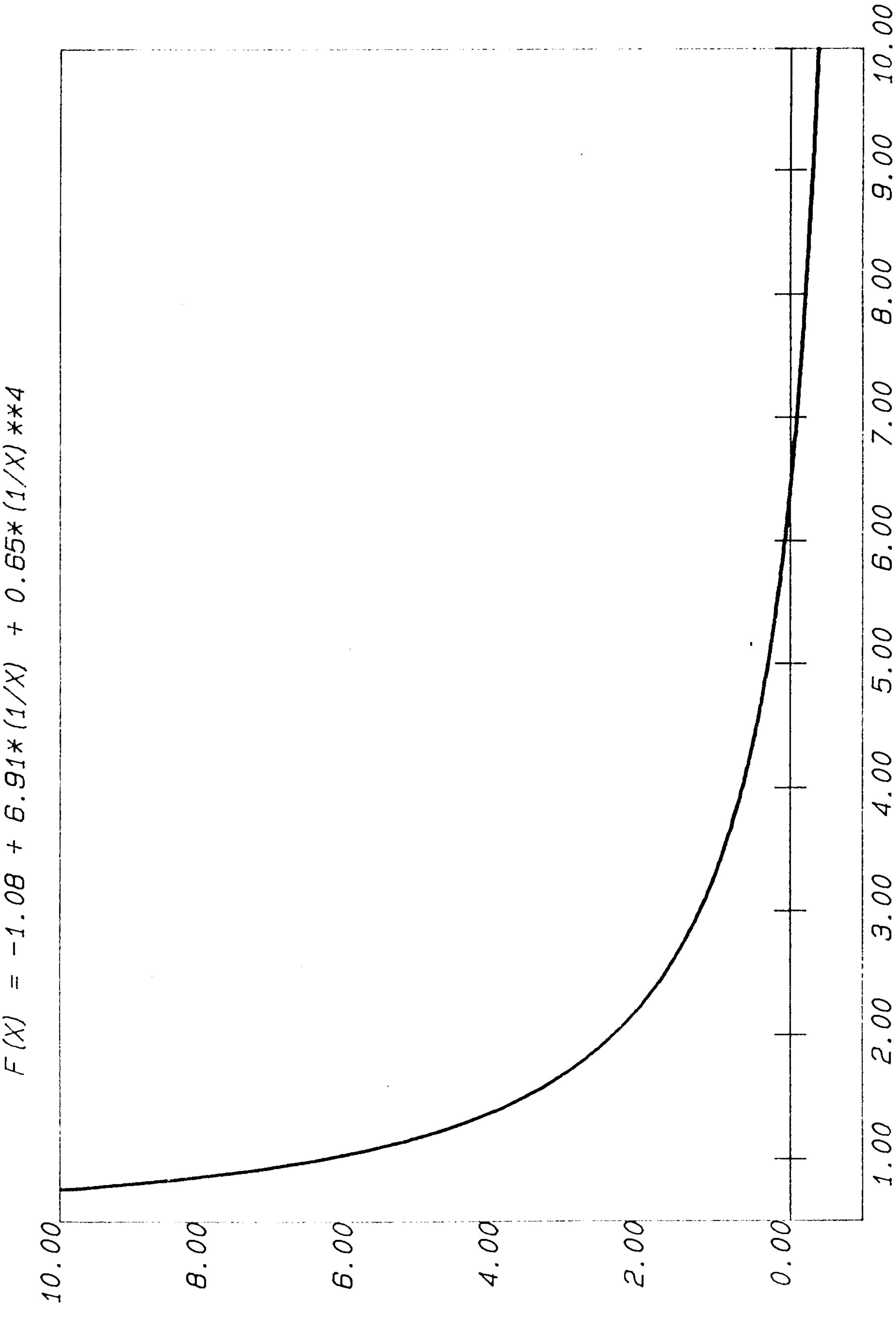


Figure 2.13 1862-1913 CORC UU^{-1} Equation

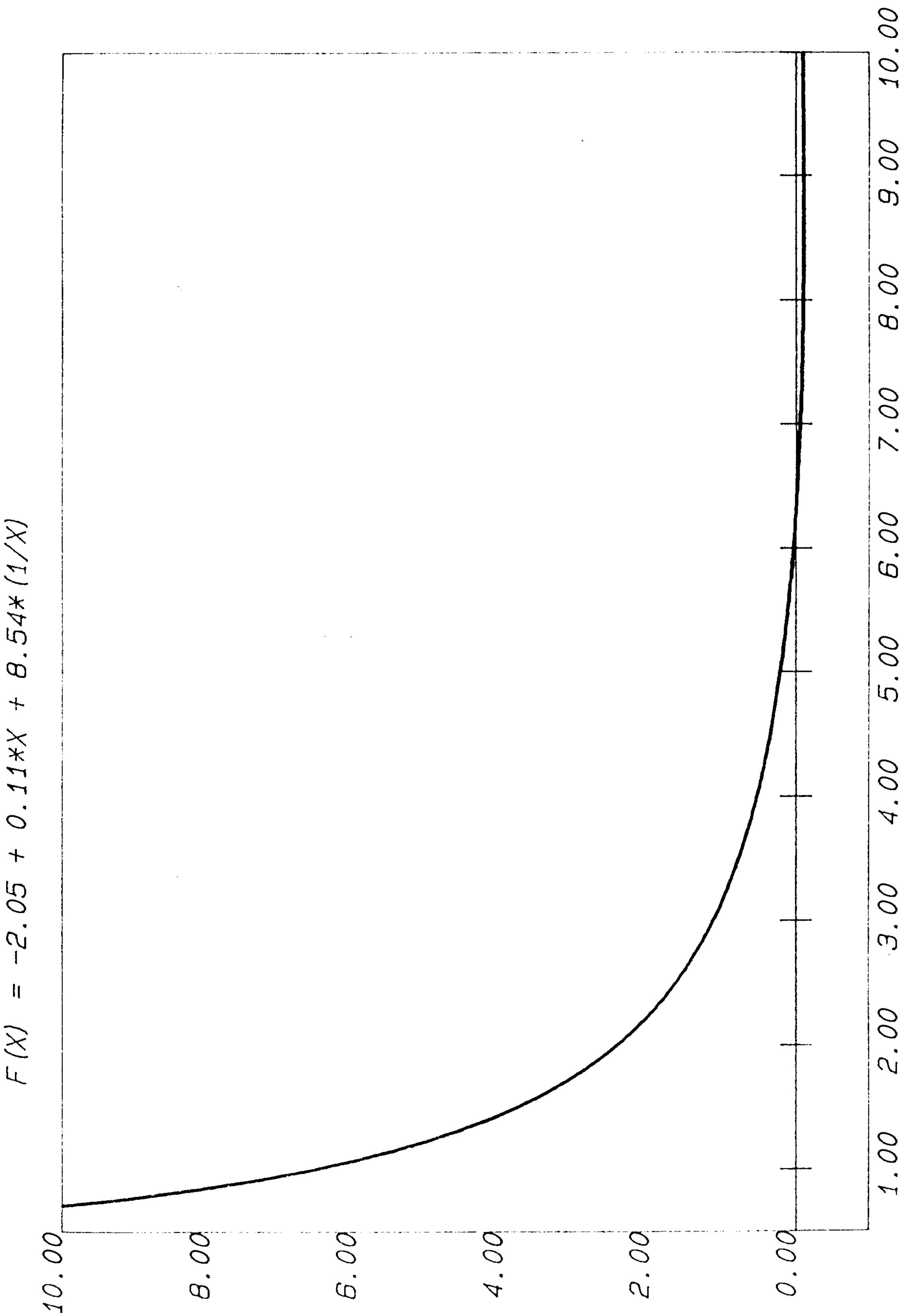


Figure 2.14 1851-1913 CORC $U^{-1}U^{-2}$ Equation

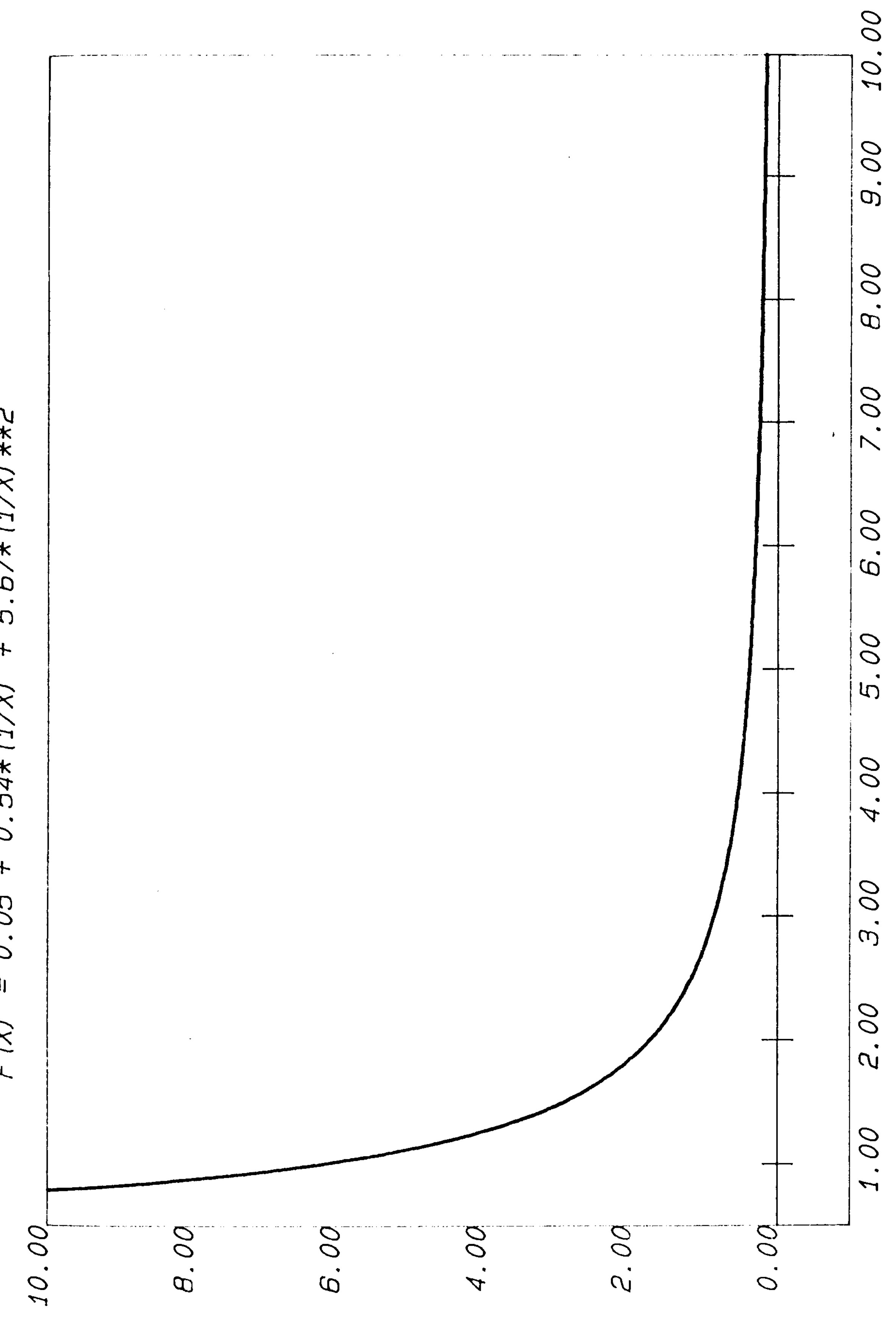


Figure 2.15 1851-1913 CORC $U^{-1}U^{-4}$ Equation

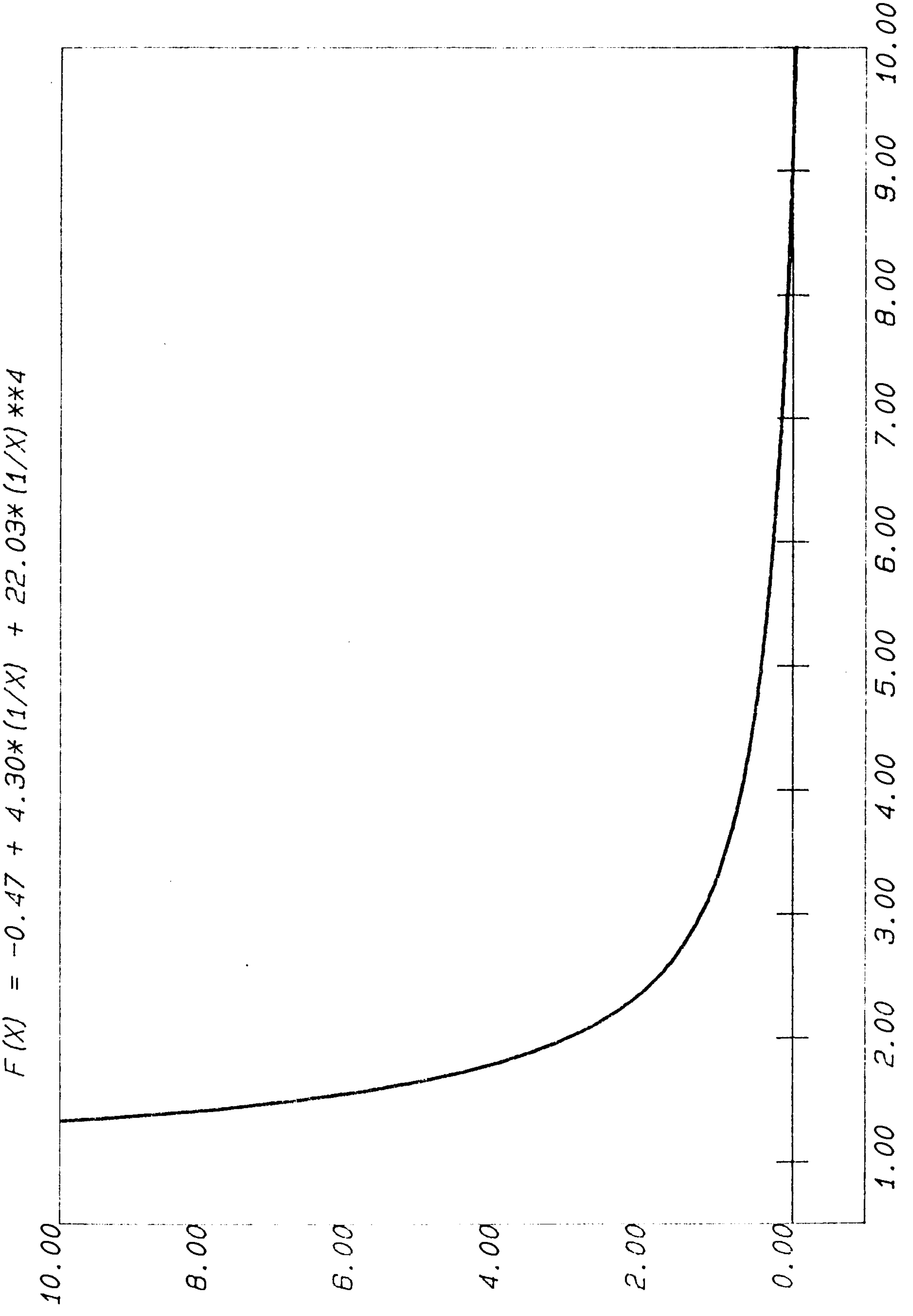


Figure 2.16 1851-1913 CORC UU^{-1} Equation

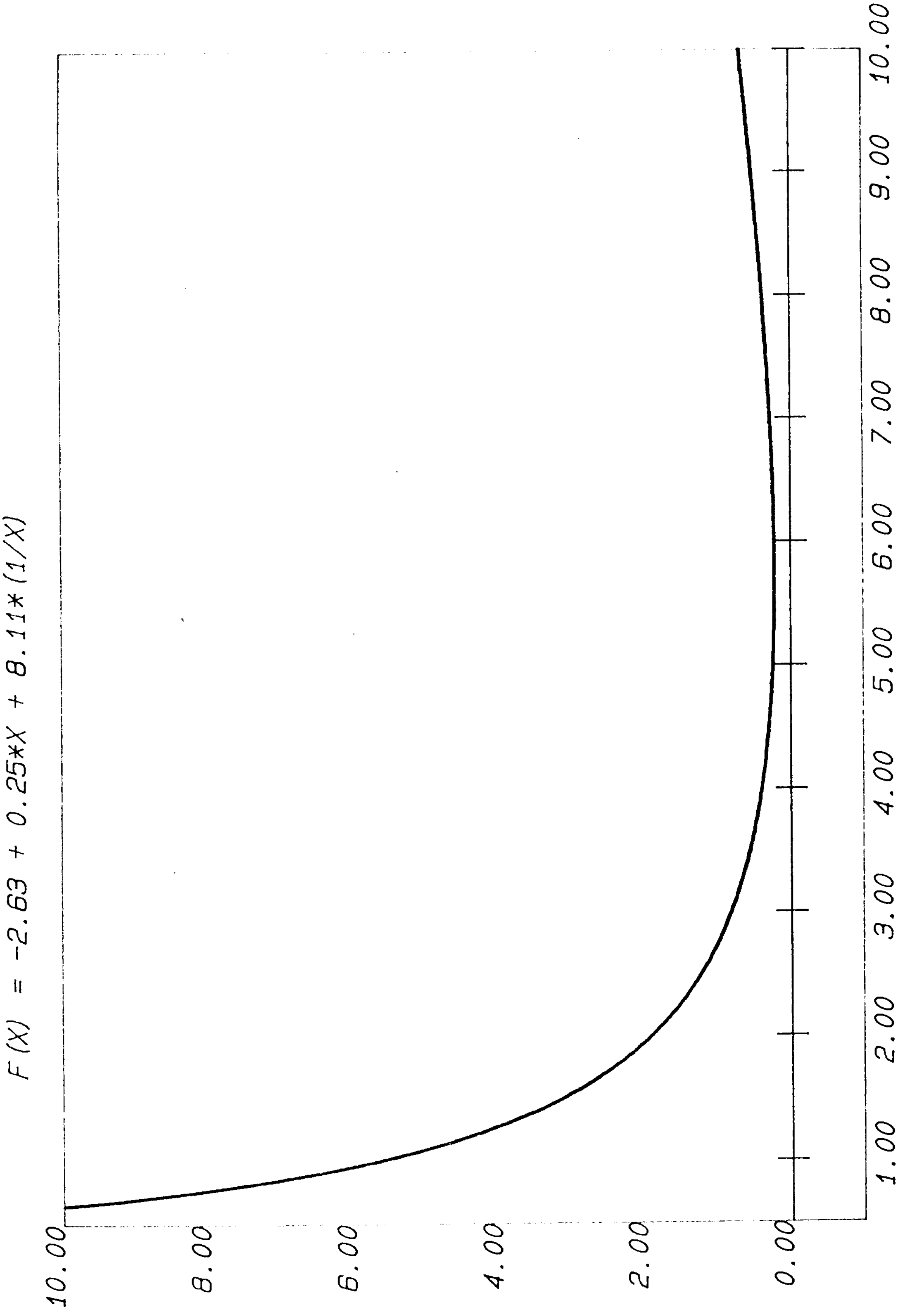


TABLE 2.2

VALUES OF U* (CORRESPONDING TO $\dot{W} = 0$)

FOR THE PRE-1913 EQUATIONS

	%
Phillips (1861-1913, 6 Averaged Points)	5.47
Lipsey (1862-1913, 6 Averaged Points)	5.35
Lipsey (1862-1913; all 52 observations)	5.44

1862-1913	OLS	CORC
$U^{-1}U$	5.36	6.28
$U^{-1}U^{-2}$	5.89	6.63
$U^{-1}U^{-4}$	5.75	6.40

1851-1913	OLS	CORC
$U^{-1}U$	5.1	--
$U^{-1}U^{-2}$	6.98	--
$U^{-1}U^{-4}$	6.13	9.2

estimates of U* obtained from our replication experiment are (with the exception of the first--and unacceptable--UU^{-1} value) considerably larger, with the average size increasing as we go from the OLS to the CORC estimates, and that the Lipsey $U^{-1}U^{-2}$ specification has a zero asymptote for the 1851-1913 CORC equation.

Our overall conclusion is that the pre-First World War data, do not provide grounds for rejecting the Phillips curve.[59] We now examine the inter-war period.

(2) The Inter-War Period

Although Phillips was originally trained as an engineer and although his primary interest in economics was in model building and estimation, Phillips' paper reads more like a sophisticated piece of economic history than an exercise in applied econometrics. Section III of Phillips' paper, which deals with the years from 1913 to 1948, contains no new estimate of the Phillips curve but rather a detailed, almost year by year, account of the behaviour of the level of unemployment and the rate of change of money wage rates.

Lipsey's section III covers the overlapping period from 1919 to 1957. Lipsey first considers data for the years from 1920-39 and 1947-57; then he deletes the years 1920 to 1922 and 1947 leaving him with the combined sample for the years 1923-39 plus 1948-57. Lipsey deletes the post-First and Second World War years on the grounds that they represent outliers that would seriously distort the estimates of the coefficients of the "normal" Phillips curve if they were retained in the sample.

Specifically, the 1920-22 years were excluded because of their extremely volatile rate of change of money wage rates and of inflation.

As Phillips had noticed (1958, pp. 293-4), wages had become linked to prices via cost-of-living clauses written into trade union wage contracts during and immediately after the First World War. Apparently it had never occurred to union members that such clauses are symmetrical and hence, when the bottom fell out of the post-war re-stocking boom in early 1920 and world prices began to drop rapidly, the United Kingdom experienced its last, and perhaps its most violent, period of downward wage flexibility.[60] Naturally these automatic cost of living adjustments were rapidly dropped after 1921.

The re-estimated equations for the inter-war periods (both 1919-1938 and Lipsey's 1923 to 1939 period) appear in Table 2.3. Unfortunately, and despite a great deal of effort, we have not been able to reproduce exactly the data used by Phillips and Lipsey after 1920, so that even if Lipsey had reported results for this period, there would have been problems replicating them.[61]

An examination of Table 2.3 reveals several obvious points. In the first place the relationship between W and U, U and P was <u>not</u> the same in the inter-war period as it had been in the pre-World War One period. When Phillips said that his 1861-1913 curve was able to explain adequately the behaviour of money wage rates after World War Two that may have been true, but most economists in the early sixties seem to have believed that Phillips had discovered a statistical relationship between $\dot{W}$ amd U, $\dot{U}$ and $\dot{P}$ which accounted for the behaviour of $\dot{W}$ over the whole ninety-seven years from 1861 to 1957. That belief was false and it should have been possible in 1961, or thereabouts, to discover the error.

Table 2.3

The Inter-War Regressions

<u>1923-1939: OLS</u>

$$W = -2.48 + 98.34\ U^{-1} - 673.54\ U^{-2} + 0.022\ U + 0.64\ P$$
$$(-0.62)\quad (0.87)\qquad (-0.89)\qquad (1.21)\qquad (6.73)$$

$R^2 = 0.89$ $\quad \bar{R}^2 = 0.85$ $\quad F(4,12) = 24.1$ $\quad DW = 0.97$

$F(2,12) = 0.41$

$$W = -1.16 + 40.49\ U^{-1} - 23324.\ U^{-4} + 0.022\ U + 0.64\ P$$
$$(-0.51)\quad (0.97)\qquad (-1.06)\qquad (1.20)\qquad (6.76)$$

$R^2 = 0.89$ $\quad \bar{R}^2 = 0.86$ $\quad F(4,12) = 24.8$ $\quad DW = 1.02$

$F(2,12) = 0.57$

$$W = 5.82 - 0.16\ U - 34.86\ U^{-1} + 0.023\ U + 0.65\ P$$
$$(0.77)\ (-0.64)\ \ (-0.65)\qquad (1.22)\qquad (6.69)$$

$R^2 = 0.89$ $\quad \bar{R}^2 = 0.85$ $\quad F(4,12) = 23.3$ $\quad DW = 0.93$

$F(2,12) = 0.21$

<u>1919-1938: OLS</u>

$$W = 2.52 - 42.56\ U^{-1} + 253.19\ U^{-2} - 0.046\ U + 1.07\ P$$
$$(0.70)\ (-0.78)\qquad (2.03)\qquad (-2.03)\qquad (7.26)$$

$R^2 = 0.92$ $\quad \bar{R}^2 = 0.90$ $\quad (F(4,15) = 44.8$ $\quad DW = 1.44$

$F(2,15) = 11.95$

$$W = 1.22 - 5.17\ U^{-1} + 1195.1\ U^{-4} - 0.030\ U + 1.09\ P$$
$$(0.42)(-0.14)\qquad (2.13)\qquad (-1.18)\qquad (7.39)$$

$R^2 = 0.92$ $\quad \bar{R}^2 = 0.90$ $\quad F(4,15) = 45.8$ $\quad DW = 1.61$

$F(2,15) = 12.38$

Table 2.3 continued

$$W = -11.99 + 0.43\ U + 87.91\ U^{-1} - 0.065\ U + 1.04\ P$$

(-2.72) (1.93) (4.62) (-3.07) (7.06)

$R^2 = 0.92$ $\bar{R}^2 = 0.90$ $F(4,15) = 43.7$ $DW = 1.34$

$F(2,25) = 11.52$

<u>1923-1939: CORC</u>

$$W = -2.38 + 84.45\ U^{-1} - 497.40\ U^{-2} + 0.017\ U + 0.53\ P$$

(-0.62) (0.88) (-0.83) (0.99) (5.22)

$R^2 = 0.83$ $\bar{R}^2 = 0.77$ $RHO = 0.63$ $DW = 1.57$

(3.36)

$F(2,12) = 0.41$

$$W = -1.33 + 39.66\ U^{-1} - 155.22\ U^{-4} + 0.016\ U + 0.52\ P$$

(-0.53) (-0.89) (-0.98) (-0.89) (5.16)

$R^2 = 0.83$ $\bar{R}^2 = 0.77$ $RHO = 0.64$ $DW = 1.59$

(3.45)

$F(2,12) = 0.47$

$$W = 4.62 - 0.15\ U - 20.66\ U^{-1} + 0.017\ U + 0.53\ P$$

(0.80) (-0.71) (-0.52) (1.00) (5.24)

$R^2 = 0.82$ $\bar{R}^2 = 0.77$ $RHO = 0.62$ $DW = 1.55$

(3.29)

$F(2,12) = 0.31$

<u>1919-1938: CORC</u>

$$W = -0.40 - 0.67\ U^{-1} + 174.86\ U^{-2} - 0.051\ U + 1.05\ P$$

(-0.09)(-0.01) (1.20) (-2.18) (5.75)

Table 2.3--continued

$R^2 = 0.92$ $\bar{R}^2 = 0.90$ RHO = 0.43 DW = 1.85

F(2,15) = 13.2

$$W = -1.88 + 32.92\ U^{-1} + 688.76\ U^{-4} - 0.045\ U + 1.05\ P$$

(-0.53) (0.77) (1.10) (-1.54) (5.73)

$R^2 = 0.92$ $\bar{R}^2 = 0.90$ RHO = 0.41 DW = 1.87

(2.00)

F(2,15) = 12.9

$$W = -11.21 + 0.34\ U + 91.87\ U^{-1} - 0.066\ U + 1.02\ P$$

(-2.12) (1.21) (4.71) (-3.65) (5.75)

$R^2 = 0.93$ $\bar{R}^2 = 0.91$ RHO = 0.43 DW = 1.79

(2.14)

F(2,15) = 13.2 for joint significance of U and U^{-1}

*Numbers in parentheses refer to t-statistics or, in the case of RHO, asymptotic t-statistics.

The second point to notice about Table 2.3 is that the overall fit of the equations appears to be quite good (R^2s of 0.85 or better), and that the coefficients on U and P seem to be quite well determined. The problem lies with U, U^{-1}, U^{-2} and U^{-4}. Obviously we would expect these variables to be collinear and an examination of the simple correlations between them confirms this expectation. For the period 1919 to 1938 the lowest correlation among $U^{-1}, \ldots, U^{-4}$ is 0.93 (between U^{-1} and U^{-4}) and the highest is 0.99875 (between U^{-3} and U^{-4}). For the Lipsey period, 1923-1939, the lowest correlation is 0.86 (between U^{-1} and U^{-4}), all other correlations are 0.92 or greater.[62]

Thirdly notice that, on the whole, the inclusion of the 1919 to 1922 observations in the sample, and the deletion of the 1939 war year, <u>improves</u> the performance of the model rather than making it worse. In particular, it is interesting to see that the coefficient on the $\dot{P}$ variable, which we conjectured might be acting as a crude proxy for price expectations, has a value not significantly different from one as we move from the Lipsey sample period to the whole inter-war sample. It seems likely that Lipsey's decision to exclude the 1919-1922 and 1939 observations obscured the feedback between (expected) inflation and wage changes. On the other hand, the coefficient on $\dot{P}$ may have been artificially biased towards one by the sliding scale effects we discussed above.[63]

Also notice that even the unemployment variables seem to achieve joint significance (at the 10 percent level only) for the whole inter-war period.

However, an inspection of Figures 2.17-2.28 which contain the

Figure 2.17 1923-1939 OLS $U^{-1}U^{-2}$ Equation

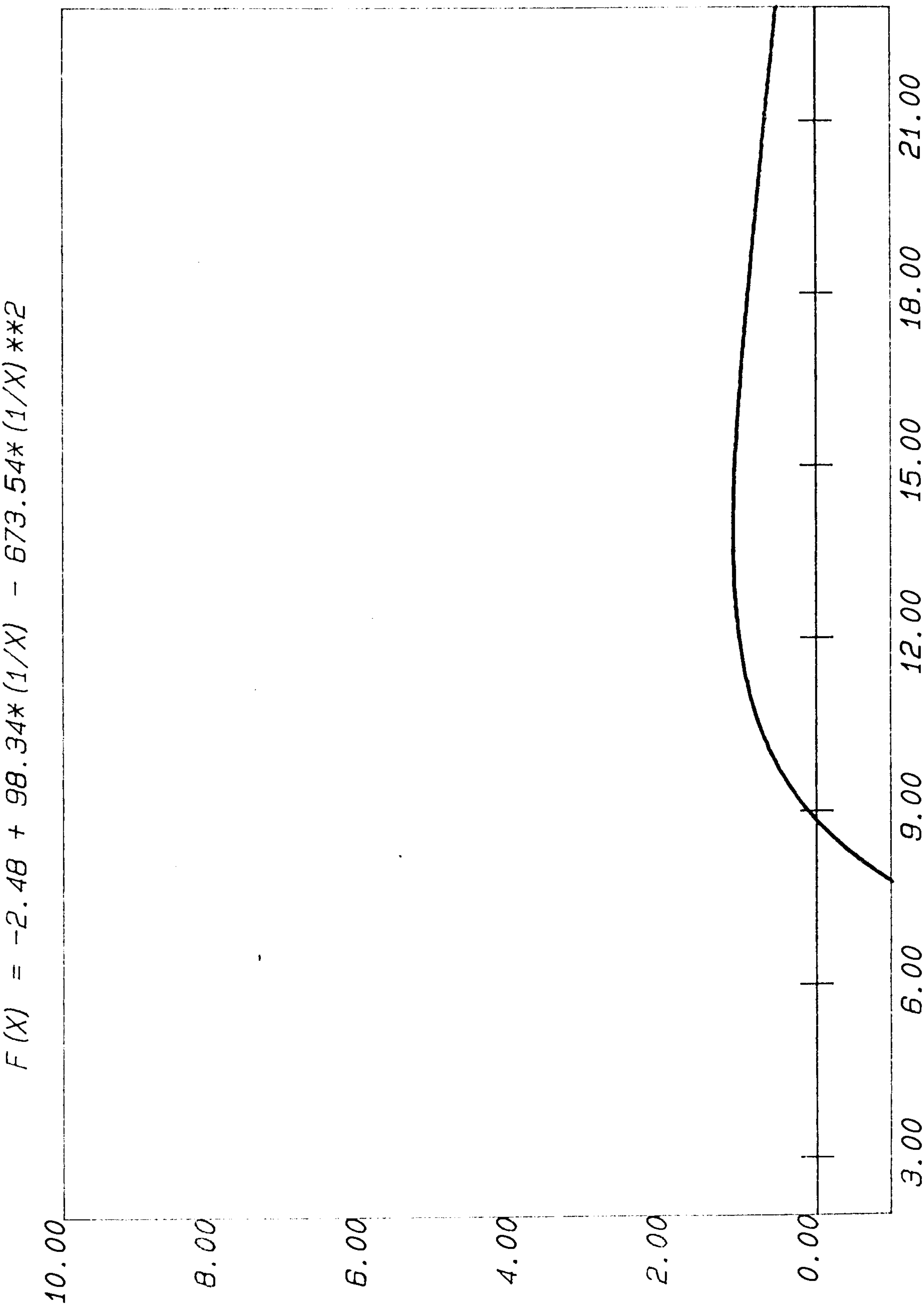


Figure 2.18 1923-1939 $U^{-1}U^{-4}$ Equation

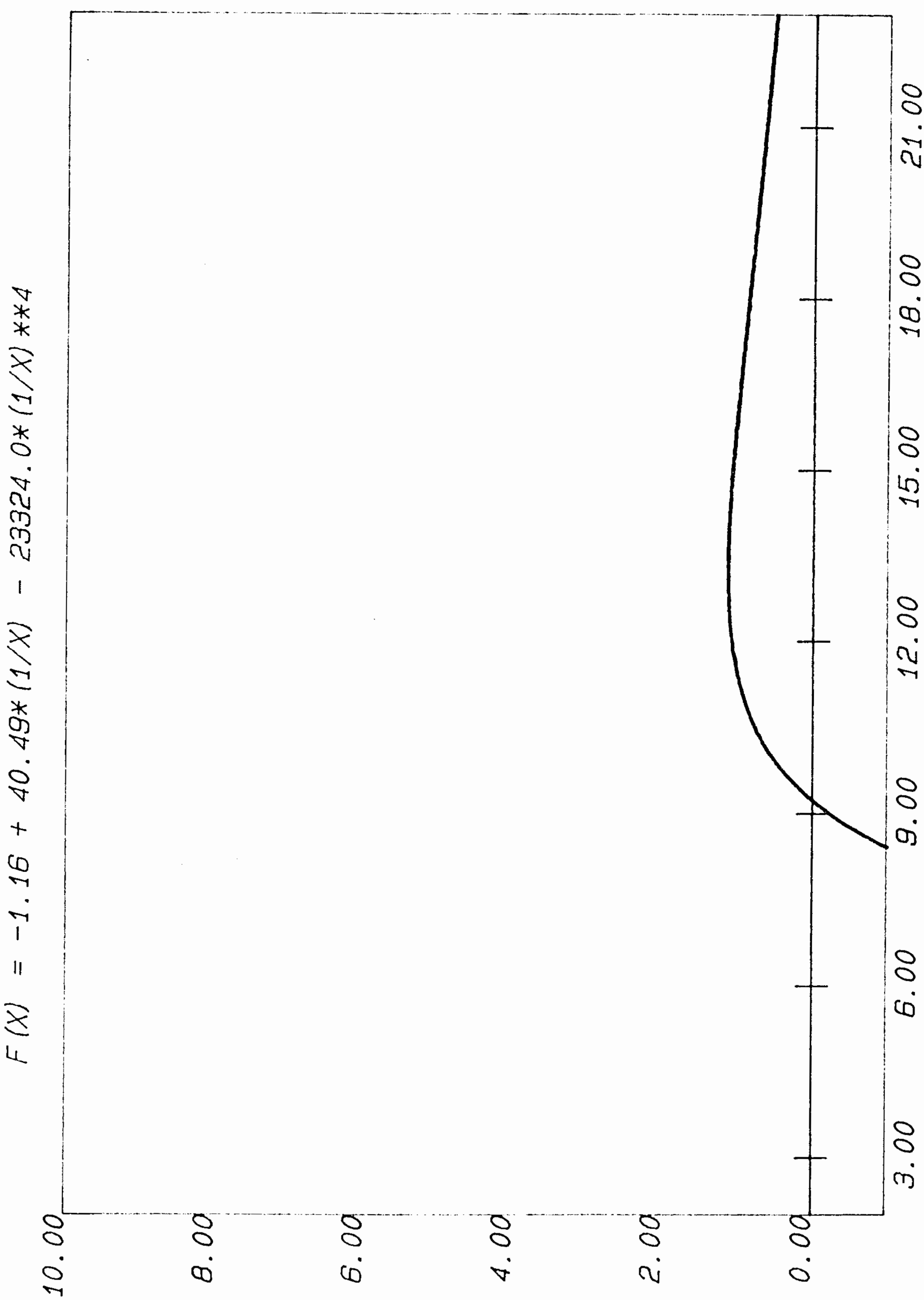


Figure 2.19 1923-1939 OLS UU^{-1} Equation

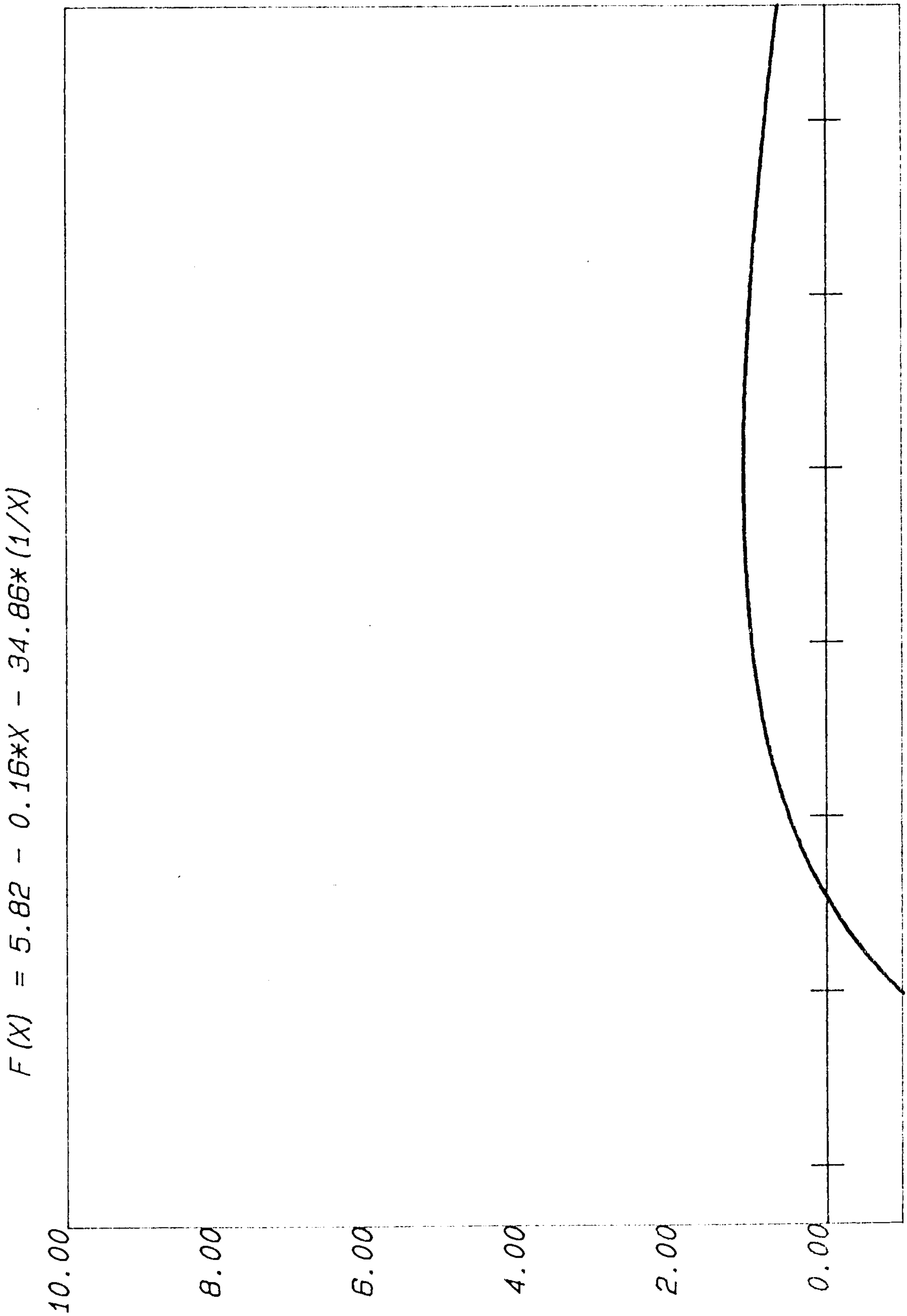


Figure 2.20 1919-1938 OLS $U^{-1}U^{-2}$ Equation

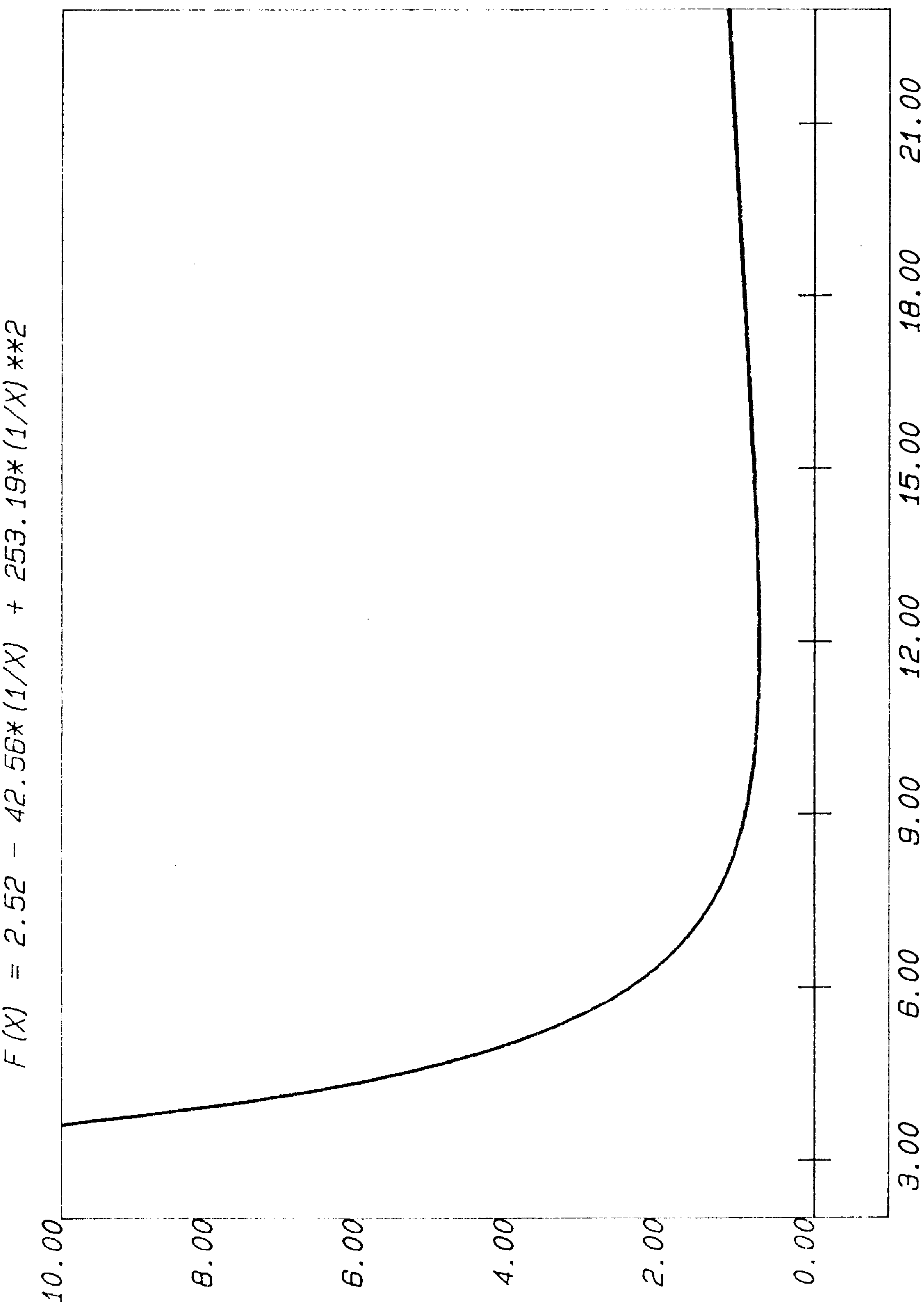


Figure 2.21 1919-1938 OLS $U^{-1}U^{-4}$ Equation

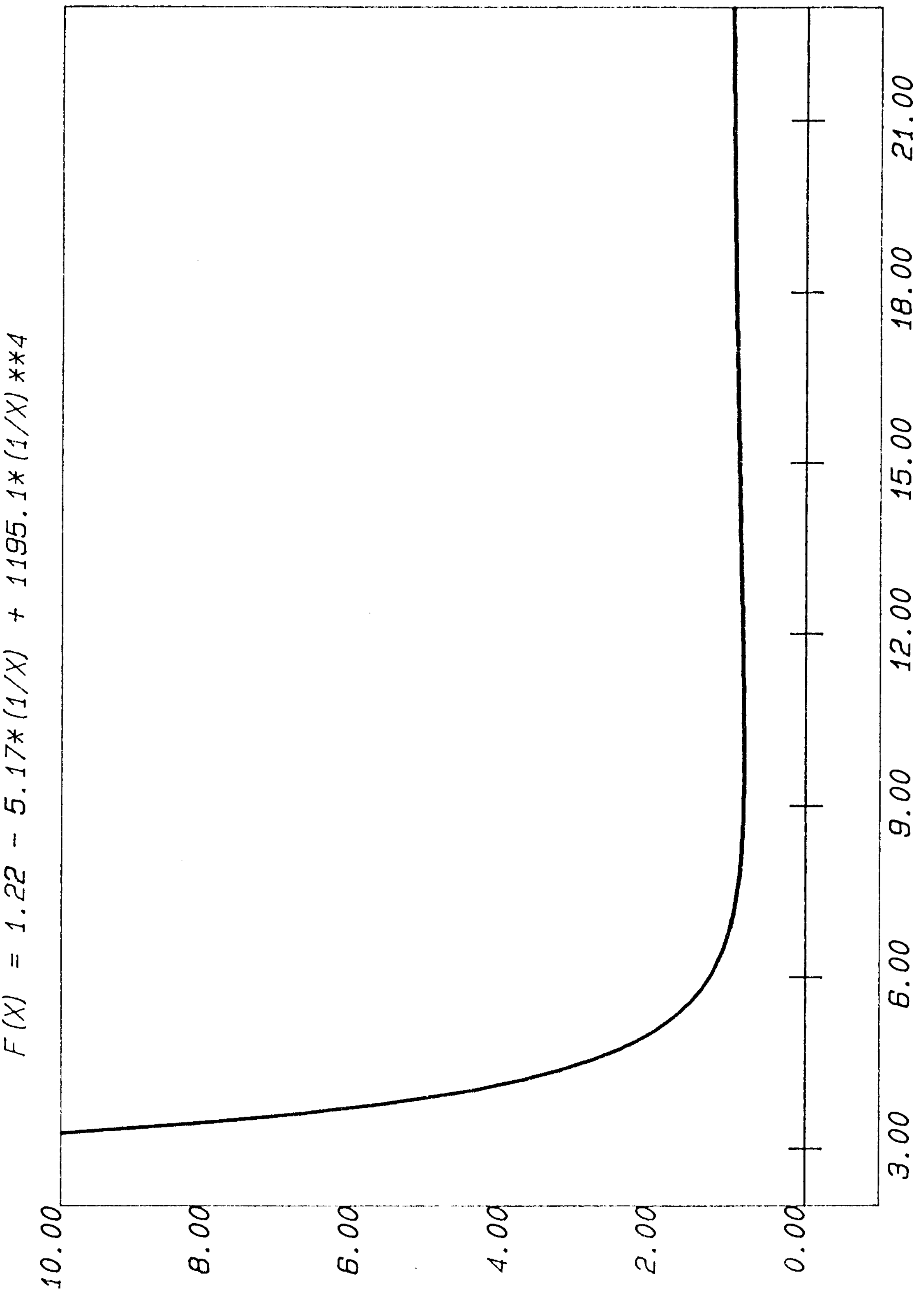


Figure 2.22 1919-1938 OLS UU^{-1} Equation

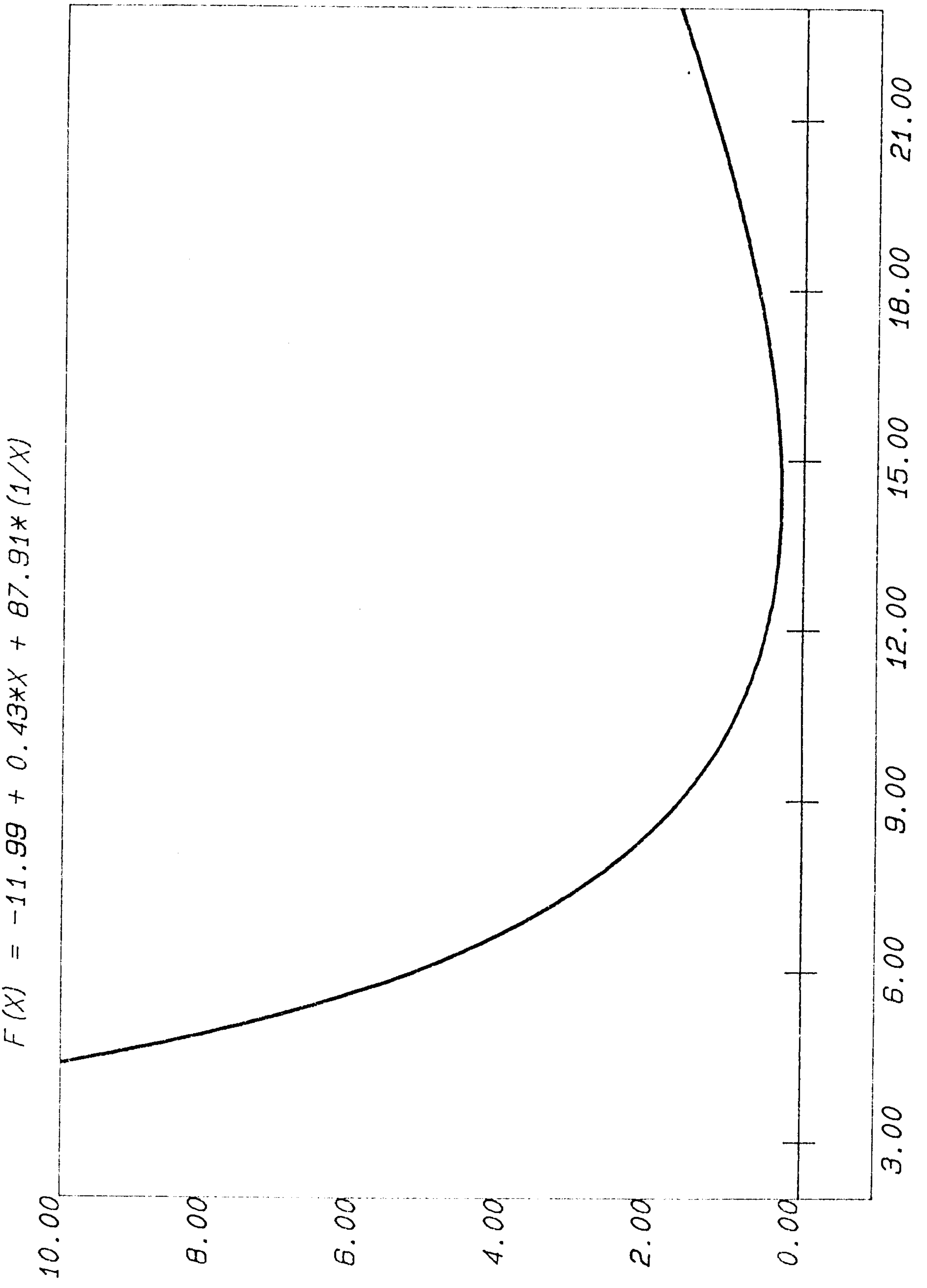


Figure 2.23 1923-1939 CORC $U^{-1}U^{-2}$ Equation

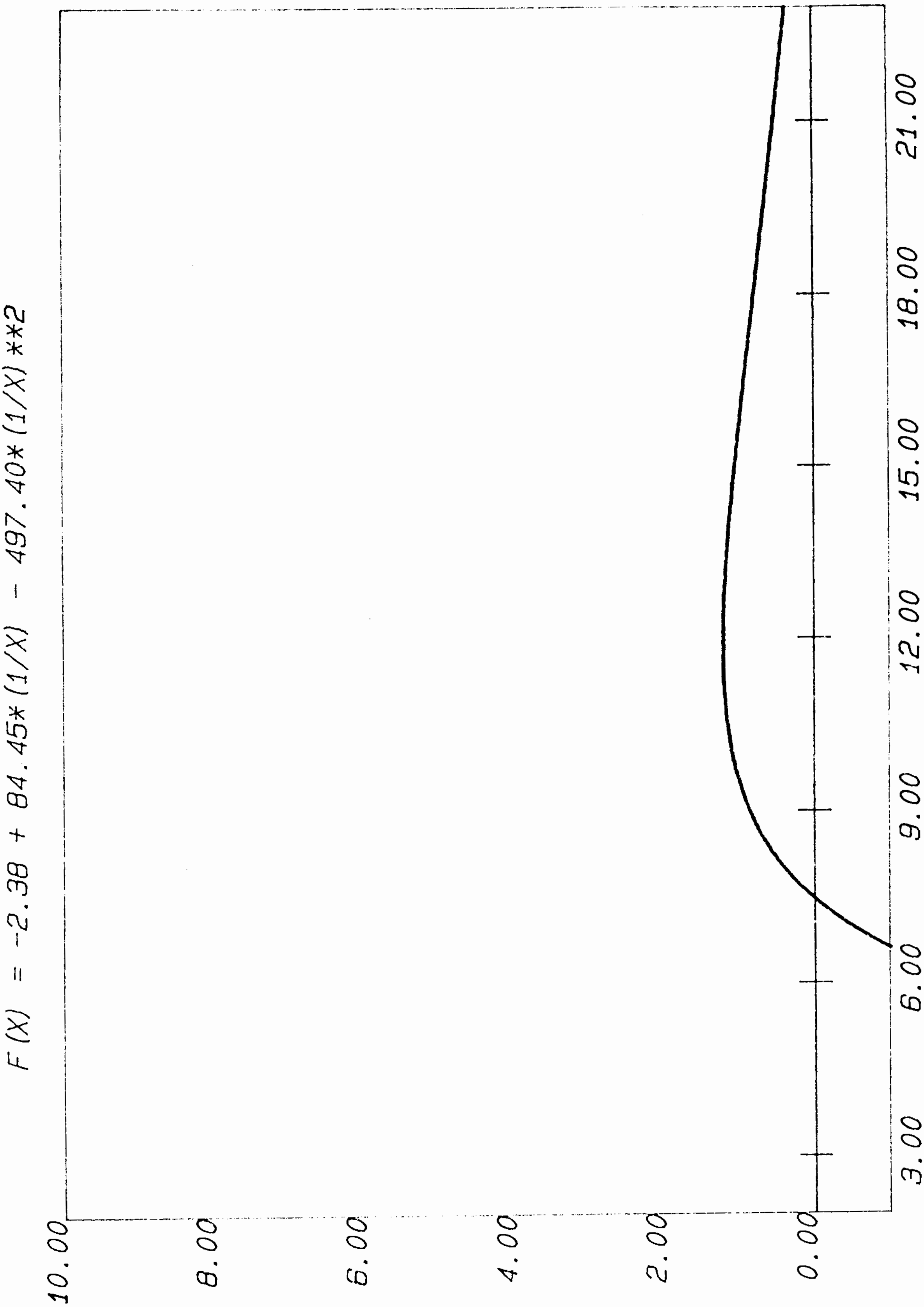


Figure 2.24 1923-1939 CORC $U^{-1}U^{-4}$ Equation

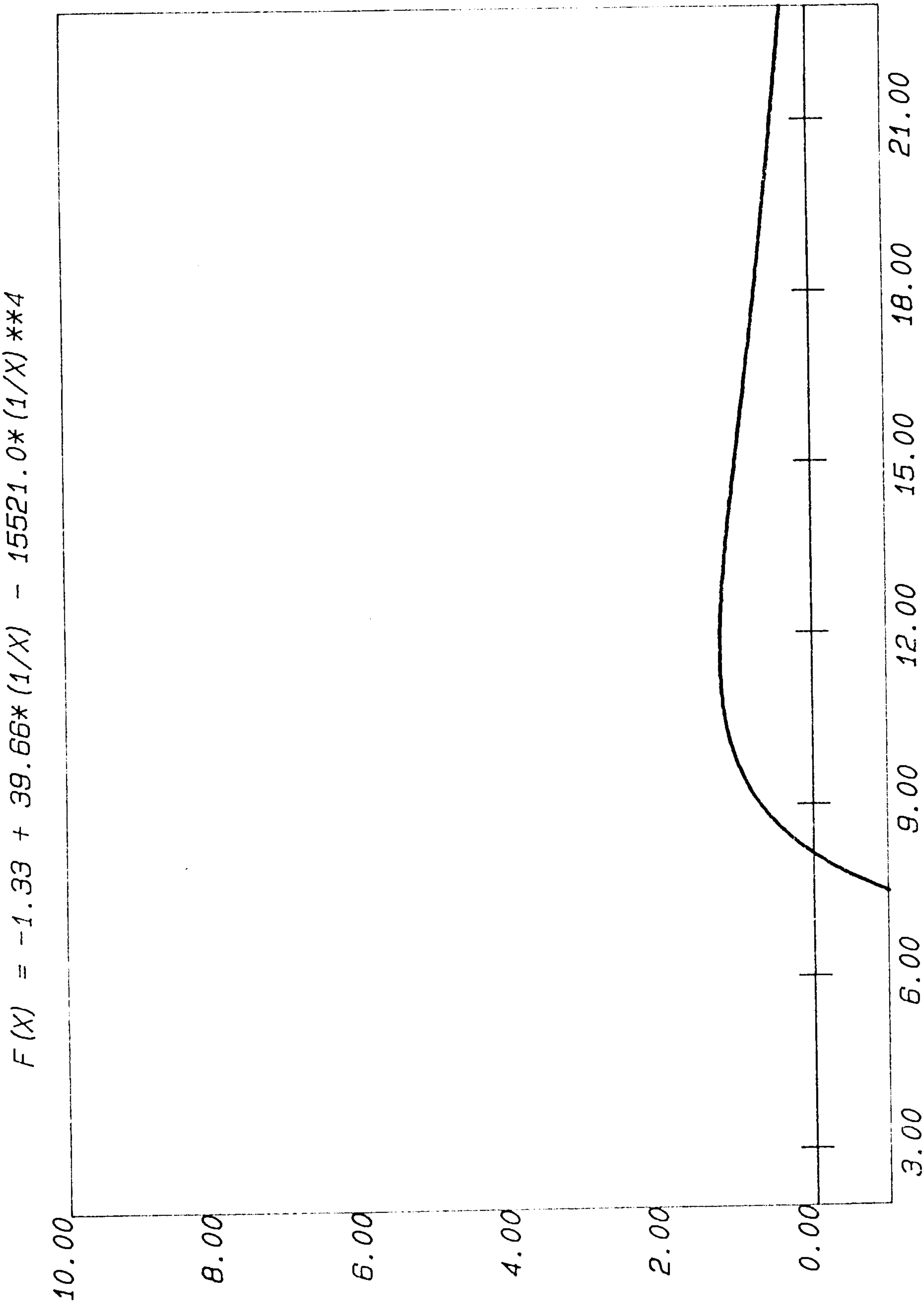


Figure 2.25 1923-1939 CORC UU^{-1} Equation

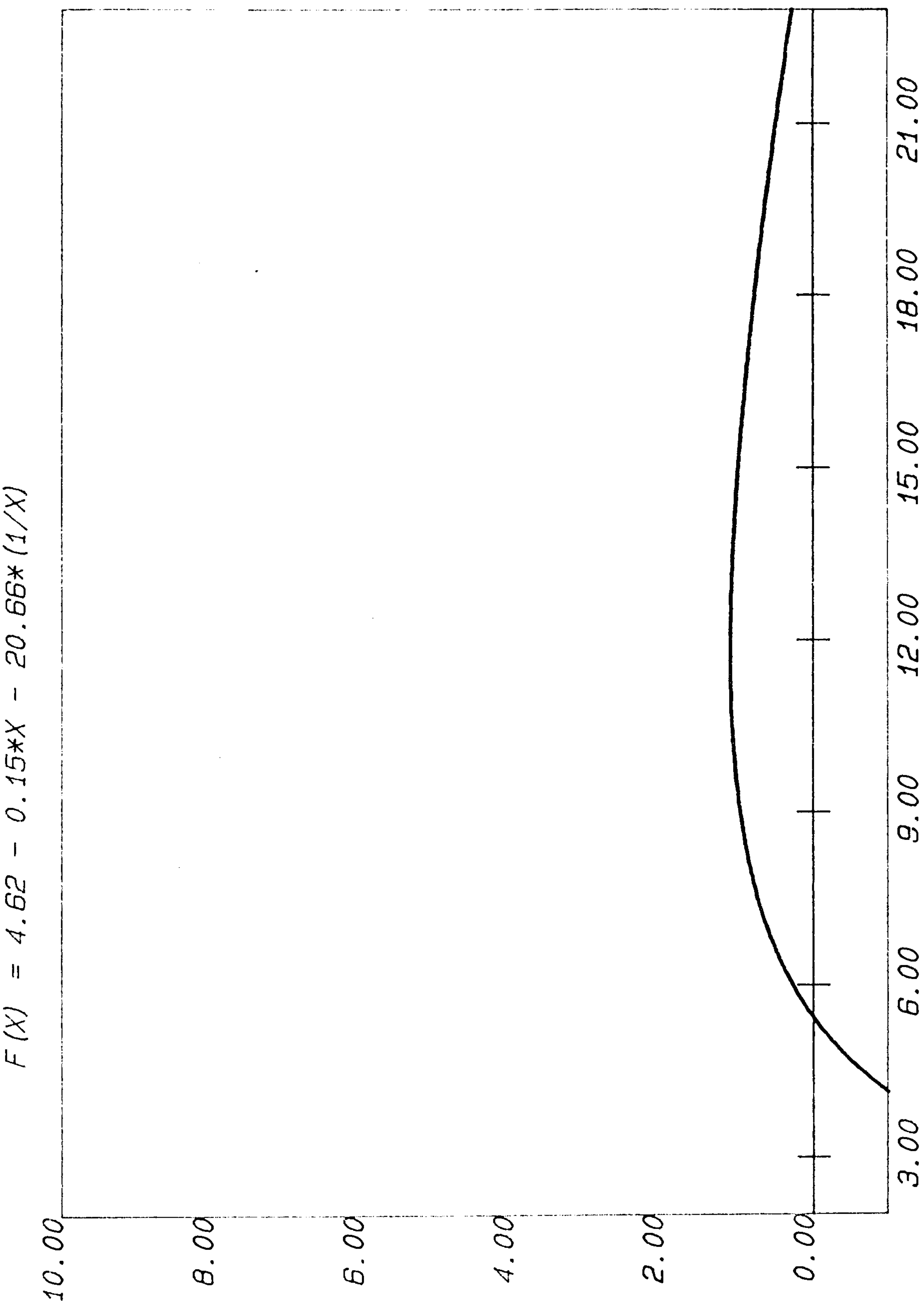


Figure 2.26 1919-1938 CORC $U^{-1}U^{-2}$ Equation

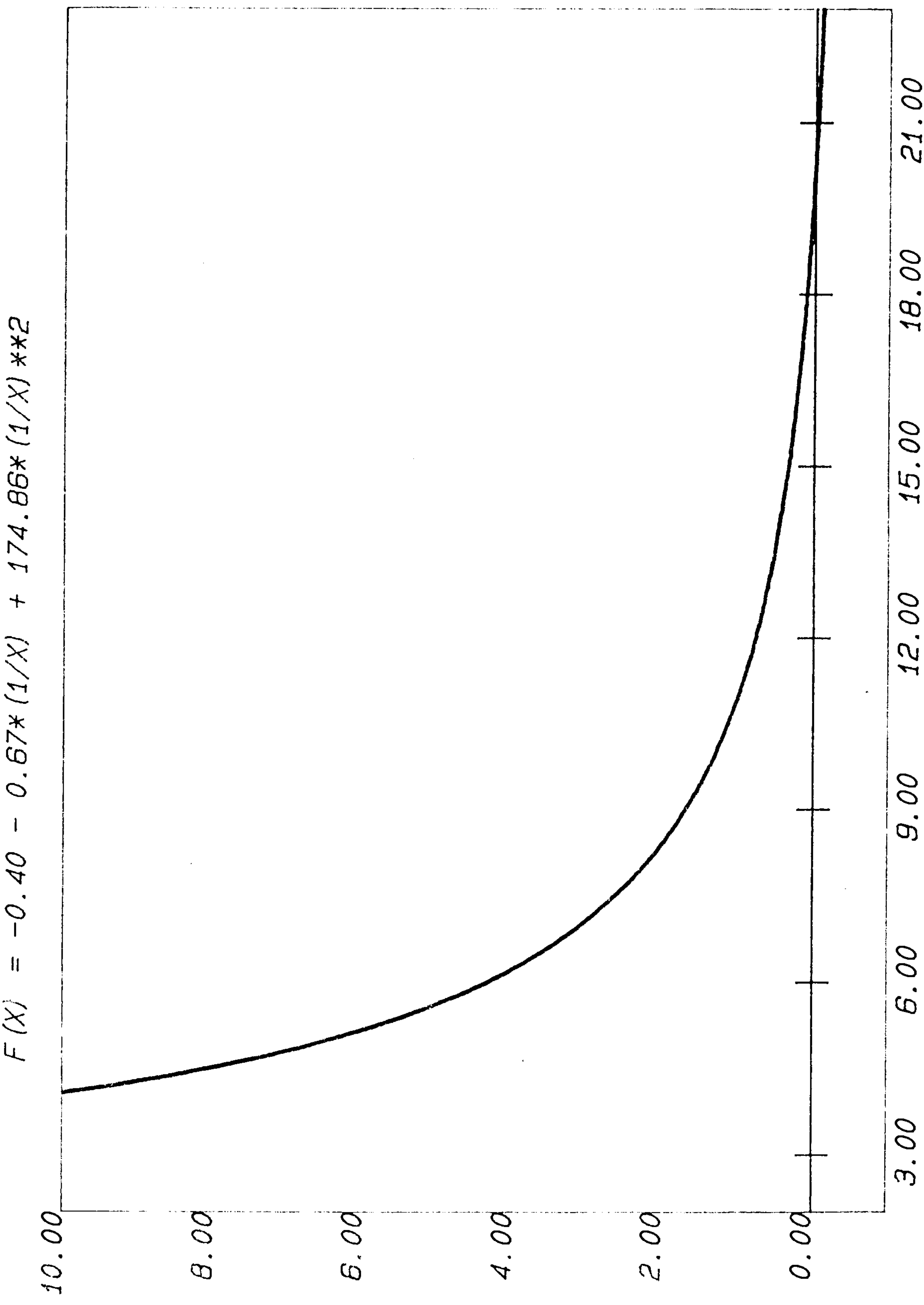


Figure 2.27 1919-1938 CORC $U^{-1}U^{-4}$ Equation

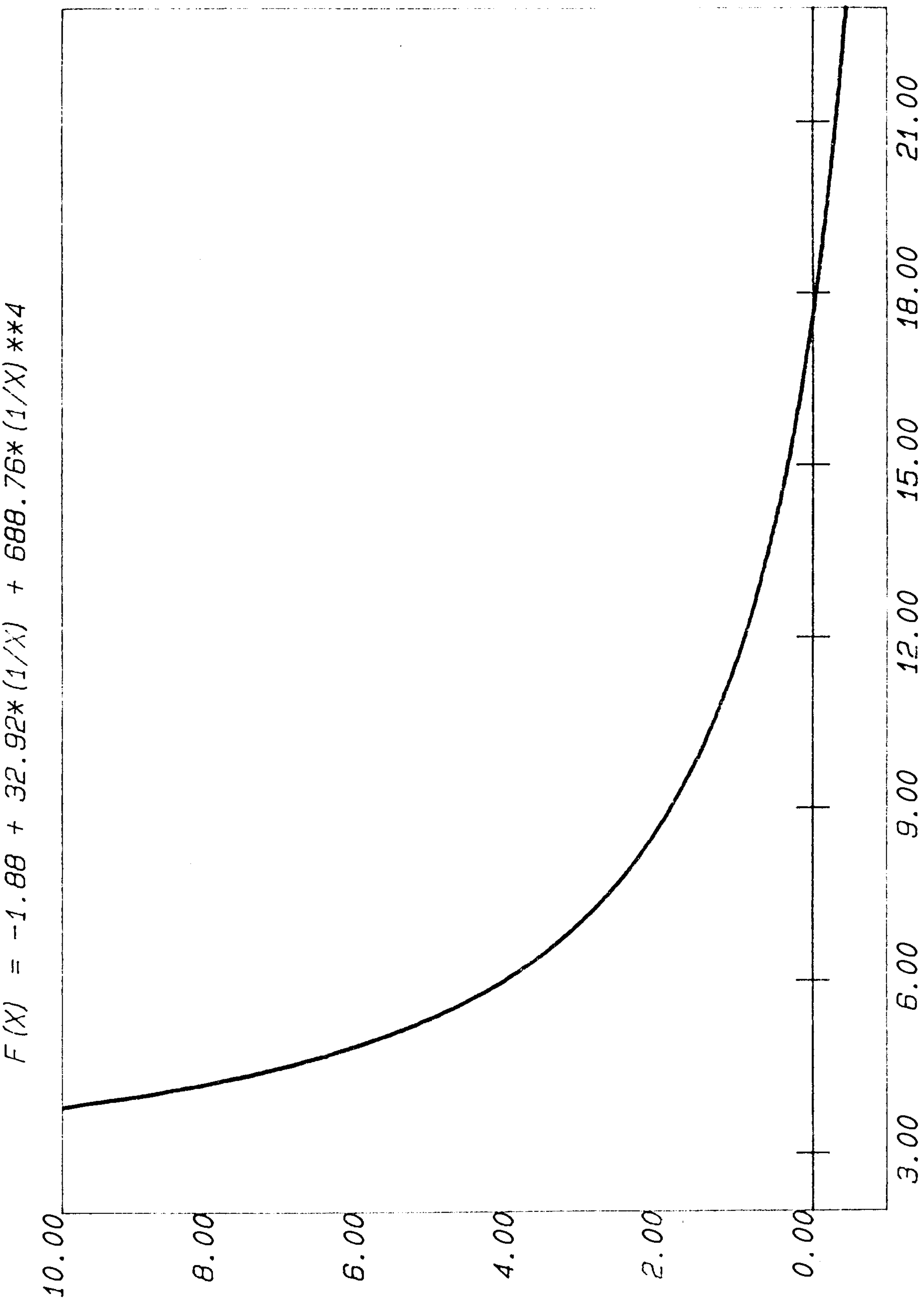
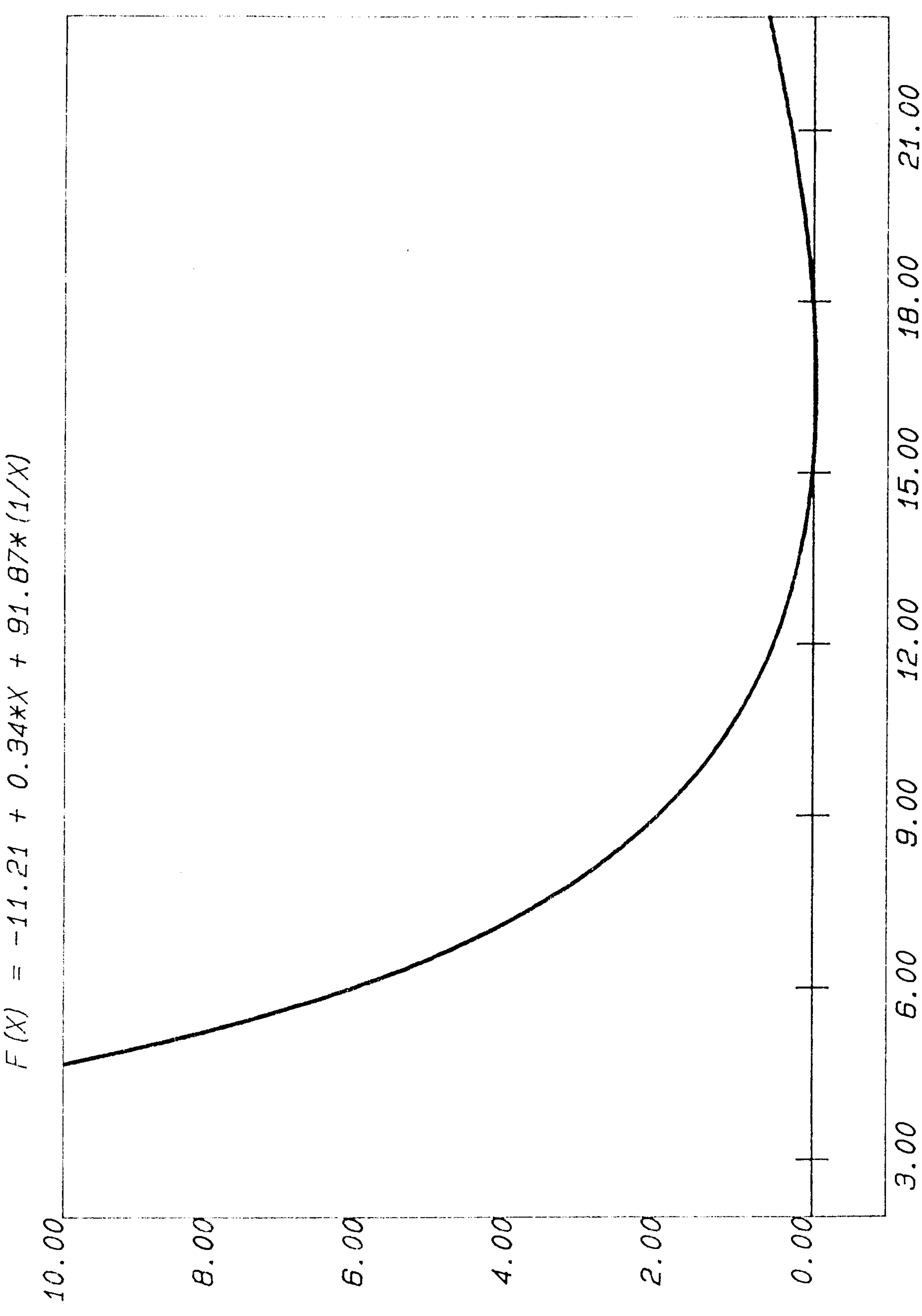


Figure 2.28 1919-1938 CORC UU^{-1} Equation



graphs of our estimated inter-war Phillips curves, force us to reject the estimated equations, with the exception of the 1919-1938 $U^{-1}U^{-2}$ and $U^{-1}U^{-4}$ forms on the grounds that they imply Phillips curves with positive slopes (at least for large values of U).[64]

It is hardly surprising that the Phillips curve performs so poorly during these years which encompass the post-war boom, the collapse of world trade in 1920, the massive structural dislocation associated with the accelerated decline of Britain's staple industries after 1919, the return to the Gold Standard in 1931, the approach of war in Europe and the rearmament program of the late 1930s. In particular, the study by Archibald et al. (1974), found that dividing the period into years on and off the Gold Standard led to a marked improvement in the behaviour of their model. We experimented with (0-1) dummy variables to try to capture this Gold Standard effect but none of the gold standard dummies had t-values larger than 0.5. One possibility is that quarterly data are needed to isolate these effects.

Let us now turn to the post-Second World War period.

(3) The Post-World War Two Period

We ran regressions for the Lipsey and Phillips' period (1948-1957) and for the complete post-war sample available to us, 1948-1979.[65] We also subdivided the whole post-1948 period at 1966, which is where the so-called structural break is supposed to have occurred.

Our OLS results for 1948-1957 appear in the first section of Table 2.4. With only ten years of data and with five estimated coefficients we have just five degrees of freedom in this period and so we are not surprised to find that the $\bar{R}^2$s are about 0.7. The joint F test on the U terms is consistent with the null hypothesis in all three cases. Notice that the coefficient on P is only about 0.4 which agrees with previous estimates for this period.[66] Also observe that U has a zero (statistically insignificant) coefficient. The signs and magnitudes of the U coefficients again suggest that collinearity is a problem. All three DWs lie right in the middle of the indeterminate range, but for so few degrees of freedom this range is very large (d_L = 0.376 and d_U = 2.414 are the one tail, 5 percent significance points of DW with 4 and 10 degrees of freedom according to the augmented Durbin-Watson tables which appear in Savin and White (1977)) and we therefore used SHAZAM to generate the exact Durbin-Watson probabilities for our equations by the Pan technique. These probabilities were 10.9, 11.4 and 10.6 percent for the three equations and so we concluded that the null hypothesis of zero autocorrelation could not be rejected.

We have graphed the implied Phillips curves in Figures 2.29-2.31, where it will be seen that they all have highly unsatisfactory shapes. We conclude that even if only the post-1948 sample had been available to reseachers in 1960, there would have been evidence that there were problems for the Phillips curve.

The most interesting feature of our OLS results for the whole period from 1948 to 1979 is that all of the P coefficients are insignificantly different from one according to a standard t-test. However, although the overall fit of the equations appear to be satisfactory, and the exact DWs are not inconsistent with the null hypothesis, the signs (and general lack of significance) of the U terms are once again worrying. However, an inspection of Figures 2.32-2.34

Figure 2.29 1948-1957 OLS $U^{-1}U^{-2}$ Equation

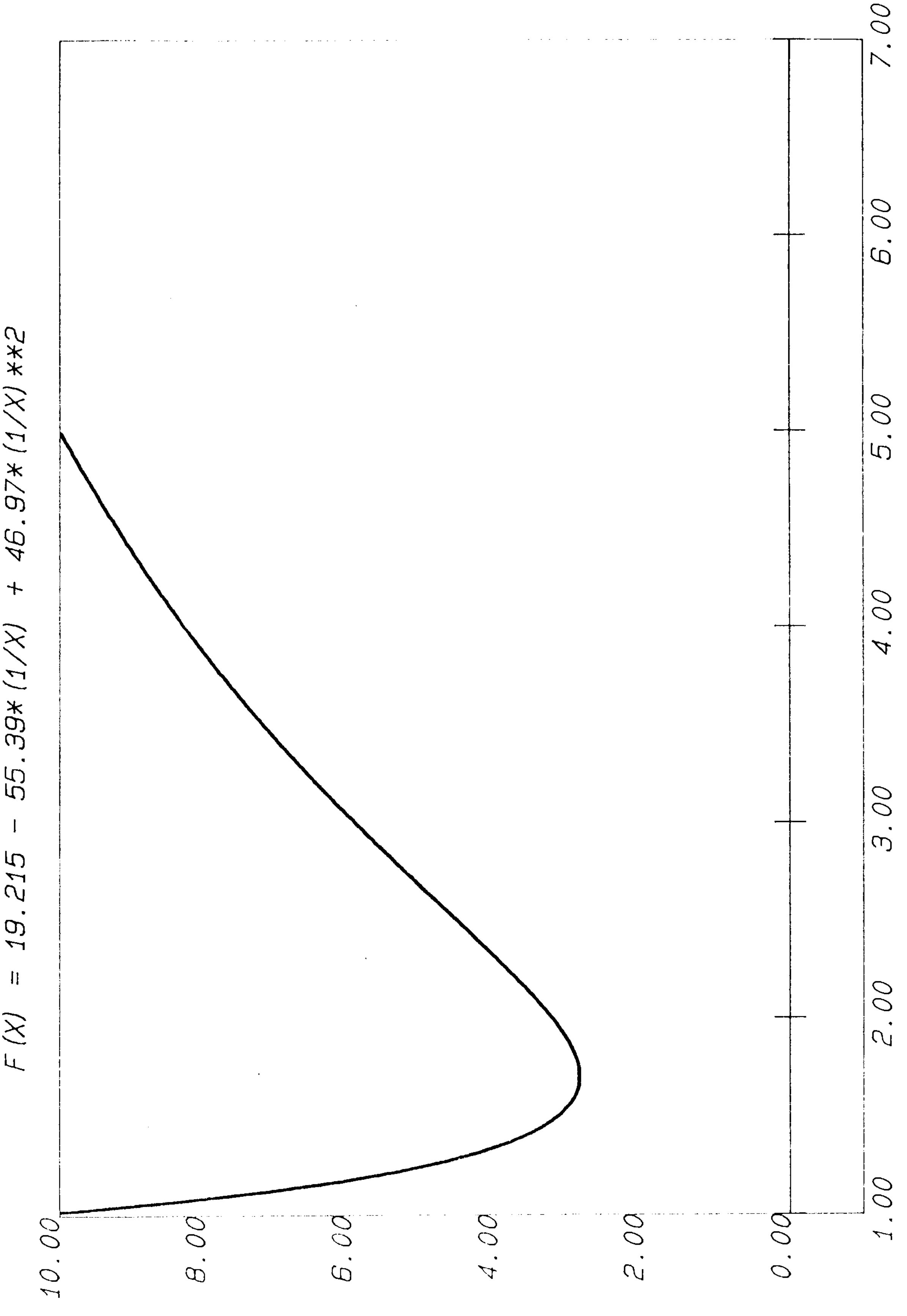


Figure 2.30 1948-1957 OLS $U^{-1}U^{-4}$ Equation

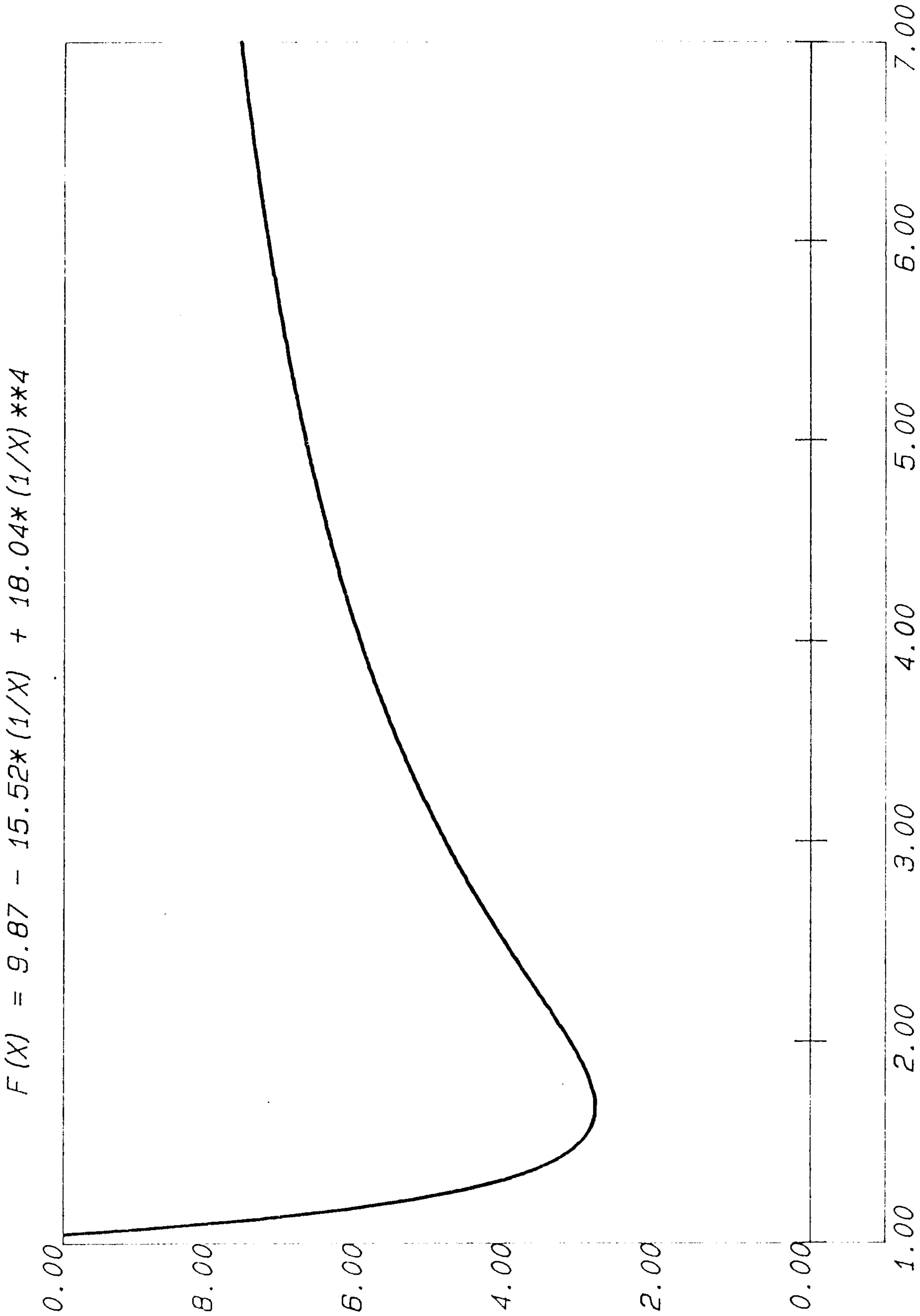


Figure 2.31 1948-1957 OLS UU^{-1} Equation

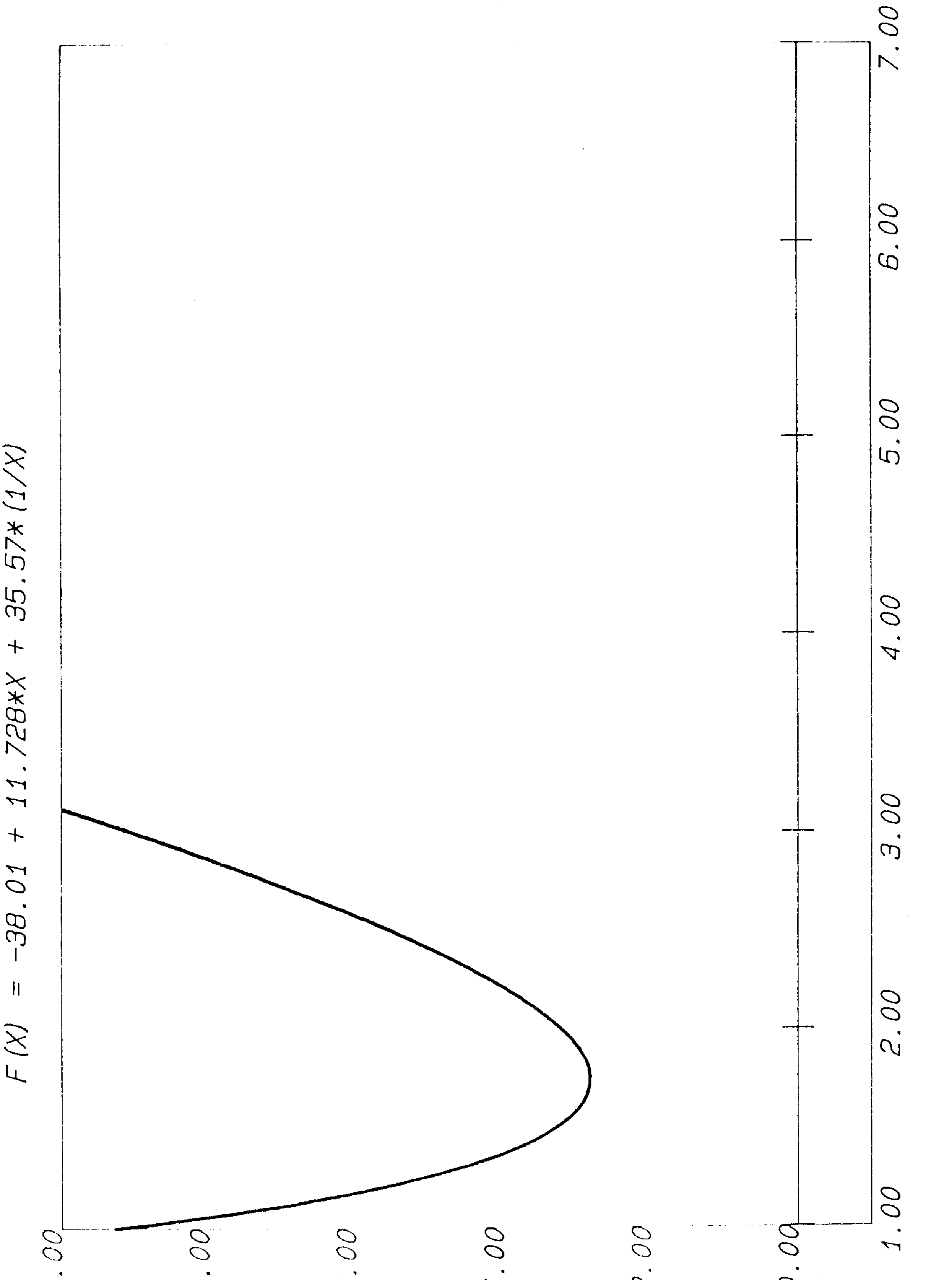


Figure 2.32 1948-1979 OLS $U^{-1}U^{-2}$ Equation

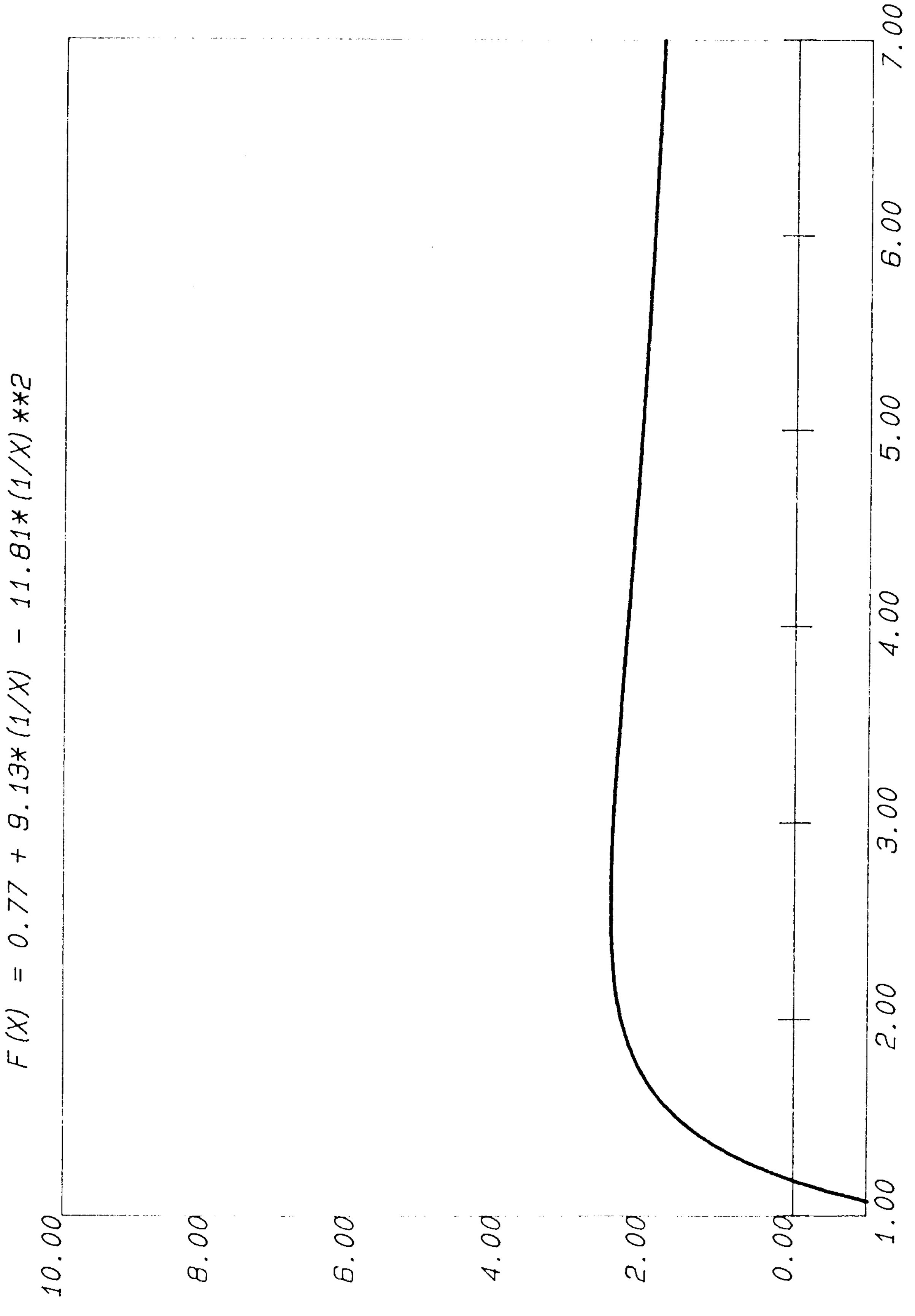


Figure 2.33 1948-1979 OLS $U^{-1}U^{-4}$ Equation

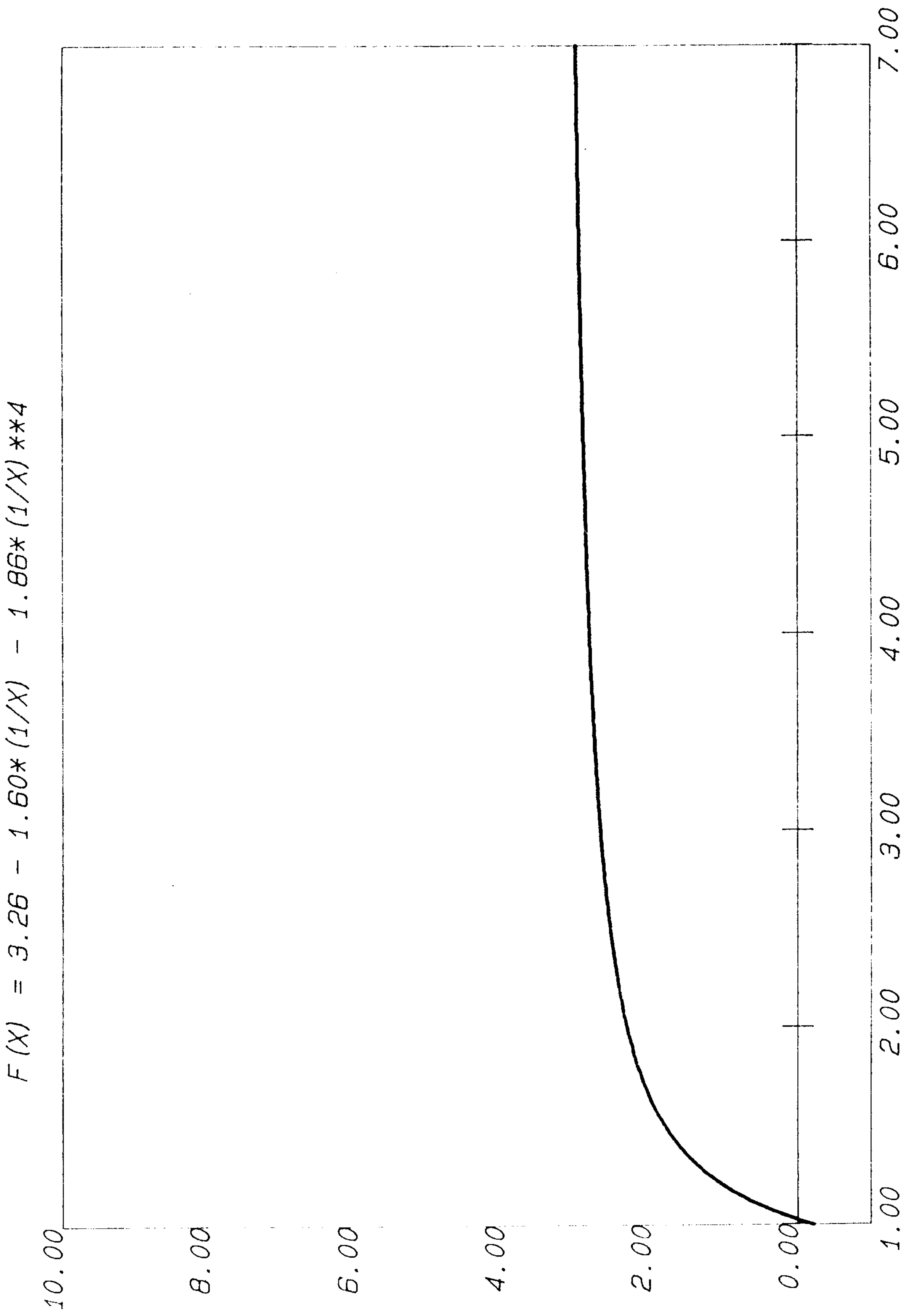


Figure 2.34 1948-1979 OLS UU^{-1} Equation

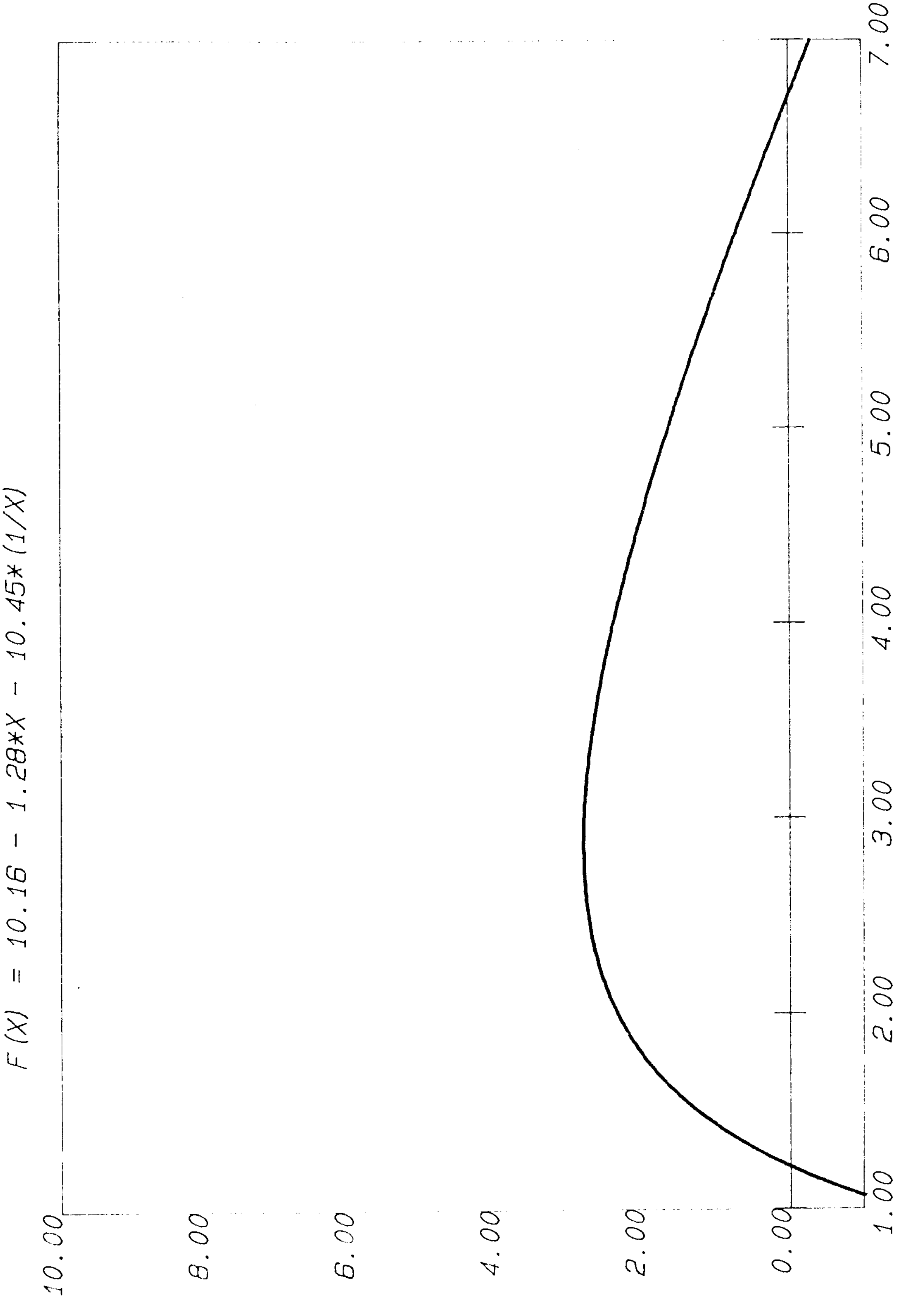


Table 2.4

Post-Second World War Regressions *

1948-1957: OLS

$$\dot{W} = 19.215 - 55.39\ U^{-1} + 46.97\ U^{-2} + 0.003\ U + 0.39\ P$$

(2.05) (-1.93) (2.11) (0.18) (2.17)

$R^2 = 0.83$ $\bar{R}^2 = 0.69$ $F(4,5) = 5.9$ $DW = 1.64$

$F(2,5) = 4.09$

$$\dot{W} = 9.87 - 15.52\ U^{-1} + 18.04\ U^{-4} + 0.004\ U + 0.41\ P$$

(1.85) (-1.47) (2.00) (0.26) (2.23)

$R^2 = 0.82$ $\bar{R}^2 = 0.67$ $F(4,5) = 5.6$ $DW = 1.65$

$F(2,5) = 3.8$

$$\dot{W} = -38.01 + 11.728\ U + 35.57\ U^{-1} + 0.000\ U + 0.38\ P$$

(-2.22) (2.22) (2.53) (0.031) (2.09)

$R^2 = 0.83$ $\bar{R}^2 = 0.70$ $F(4,5) = 6.3$ $DW = 1.64$

$F(2,5) = 4.4$

1948-1979: OLS

$$\dot{W} = 0.77 + 9.13\ U^{-1} - 11.81\ U^{-2} + 0.041\ U + 0.93\ P$$

(0.17) (0.58) (-0.78) (1.49) (6.10)

$R^2 = 0.79$ $\bar{R}^2 = 0.76$ $F(4,27) = 25.7$ $DW = 1.54$

$F(2,27) = 0.69$

$$\dot{W} = 3.26 - 1.60\ U^{-1} - 1.86\ U^{-4} + 0.041\ U + 0.89\ P$$

(0.94)(-0.21) (-0.18) (1.48) (5.74)

$R^2 = 0.79$ $\bar{R}^2 = 0.76$ $F(4,27) = 25.0$ $DW = 1.49$

$F(2,27) = 0.40$

Table 2.4--continued

$$\dot{W} = 10.16 - 1.28\ U - 10.45\ U^{-1} + 0.038\ U + 0.96\ P$$

$$(2.30)(-1.65) \quad (-1.88) \quad (1.44) \quad (6.93)$$

$R^2 = 0.81$ $\bar{R}^2 = 0.78$ $F(4,27) = 28.2$ $DW = 1.61$

$F(2,27) = 1.77$

<u>1948-1966: OLS</u>

$$\dot{W} = 14.46 - 36.70\ U^{-1} + 31.40\ U^{-2} + 0.056\ U + 0.27\ P$$

$$(1.12)\ (-0.84) \quad (0.87) \quad (1.89) \quad (0.67)$$

$R^2 = 0.32$ $\bar{R}^2 = 0.12$ $F(4,14) = 1.6$ $DW = 2.09$

$F(2,14) = 0.38$

$$\dot{W} = 9.74 - 13.32\ U^{-1} = 15.15\ U^{-4} + 0.056\ U + 0.26\ P$$

$$(1.39)\ (-0.86) \quad (0.97) \quad (1.92) \quad (0.67)$$

$R^2 = 0.33$ $\bar{R}^2 = 0.13$ $F(4,14) = 1.7$ $DW = 2.10$

$F(2,14) = 0.48$

$$\dot{W} = -12.61 + 4.54\ U + 14.77\ U^{-1} + 0.056\ U + 0.28\ P$$

$$(-0.48)\ (0.62) \quad (0.64) \quad (1.88) \quad (0.69)$$

$R^2 = 0.30$ $\bar{R}^2 = 0.10$ $F(4,14) = 1.5$ $DW = 2.09$

$F(2,14) = 0.2$

<u>1967-1979: OLS</u>

$$\dot{W} = -22.6 + 195.2\ U^{-1} - 333.51\ U^{-2} - 0.049\ U + 0.96\ P$$

$$(-3.25)\ (3.41) \quad (-3.21) \quad (-1.20) \quad (6.72)$$

$R^2 = 0.92$ $\bar{R}^2 = 0.88$ $F(4,8) = 23.5$ $DW = 1.90$

$F(2,8) = 7.14$

Table 2.4--continued

$$\dot{W} = -11.61 + 79.42\ U^{-1} - 710.48\ U^{-4} - 0.042\ U + 0.93\ P$$

(-3.00) (3.85) (-3.39) (-1.08) (6.58)

$R^2 = 0.93$ $\bar{R}^2 = 0.89$ $F(4,8) = 25.2$ $DW = 1.90$

$F(2,8) = 7.9$

$$\dot{W} = 45.03 - 5.44\ U - 72.62\ U^{-1} - 0.056\ U + 0.99\ P$$

(2.57)(-2.74) (-2.27) (-1.26) (6.54)

$R^2 = 0.91$ $\bar{R}^2 = 0.86$ $F(4,8) = 19.6$ $DW = 1.94$

$F(2,8) = 5.4$

<u>1948-1957: CORC</u>

$$\dot{W} = 8.63 - 24.26\ U^{-1} + 20.37\ U^{-2} - 0.019\ U + 0.78\ P$$

(1.71) (-1.61) (1.70) (-1.65) (5.77)

$R^2 = 0.95$ $\bar{R}^2 = 0.90$ RHO = 0.88 $DW = 0.87$

(6.00)

$F(2,5) = 1.8$

$$\dot{W} = 4.36 - 6.56\ U^{-1} + 7.40\ U^{-4} - 0.018\ U + 0.80\ P$$

(1.49)(-1.24) (1.55) (-1.51) (5.76)

$R^2 = 0.94$ $\bar{R}^2 = 0.90$ RHO = 0.88 $DW = 0.90$

(5.86)

$F(2,5) = 1.5$

$$\dot{W} = 17.19 + 5.38\ U + 16.07\ U^{-1} - 0.021\ U + 0.76\ P$$

(-1.84) (1.90) (2.02) (-1.90) (5.83)

$R^2 = 0.95$ $\bar{R}^2 = 0.91$ RHO = 0.89 $DW = 0.77$

(6.27)

Table 2.4--continued

$F(2,5) = 2.2$

<u>1948-1979: CORC</u>

$$\dot{W} = 1.76 + 5.86\ U^{-1} - 8.67\ U^{-2} + 0.046\ U + 0.89\ P$$

(0.36) (0.34) (−0.52) (1.65) (5.24)

$R^2 = 0.72$ $\bar{R}^2 = 0.67$ RHO = 0.25 DW = 1.89

(1.44)

$F(2,27) = 0.5$

$$\dot{W} = 4.04 - 3.10\ U^{-1} = 0.15\ U^{-4} + 0.84\ P$$

(1.08)(−0.39) (0.014) (4.92)

$R^2 = 0.70$ $\bar{R}^2 = 0.66$ RHO = 0.27 DW = 1.88

$F(2,27) = 0.36$

$$\dot{W} = 9.93 - 1.21\ U - 10.02\ U^{-1} + 0.043\ U + 0.93\ P$$

(2.04)(−1.39) (−1.65) (1.59) (6.08)

$R^2 = 0.75$ $\bar{R}^2 = 0.71$ RHO = 0.20 DW = 1.89

( )

$F(2,27) = 1.36$

<u>1948-1966: CORC</u>

$$\dot{W} = 14.42 - 36.68\ U^{-1} + 31.52\ U^{-2} + 0.055\ U + 0.26\ P$$

(1.12) (−0.84) (0.87) (.92) (0.68)

$R^2 = 0.33$ $\bar{R}^2 = 0.14$ RHO = −0.07 DW = 1.98

(−0.31)

$F(2,14) = 0.4$

Table 2.4--continued

$$\dot{W} = 9.69 - 13.20\ U^{-1} + 15.18\ U^{-4} + 0.055\ U + 0.26\ P$$

(1.39) (-0.85) (0.98) (1.95) (0.68)

$R^2 = 0.34$ $\bar{R}^2 = 0.15$ RHO = -0.07 DW = 1.98

(-0.31)

F(2,14) = 0.5

$$\dot{W} = -13.01 + 4.63\ U + 15.25\ U^{-1} + 0.056\ U + 0.27\ P$$

(-0.13) (0.64) (0.66) (1.91) (0.69)

$R^2 = 0.31$ $\bar{R}^2 = 0.11$ RHO = -0.07 DW = 1.98

(-0.32)

F(2,14) = 0.2

<u>1967-1979: CORC</u>

$$\dot{W} = -22.72 + 192.33\ U^{-1} - 335.44\ U^{-2} - 0.048\ U + 0.96\ P$$

(-3.20) (3.36) (-3.17) (-1.16) (6.61)

$R^2 = 0.92$ $\bar{R}^2 = 0.87$ RHO = 0.04 DW = 1.92

(0.13)

F(2,8) = 6.9

$$\dot{W} = -11.67 + 79.82\ U^{-1} - 714.20\ U^{-4} - 0.042\ U + 0.92\ P$$

(-2.96) (3.81) (-3.37) (-1.05) (6.50)

$R^2 = 0.92$ $\bar{R}^2 = 0.88$ RHO = 0.02 DW = 1.92

(0.09)

F(2,8) = 7.7

Table 2.4--continued

$$\dot{W} = 45.07 - 5.44\ U - 72.64\ U^{-1} - 0.055\ U + 0.99\ P$$

$$(2.55)(-2.71) \quad (-2.25) \quad (-1.22) \quad (6.44)$$

$R^2 = 0.90$ $\quad \bar{R}^2 = 0.85$ $\quad$ RHO = 0.03 $\quad$ DW = 1.95

(0.11)

$F(2,8) = 5.2$

*t-values (or asymptotic t-values in the case of Rho) in parenthesis.

shows that all three equations have positive slopes (for low values of U) in the U, W plane and so we must reject these estimates. Our results appear to be consistent with those of Henry, Sawyer and Smith (1976).

Turning to the pre-structural break results, we observe that the equations exhibit very poor fits and that the addition of the nine extra years to the Phillips sample has reduced the $\bar{R}^2$s to less than one fifth of their previous magnitudes. However, there is no evidence of serial correlation (the exact DW probabilities are close to 41 percent), but there is also no evidence that the excess demand proxies--and this is the period before the structural break--exert any influence upon W. Figures 2.35-2.37 confirm that the equations generate preversely shaped Phillips curves.

Turning to the second half of the post-war period we see that the apparently good fit, satisfactory DW statistic, and significant coefficients on all variables except U, is somewhat marred by the magnitudes of the coefficients on some of the unemployment variables, and also the number of doubtful signs on these variables. Here again we note the extremely large simple correlations between the unemployment variables.

The CORC transformation seems to have worked satisfactorily for the whole 1948-1979 period although none of the regressions have particularly good fits, while the results for the two subperiods suggest, as we suspected, that autocorrelation was not present to an extent that the generalized least squares procedure would improve the overall properties of the estimates.

Figures 2.41-2.43 graph the corrected 1948-1979 equations which, as

Figure 2.35 1948-1966 OLS $U^{-1}U^{-2}$ Equation

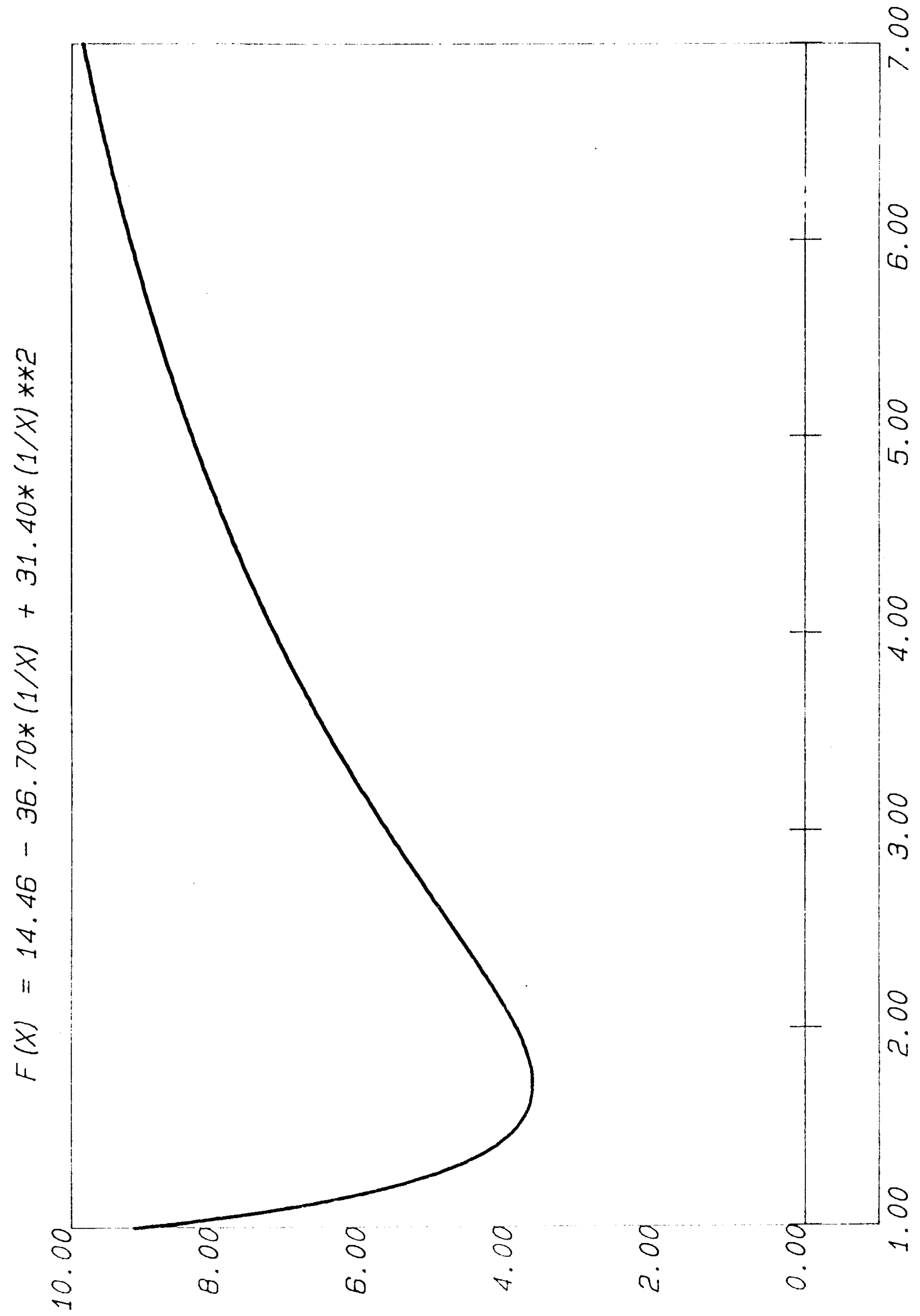


Figure 2.36 1948-1966 OLS $U^{-1}U^{-4}$ Equation

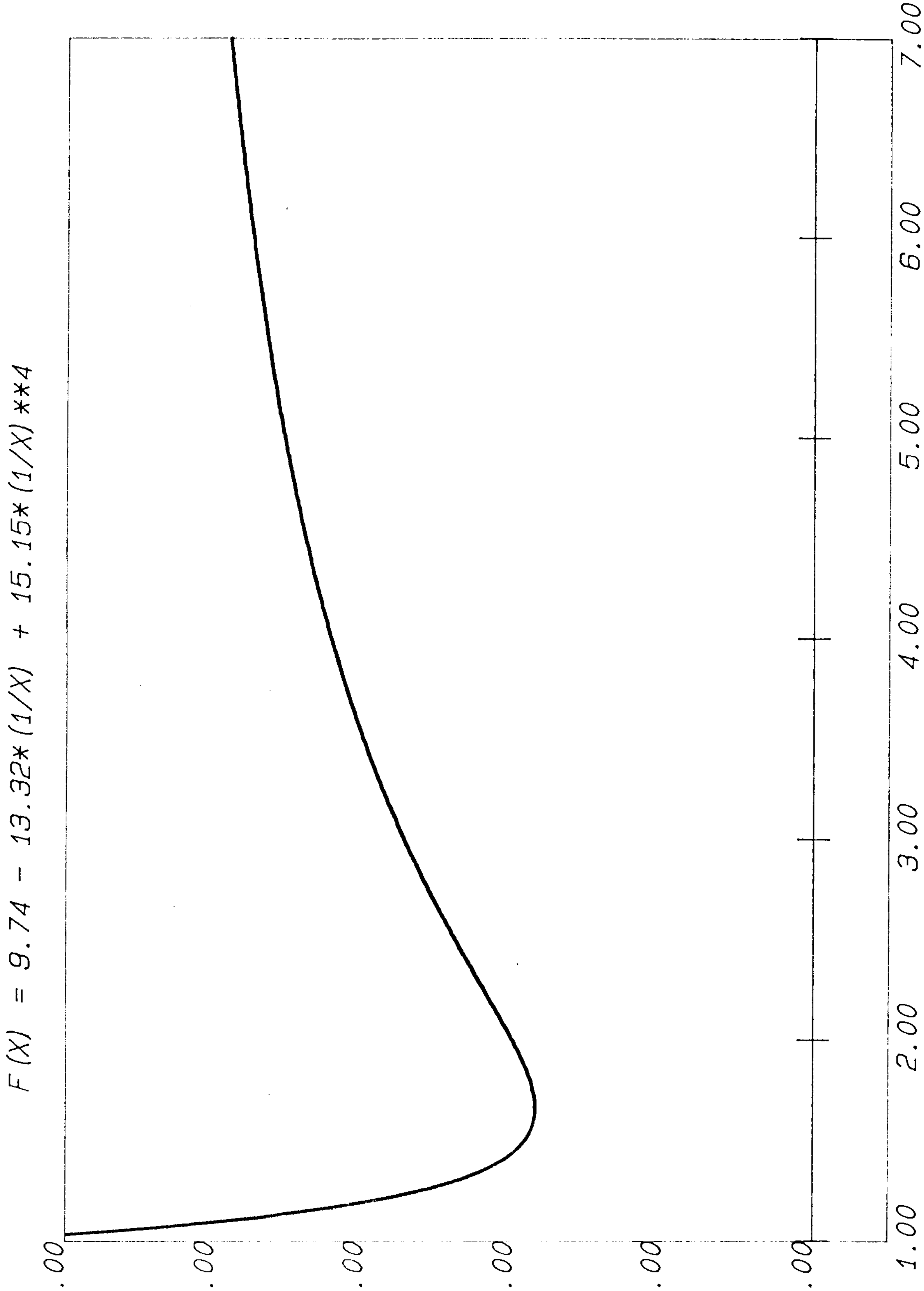


Figure 2.37 1948-1966 OLS UU^{-1} Equation

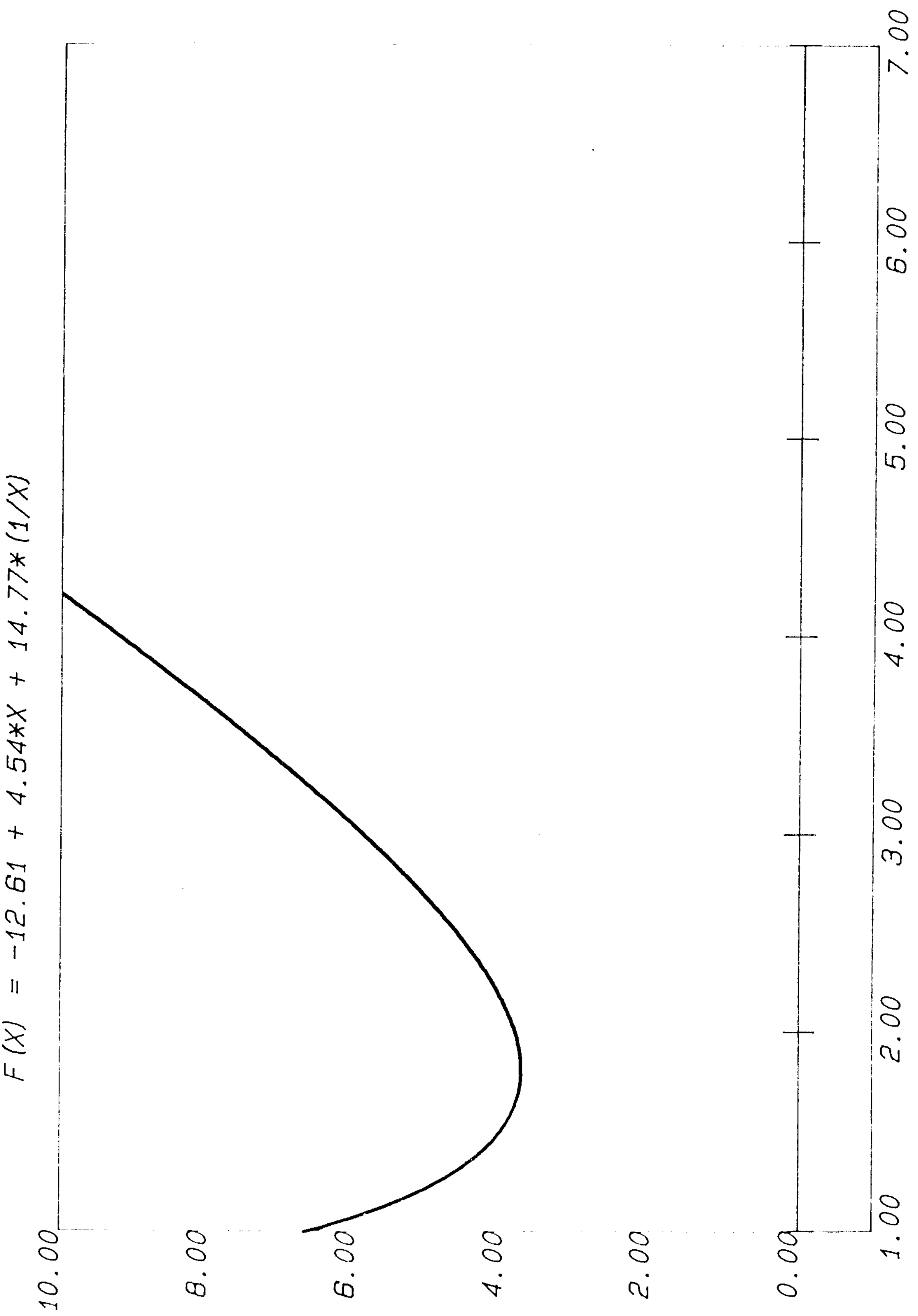


Figure 2.38 1967=1979 OLS $U^{-1}U^{-2}$ Equation

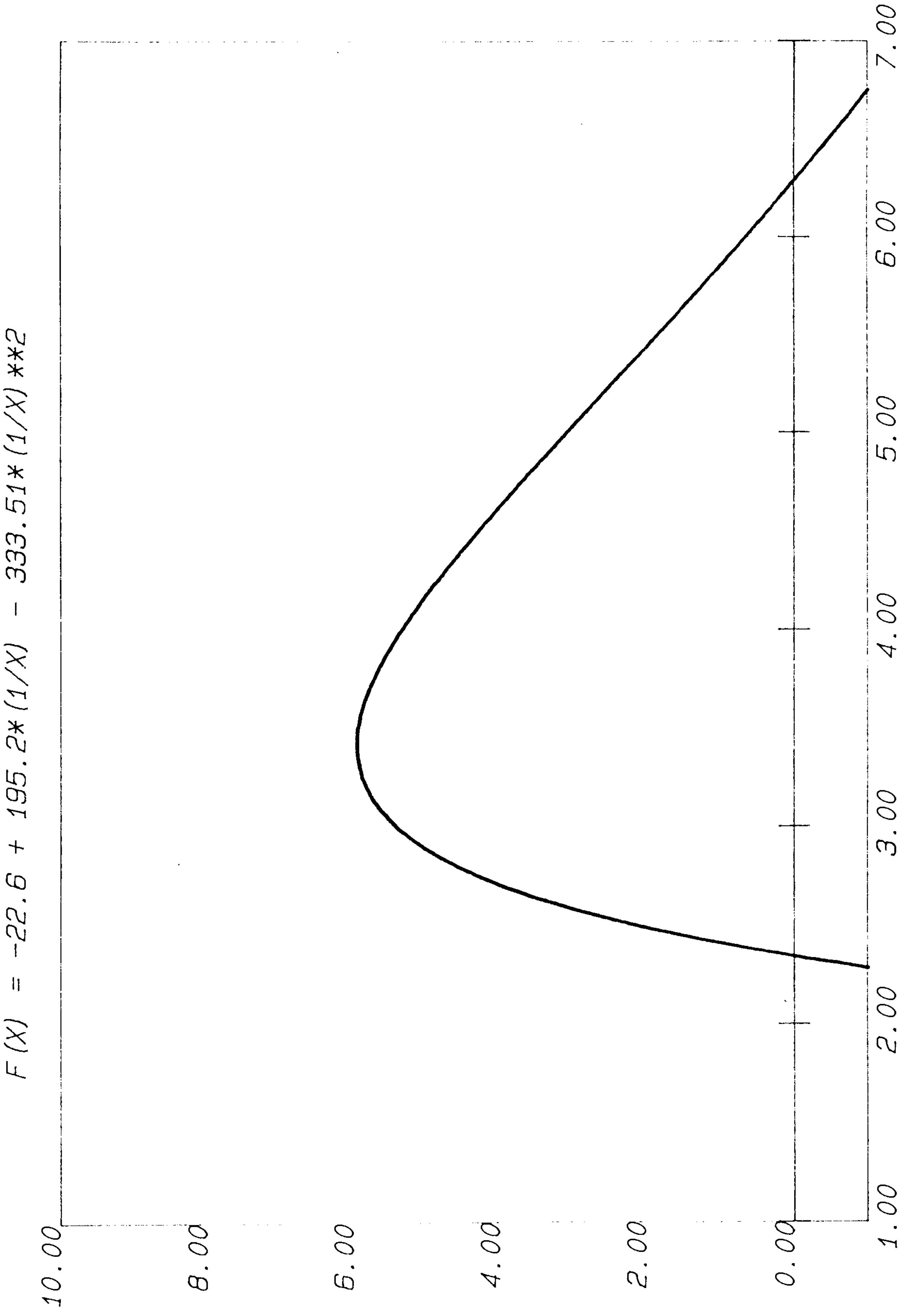


Figure 2.39 1967-1979 OLS $U^{-1}U^{-4}$ Equation

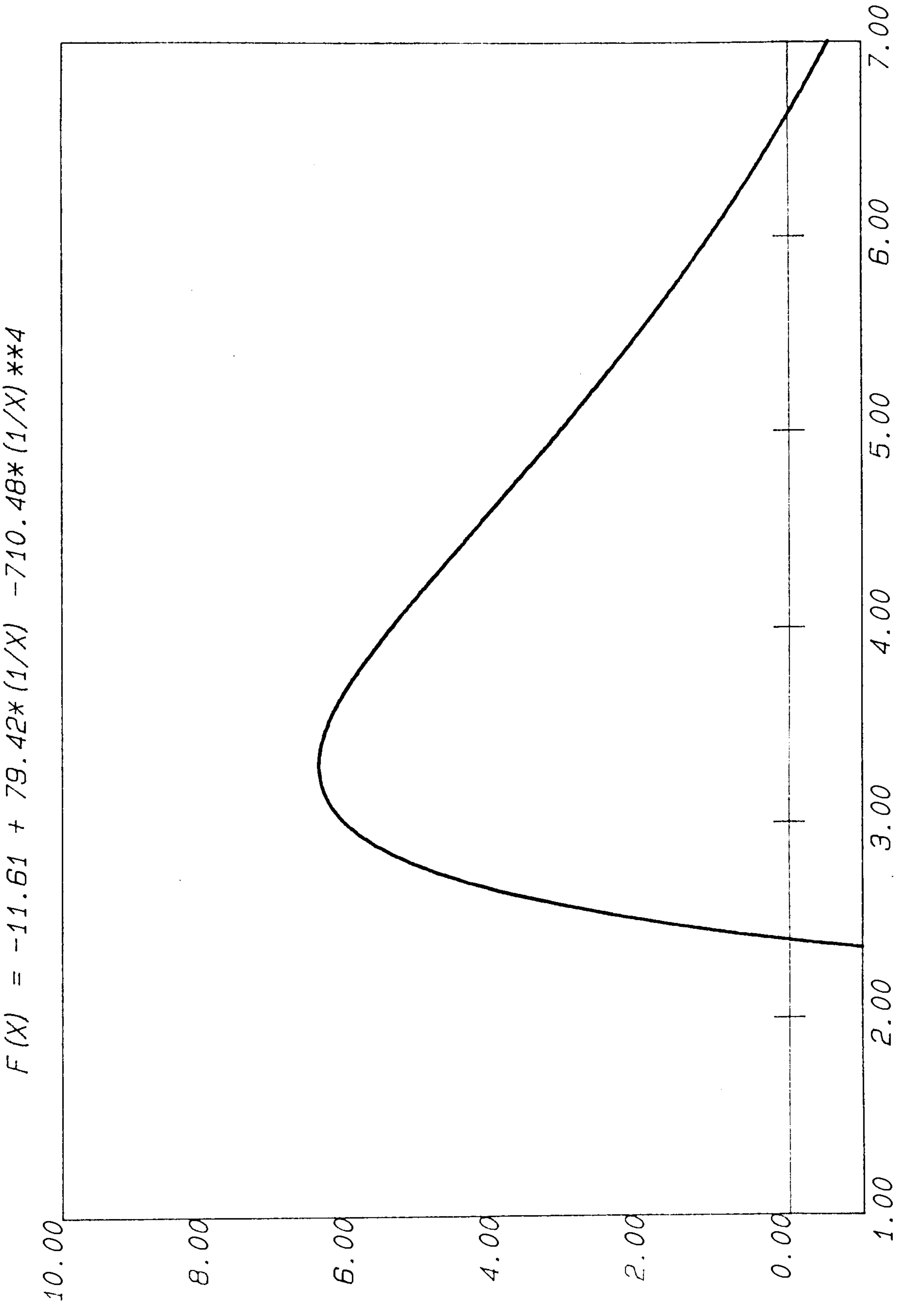
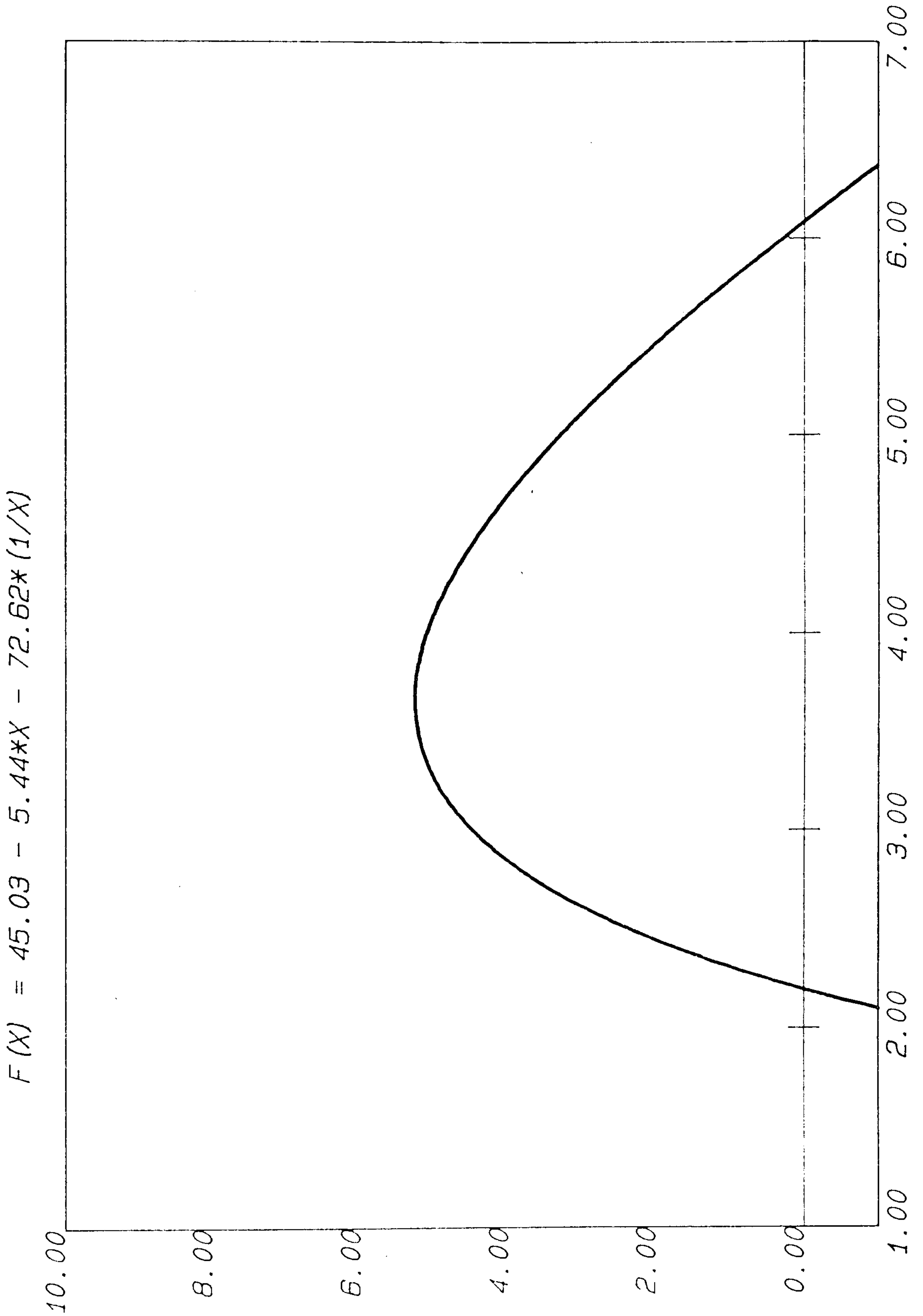


Figure 2.40 1967-1979 OLS UU^{-1} Equation



we would expect, all have unsatisfactory shapes. We have not plotted the other corrected equations because of the evidence that the procedure was inapplicable. We will now present our general conclusions.

4. CONCLUSIONS

We conclude from our experiment that the Phillips curve--at least in the original formulation adopted by Phillips and Lipsey--does not exist, if by existence we mean that a single, temporally stable equation describes the one hundred and twenty-nine years of wage behaviour in the U.K. from 1851 to 1979. The answer to the first question we posed in the introduction (If the Phillips curve is dead, was it ever alive?) is: Yes. According to conventional econometric criteria there was a Phillips curve for the U.K. economy before the First World War. The answer to our second question (If the Phillips curve was once alive, when did it die?) is: Sometime after World War One. We can find no trace of the standard Phillips-Lipsey curve during the inter-war period,[67] and therefore conclude that a researcher working in the 1930s would have noted the failure of the relationship to re-assert itself after the Armistice. On the other hand we feel that, even if the inter-war data had failed to exist, an economist could have detected the failure of the Phillips curve to materialise outside of the pre-1913 period as early as 1960, and certainly by 1967.

How can we account for our failure to find a Phillips curve after 1913? There are a number of obvious problems with our experiment.

1. Our data are generally of poor quality (the unemployment series, in particular, poses obvious problems of comparability).

2. In the nineteenth century there was a regular cycle in economic

Figure 2.41 1948-1979 CORC $U^{-1}U^{-2}$ Equation

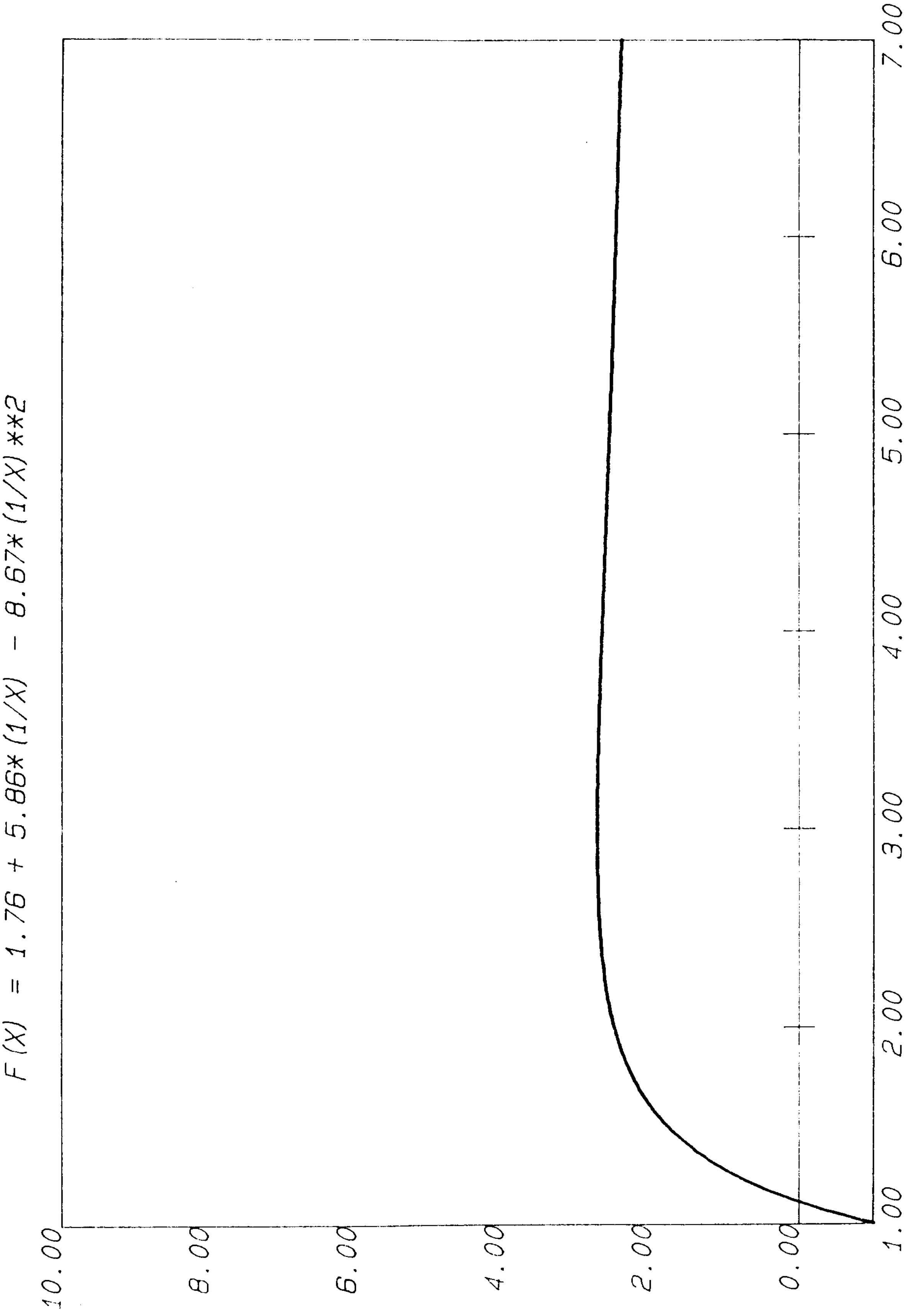


Figure 2.42 1948-1979 CORC $U^{-1}U^{-4}$ Equation

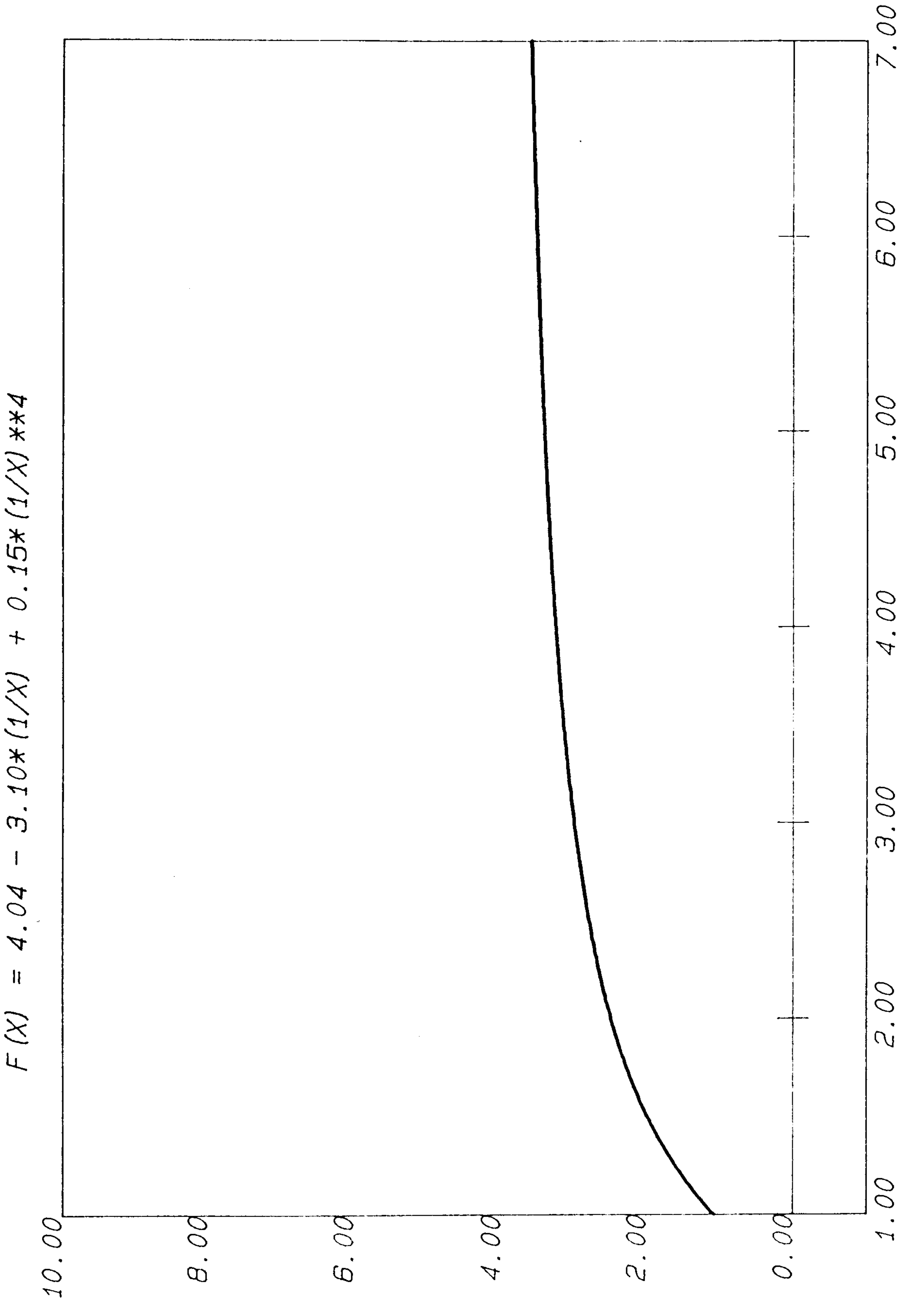
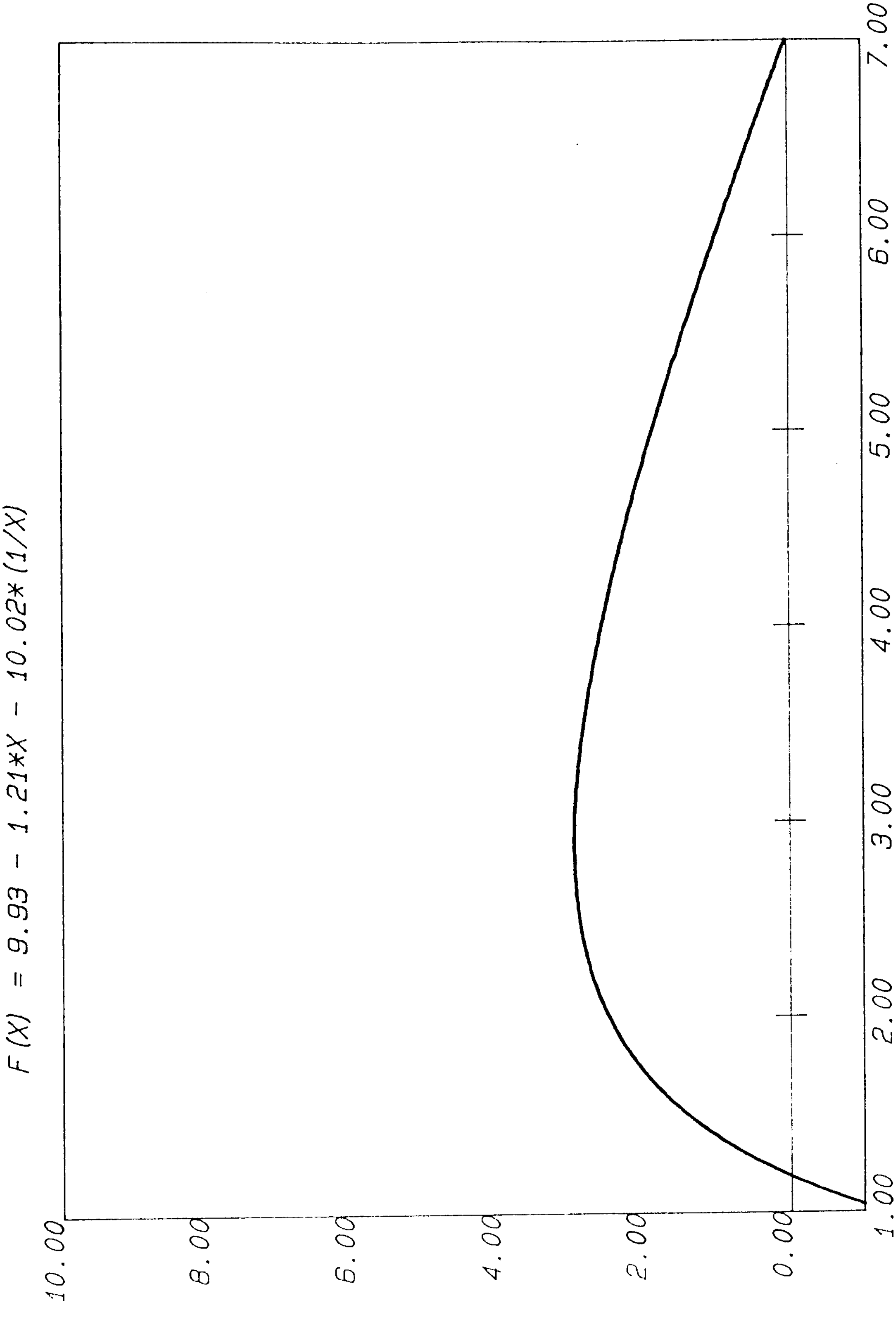


Figure 2.43 1948-1979 CORC UU^{-1} Equation



activity with an average duration of about eight years. After 1918 both the regularity and the period of the cycle changed (particularly after 1945). It may be that annual observations are too temporally aggregated to pick up the fluctuations in aggregate activity.

3. We have carefully kept to the original Phillips-Lipsey specification of the estimating equation. This was in part a reflection of our desire to keep the paper within reasonable bounds, but it also reflects our belief that the first step in a replication experiment is to try to reproduce and extend the original formulation of the hypothesis being tested. As a consequence we have ignored all of the "intruder" variables which have been introduced at one time or another into Phillips curve regressions.[68]

Further we have deliberately confined ourselves to the static, equilibrium formulation of Phillips' model of labour market adjustment. We have not introduced lags nor have we attempted to model the error dynamics of the equations beyond the most cursory recognition of the possibility of first order autocorrelation.

4. There are many institutional features of the U.K. economy which we have ignored, such as the frequent and prolonged bouts of incomes policy, and the high degree of openness which characterises the U.K. economy.

5. A recurrent problem with our empirical estimates was the collinearity between the U terms induced by the polynomial specification. Some preliminary empirical work suggests that this problem may be in part circumvented by the replacement of our three functional forms by the U^{-1} proxy.

6. Phillips and Lipsey both commented on the obvious interdependence of wages and prices. There is obviously a need to provide simultaneous equation estimates of our Phillips curves.

7. Since 1968 the Acceleration Hypothesis/Augmented Phillips curve approach has been the standard formulation of the Phillips curve. We need, if possible, to find a better proxy for P^e than P.

It seems that a more sophisticated economic model and a more elaborate set of econometric tools than the ones we have used, will be necessary intellectual baggage for any economist attempting to capture the Phillips curve in a single stable statistical relationship. However, and despite its obvious defects, the traditional "fit maximisation" approach to applied econometrics--at least when applied in a systematic and coherent fashion--seems to pass the test, and is able to detect the instability of the U.K. Phillips curve.

FOOTNOTES

[1]Blyth in his memorial outlines Phillips' career and provides some background information about the Economica paper. Lipsey (1979) also contains some brief remarks concerning the antecedents of Phillips article.

[2]Phillips (1958). There is some dispute concerning the origins of the Phillips curve concept. Humphrey (1982) has pushed these origins back to Hume (but see Mayer (1980) and Frenkel (1981)), Sylos-Labini (1971, p. 60) favours Karl Marx, and Friedman (1976, pp. 215-216), naturally, believes that Irving Fisher provided the first (and only correct) formulation of the Phillips curve. Other precursors have been proposed (see, for example Wilton (1980, pp. 8-9), Amid-Hozour, et al. (1971), Bacon (1973), Donner and McCollum (1972) and Thirlwall (1972)). As is well known, at least in Britain, in 1955 A. J. Brown had analysed a scatter diagram of money wage rates against unemployment for the U.K. without unearthing the Phillips curve (Brown (1955)). (See Worswick (1979, p. 37) for an unfavourable and, in our opinion, unjust, comparison between the work of Brown and Phillips). There is no suggestion in Phillips' work that he thought he was propounding a startlingly new doctrine and, as we will see, he might well have justified his construct by referring to his own 1954 paper.

[3]The genesis of the Samuelson and Solow (1960) paper is described by Solow (1979a, pp. 36-39). The term "Phillips curve" seems to have been introduced into economics by Samuelson and Solow in the caption to their Figure 2 (ibid, p. 192). See also Solow ((1976), p. 4).

[4]Lipsey (1979, p. 51) incorrectly assigns the first appearance of the Phillips curve in Samuelson's text to the 6th edition of 1964, although, as noted by Wilton (1980, n. 5, p. 73), and confirmed by Samuelson in a note to the author (dated 6/15/81), the Phillips curve actually made its debut in the 5th edition (Samuelson (1961, p. 383)). We believe that Samuelson's inclusion of the Phillips curve in his text, which at that time dominated the introductory economics textbook market on both sides of the Atlantic, was a major factor in its rapid dissemination throughout the economics profession. Professor Samuelson (in the note just referred to) claims that we exaggerate his influence.

[5]For a partial list of such studies see Santomero and Seater (1978). The literature on the Phillips curve is voluminous. Solow (1979, p. 36) has described Phillips' article as "one of the great public work enterprises of all time. In the last twenty years it has provided more employment, than the Erie canal." We do not intend to present even a partial survey in this paper.

[6]Friedman (1968) and Phelps (1967).

[7]See Friedman (1976), p. 232). A careful study of the late Professor Johnson's magisterial surveys of macro and monetary economics would provide a good index of the standing of the Phillips curves in the profession. But see Bhagwati (1977, p. 225).

[8]Because there still seems to be some confusion about the point it may be worth reiterating that the "long-run" referred to in the text is an analytical concept akin to the Marshallian long-run in the theory of the firm. In this sense the long-run here refers to a hypothetical state of affairs in which all economic actors have adapted their wage

and price expectations until they correspond exactly to realized outcomes. The long-run in this sense does not refer to a long temporal sequence.

[9]Tobin (1972, n. 2, p. 4) writes: "His article was probably the most influential macro-economic paper of the last quarter century," while Johnson (1970, p. 110), discussing major post-war contributions to the theory of economic policy, remarks that "in my judgement the only significant contribution to emerge from post-Keynesian theorising--has been the 'Phillips curve.'"

[10]It is, after all, the fate of the majority of hypotheses to be proved incorrect. What is important, surely, is the amount of insight we gain from the examination of the hypothesis.

[11]See Poole (1978, p. 210), Friedman (1977) and the analysis of post-war Canadian monetary policy in Grubel (1982). Two points need to be borne in mind when attempting to interpret the actual policy record of an economy in terms of the theoretical constructs of the Phillips curve and the Natural Rate (Acceleration) Hypothesis. In the first place, these narratives are extremely difficult to document because of the nature of the policy process, and we are therefore always in danger of "rationalising" as a systematic application of a theoretical paradigm what may have been, in fact, a rather haphazard series of policy responses. Secondly, we may be in danger of confusing the rhetoric of policy with its implementation. Governments may use the jargon of some economists' policy prescriptions to give the appearance of exploring new ground while, in fact, continuing their steady progress down old paths.

In Grubel's case it is interesting to observe that his description of Canadian monetary policy during the nineteen fifties (Grubel (1982, p. 8)), although that policy obviously antedates Phillips' paper, could also have been interpreted in terms of a policy designed to exploit a stable inflation-unemployment trade-off.

Finally, as Tobin (1972, n. 2, p. 4) observes, it should be remembered that Phillips never advocated the sort of policies usually associated with his name.

[12]See Brinner (1977).

[13]For the 1860 to 1919 period our data corresponds to that used by Phillips and Lipsey, and we have attempted to make the remaining data as consistent as possible with theirs. The data consists of annual observations on the level of unemployment and on the rates of change of money wage rates, retail prices and unemployment for the U.K. from 1851 to 1979. The data sources are described in a separate appendix.

[14]Although more satisfactory econometric procedures exist (see Hendry (1980) for some references, and Judge, et al. (1981) and Leamer (1978) for critiques from different perspectives) we have stayed with the conventional approach in order to see what a consistent application of that approach would have yielded.

[15]See Lipsey (1979, pp. 49-50).

[16]Lipsey (1979, pp. 57-58) emphasises that Phillips always conceptualized the economy in terms of a large set of interrelated <u>micro</u> markets, which were continually subject to disturbances (both random shocks and systematic disturbances associated with the unending process of growth and adaptation which characterises real world economies).

However, Phillips' formal algebraic models were always couched in terms of the traditional, comparative static, macro markets for output, money, bonds and labour. The behaviour of this system was then modelled in terms of fluctuations around a long-run equilibrium growth path. Tobin (1972) provides an illuminating verbal exposition of a model of the Phillips micro type, and Baumol (1979) has presented an algebraic treatment of such a system.

[17]Solow, in a letter to the author dated 11/1/82, comments "From the very beginning, I regarded the Phillips curve as analagous to any price adjustment equation driven by excess supply or demand. We were quite used to the idea that "the wage bargain determines the nominal wage"...."

[18]Samuelson and Solow (1960, p. 190) write "The English data show a quite clearly nonlinear (hyperbolic) relation between wage changes and unemployment, reflecting the much discussed downward inflexibility." It is only in the last ten years that economists have seriously come to grips with the task of explaining this downward rigidity of wages (see, for example, Solow (1979)).

[19]Phillips makes the transition from excess demand for labour to unemployment in the fourth sentence quoted above. In his 1959 paper he deals with this point more explicitly: "There is no direct measure available of the demand for labour. Two indirect indices are unfilled vacancies and unemployed applicants registered with the Commonwealth Employment Service. I find that these two indicators are very closely correlated so that either one may be used alone. I have chosen to use the unemployment figure" (Phillips (1959, p. 3)). The relationship

between excess demand for labour and unemployment, and the role of the latter in the Phillips curve, was not explicitly spelled out until Lipsey's (1960 (pp. 13-14)) paper, but Phillips probably felt that the point was both obvious and well known (see, for example, Dicks-Mireaux and Dow (1959)).

[20]Also Phillips was "opposed to rigorous formulations of simple (naive) theories and preferred to assert relations without enquiring in any detail into their derivation" (Lipsey, letter to the author, dated 7/26/78).

[21]The first section, dealing with the basic relationship between $\dot{W}$ and U, was jointly authored with Professor G. C. Archibald. The second part of Lipsey's theory section is devoted to the relationship between $\dot{W}$ and $\dot{U}$. Surprisingly there is no parallel treatment of the relationship between $\dot{W}$ and $\dot{P}$.

[22]In his 1979 paper Lipsey does provide such a macroeconomic setting for the Phillips curve (see also Reid (1975, pp. 30-34)). Lipsey's labour market model is articulated more fully in his exchange with Holmes and Smyth (see Lipsey (1974) and Holmes and Smyth (1970)). Related papers of interest are: Corry and Laidler (1967), Hansen (1970), Hines (1971, 1972, 1976), Holmes and Smyth (1977, 1979), and Peston (1971).

[23]Lipsey comments (1979, p. 56), "I have been unable to trace down (sic) the source of this particular prediction (that the government can choose to maintain any combination of inflation and unemployment it wishes so long as that combination lies on the economy's Phillips curve)" (Lipsey (1979, p. 56)--parenthesis added). Of course, Lipsey

did utilise the trade-off interpretation in his article on structural unemployment (Lipsey (1964)).

[24]There are two further references to the menu on p. 193.

[25]"...much of the work done since Phillips' paper has been based on a misunderstanding of the original relationship. (Desai (1975, p. 2, emphasis in original)). "...we shall label all subsequent work as the Lipsey equation following the pioneering article by Lipsey (1960) and confine the label Phillips curve to the relationship estimated by Phillips. This distinction arises from the different estimation methods applied by these two and leads to different economic interpretations of their results" (Desai (1975, p. 2)).

[26]Phillips (1958, p. 290), Lipsey (1960, p. 3 and n. 2, p. 5) and Gilbert (1976, pp. 52-53, and particularly p. 56).

[27]Phillips (1958, p. 285) and Lipsey (1960, p. 4).

[28]See also Phillips (1958, n. 3, p. 290).

[29]Lipsey (1960, pp. 3-4) comments: "Since...it seemed desirable to treat the data by standard statistical methods if at all possible, a new equation was adopted which could be fitted to all the original observations....It was found that, by suitable choice of the constants b and c, this curve could be made to take up a position virtually indistinguishable from that taken up by curve (1) for any value of γ between -1 and -2. Thus choosing between the two curves does not necessitate choosing between different hypotheses about the nature of the relation between $\dot{W}$ and U." (Lipsey's gamma term corresponds, of course to Phillip's c).

[30]In this context Santomero and Seater's (1978, p. 501) comment, "Unfortunately, Phillips does not report significance tests," is therefore somewhat puzzling.

[31]He says, "Since each interval includes years in which unemployment was increasing and years in which it was decreasing, the effect of changing unemployment on the rate of change of wage rates tends to be cancelled out by this averaging, so that each cross gives an approximation to the rate of change of wages which would be associated with the indicated level of unemployment if unemployment were held constant at that level" (Phillips (1958, p. 290)).

[32]Desai continues to advocate his original position (Desai (1981)).

[33]"The Phillips curve is therefore removed from the time domain and hence it cannot be interpreted as a time series relationship. It does not relate to a single point along (sic) a cycle or any particular phase thereof. It is more appropriate to interpret it as a long-run equilibrium locus corresponding to a short-run relationship.

The Phillips curve _is_ a long-run Phillips curve. There can be no short-run Phillips curve, only a short-run Lipsey equation" (Desai (1975, p. 5, emphasis in the original)).

[34]Desai interpreted Phillips (Desai (1975, p. 4) as estimating b and c by least squares and then fitting a by eye. In fact, as we noted above, Phillips first estimated a and only then estimated b and c. Gilbert (1975, p. 56), following the latter procedure, was able to replicate Phillips' results exactly whereas Desai's replication attempt was a failure (Desai did not succeed in part one of his exercise (Desai (1975, p. 1)).

[35]Our attention was drawn to this paper by Perry's <u>Economic Record</u> article, although it is listed in Blyth's biographical sketch (Blyth (1979, p. 17)) and, as Perry (1980, n. 1, p. 87) observes, is also referred to by Holt (1970, p. 117) and Horn (1975, p. 148). We are most grateful to Professor Perry for supplying us with a photocopy of the Victorian Branch printing of Phillips' article.

[36]The well known Dicks-Mireaux and Dow (1959) study had, of course, used quarterly British data but their theoretical framework was somewhat different from the standard Phillips curve model.

[37]Phillips reports two equations, both in footnotes to p. 5. In footnote 1 we find the equation

$$\dot{W}_t = 2.11 + 1.46\ U_{t-3}^{-2} + 0.41\ U_{t-3}^{-3}$$
$$+ 0.15\ \ (1/2\ (\dot{X}_{t-1} + \dot{X}_{t-2}))\ \ + 0.13\ \dot{M}_{t-3}$$

where $\dot{W}_t$ is the rate of change nominal wage rates (of adult males), U_t is the "number of unemployed applicants as a percentage of the number of persons in civilian employment" (Phillips (1959, p. 3)), and $\dot{X}_t$ and $\dot{M}_t$ are rates of change of indices of export and import prices respectively. The rates of change variables are "percentage changes...calculated quarterly" and "were smoothed by applying a four-quarter moving average, to reduce seasonal and random fluctuations" (Phillips (1959, pp. 1-2)). The estimation period seems to have been from the first quarter 1947 to the last quarter of 1958.

The equation in the second footnote is:

$$\dot{W}_t = 0.30 + 0.57\ \dot{W}_{t-1} + 0.93\ (U_{t-2} - 0.26)^{-1}$$
$$+ 0.05\ \ddot{X}_{t-1} + 0.02\ \dot{M}_{t-2}$$

where $\ddot{X}_t = 50.0\ (\exp 0.02\ \dot{X}_t - 1)$

(In this and the previous equations we have rounded Phillips' results to two decimal places.)

[38]He writes (Phillips (1959, p. 3)): "When the percentage unemployment is very high, it is likely to be a fairly good direct measure of the demand for labour. At low levels of unemployment, however, there may be considerable excess demand for labour, and quite large changes in the excess demand for labour will be associated with only small changes of the percentage unemployed. To obtain an indicator of changes in (sic) demand for labour, therefore, it is necessary to accentuate changes in the percentage unemployed when unemployment is very low. This may be done by calculating the reciprocal of unemployment, or to accentuate the changes at low levels of unemployment still more, to take the reciprocal of unemployment after deducting a constant. ....Another method of obtaining a similar effect is to calculate the reciprocal of the square, or some other power, of unemployment."

[39]The author attended some of those lectures delivered in about 1962 or 1963. At least one of them was devoted to the Phillips curve and the empirical work by Phillips.

[40]After a quarter of a century it is unlikely that we will ever untangle the specific web of influences which surrounded this early work on the Phillips curve.

[41]Phillips (1961, 1962).

[42]Desai (1981, p. 70) does refer to Perry's paper but in the context of Perry's reduced form interpretation. He fails to see its significance for his own reinterpretation of the Phillips curve (see Desai (1981, p. 56)).

[43]Phillips' 1961 inaugural lecture on the occasion of his election to the Tooke Chair of Economics contains a paragraph devoted to the Samuelson and Solow paper and the U.S. Phillips curve. Phillips (1962, p. 15) refers to "some estimates which I have made lead me to think that the situation in the United States is less favourable than Samuelson and Solow's estimate that a 5 to 6 percent unemployment level would suffice to maintain price stability." To our knowledge these estimates of the U.S. Phillips curve have never been published.

[44]If Phillips really conceived of the Phillips curve in terms of a phase equation it seems to us extremely unlikely that he would never have mentioned the fact to Lipsey or to his colleagues at L.S.E. (or, for that matter, subsequently at A.N.U.).

We would like to stress that the issue of priority is a matter of intellectual interest rather than of great academic import, and concur with Kaufmann (1981, p. 5) that "Entirely too much energy is devoted to clearing up what happened long ago." Lipsey's article made major theoretical and empirical contributions to economics, and its standing in the profession is not going to be altered whether or not Phillips was the first person to write down, estimate and publish the "Lipsey" equation.

[45]Phillips (1961, pp. 2-3) writes "We also need to investigate the degree of error that there may be in the estimate, the extent to which the relation in successive short time periods departs from its average over longer periods and whether there is any evidence that the average relation changes in any systematic way through time."

[46]If our conception of Phillips' model is correct then the considerations discussed in Gersovitz's important paper (1980) are relevant.

[47]All of the computations reported in this paper were run on the IBM 4341 computer at Western Washington University Computing Center using the ESP and SHAZAM software programs. I would like to thank Mrs. Evelyn Albrecht and Mr. Bent Faber for their help with the software without, of course, in any way implicating them in any errors, computational or otherwise, which may remain in the paper.

[48]The data used in the regressions are described in the data appendix.

[49]Lipsey (letter 7/16/78) describes his work as having been done "by brute force on a desk calculator. . . ."

We concentrate on Lipsey's paper both because of its intrinsic interest and very high quality, and also because it deals with U.K. data and of all countries the U.K. seems to have the longest sample of data available. In a recent paper Lipsey (1979) puts forward three precepts to be followed in testing economic hypotheses. The second precept he formulates as follows: "Second, theories should be tested systematically against all relevant data. The real world is so complex that a subset of data can be selected to conform with almost any bizarre theory you care to state. We should not be impressed by a theory until it has survived a rough handling against all relevant data and particularly in the hands of someone not precommitted to the theory's truth. Awkward facts are the strength, not the weakness, of any science, and the more awkward the better. They constrain our ability to state acceptable theories. But if we selectively ignore facts that are awkward for our theories, we loosen this constraining power so that any theory becomes as good as any other."

[50]Lipsey (1960, p. 10, equation in footnote). Lipsey actually estimates two sets of equations, one with and one without the substitution of Bowley data for the rate of change of money wage rates 1881-1885. Phillips suggested the Bowley substitution on the evidence of his plots of W against U over the 1879-1886 cycle. During this cycle the Phelps Brown and Hopkins wage index show almost no variation despite large fluctuations in unemployment (from 2 to almost 11 percent). Bowley's data provide a more typical "loop." One of the major difficulties with the wage series available is that they refer to standard rates which, in the nineteenth century, probably corresponded to <u>maximum</u> rates. The astonishing stability of these rates was the subject of an article by G. H. Wood (1901), whose wage series provided the basic series used by Phelps Brown and Hopkins. Wood quotes 55 cases in which wages within a trade remained stationary for 20 years or more (London Compositors' rates remained unchanged from 1810 to 1894). (See also Routh, p. 300).

We have conducted experiments with three wage series, W (Phelps Brown and Hopkins), WL (PBH with the Bowley substitution) and WB (the Bowley index). Over the period 1862-1913 the simple correlation coefficients between the series were: W and WL, 0.93; W and WB 0.85; and WB and WL, 0.87.

Our results for the 1862-1913 period are:

$$\dot{W} = -0.94 + 4.92\, U^{-1} + 3.67\, U^{-2} - 0.016\, \dot{U} + 0.20\, \dot{P}.$$

(-2.08) (2.15) (1.60) (-4.24) (2.68)

$R^2 = 0.82$ $F(4,47) = 52.2$ $DW = 1.12$

$$\dot{WL} = -1.20 + 6.43\ U^{-1} + 2.28\ U^{-2} - 0.018\ \dot{U} + 0.21\ \dot{P}$$

(-2.90) (3.05) (1.08) (-5.28) (3.10)

$R^2 = 0.85$ $F(F,47) = 67.0$ $DW = 1.45$

$$\dot{WB} = -0.51 + 4.14\ U^{-1} + 2.81\ U^{-2} - 0.016\ \dot{U} + 0.47\ \dot{P}$$

(-0.76) (1.23) (0.183) (-2.79) (4.32)

$R^2 = 0.70$ $F(4,47) = 27.0$ $DW = 1.01$

On conventional "fit" criteria the Bowley series does less well than the other two although the R^2 statistics are not strictly comparable since the dependent variables in the equations are different. However, the high correlations between these dependent variables suggests this problem may not be severe. We are very suspicious of arguments which suggest tampering with data to avoid inconvenient features (see the Lipsey quote in footnote 11 above), and so we have used the Phelps Brown-Hopkins data through this section.

[51]". . .: although he believed in high-powered econometrics, he was opposed to rigorous formulations of simple (naive) theories and preferred to assert relations without enquiring in any detail into their derivation." Letter to the author from R. G. Lipsey 7/26/78.

[52]Lipsey explains the Phillips curve loops in terms of aggregation phenomena. Attempts to test this hypothesis are reviewed by Santomero and Seator (1978, p. 508). The recent study by Smyth (1979) which includes the pre-World War One period rejects Lipsey's hypothesis.

[53]Visual examination of the OLS residuals suggests that there is a structural break in the data about 1884. For example, for the period 1862-1884 there were 18 residuals which exceeded or equalled the standard error of the regression, but only 5 residuals were that large from 1885-1913. It was probably this phenomenon that Phillips was observing when he claimed that his loops were getting narrower over time. Lipsey rejected Phillips' hypothesis on the basis of fitting a straight line through each cycle and using the line to measure the width of the cycle. We have been unable to account for this apparent structural shift in 1884 on the basis of known changes in the characteristics of the U.K. labour market at this time, and such a break is not confirmed by a standard chow test.

We agree with Lipsey's finding that the residual plots from the various equations do not indicate that the residuals were particularly large in absolute magnitude during the years 1893-96.

[54]Let $E^S = (N^S - N^D)/N^S$ and $N^D = N + V$, $N^S = N + U$ then $E^S = u - v$ where u and v are the percentage unemployment and vacancy rates respectively, and where N is total employment, N^S the total labour supply, N^D the total demand for labour, U the total number of persons unemployed and V is the total of job vacancies. If Dicks-Mireaux and Dow are correct then $uv = k$, where k is some constant, and so $E^S = u - ku^{-1}$. (See Santomero and Seater (1978, p. 505.))

[55]One puzzling question raised by Lipsey's paper is why he dropped Phillips 1861 observation. In his letter to the author (7/26/78) he writes: "Phillips could include 1861 because he only formally fitted $\dot{W}$ to U. I wished to fit $\dot{W}$ to U and $\dot{U}$ and to use Phillips' definition of $\dot{U}$

as a first-central difference. This meant that since the observations started at 1861 I could not define U before 1862." However, the Phelps-Brown and Hopkins, and the Beveridge data all extend to 1860, and so this explanation doesn't clear up the difficulty. It is possible that Lipsey's research assistant was working from Phillips' worksheets rather than from the original Beveridge and Phelps Brown and Hopkins series.

[56]These results represent only a fraction of the several hundred regressions we have run. In general, Lipsey's version of the excess demand for labour proxy (U^{-1}, U^{-2}) has a satisfactory R^2 but only infrequently did it possess the largest R^2 of the three functional forms.

[57]The regressions were run on the IBM 4341 computer of the Computing Center at Western Washington University, using the SHAZAM software package (White (1982)). The generalized least squares (CORC) estimates were obtained, by the standard iterative technique, using ordinary least squares to generate the linear approximating equations. These estimates <u>include</u> the first observation in its usual Prais and Winsten approximation (see Poirier (1978)).

Recently LaFrance and Belanger (1981), Dufour, Gaudry and Tran (1980), and Oxley and Roberts (1982) have expressed concern at the possibility (first noted by Sargan (1964)) that the CORC procedure may fail to converge to the global minimum of the sum of squared residuals. Professor R. A. Holmes has conducted some Monte Carlo experiments which have emphasized the importance of using the Prais-Winsten procedure when using two-stage estimators if one wishes to obtain, as we do, reliable estimates of the constant term in the regression equation. (We are indebted to Professor Dennis Maki for drawing our attention to Holmes' paper.)

In order to throw some light on these issues in the context of an actual empirical experiment, we made use of the excellent autocorrelation options available with the SHAZAM system and ran alternative estimations of a number of our equations. Specifically we ran each of the three functional forms in nine different ways (OLS, CORC, CORC dropping the first observation, a Hildreth-Lu type grid search (GS) (dropping the first observation), and repeating the last four procedures using a maximum likelihood procedure), for each of the samples: 1851-1979, 1948-1979, 1948-1966, 1967-1979. We conclude from an examination of our results (which we have not included in the paper because of lack of space, but which may be obtained from the author upon request) that there is little difference between the (non-OLS) results for the two longer time periods. For the two post-War sub-periods, however, there was much greater variation--with the crucial distinctions being: (i) the inclusion or exclusion of the first observation materially affected not only the constant term but also the coefficients on the U terms; and (ii) whether the grid search was used with the first observation dropped.

Two final points concerning our CORC results are in order. We are indebted to Professor Maki for reminding us that the fit of these equations is not directly comparable with that of the OLS regressions, because of the different left hand side variables. Secondly, the CORC procedure has been used because of the generally low Durbin-Watson (DW) statistics accompanying the OLS estimates and, at least until recently, this was the standard response of applied econometricians to this phenomenon. However, low DW statistics may also reflect equation mis-specification, or a mis-specification of the error term other than the first-order autoregressive form we have specified. We have not pursued this issue here.

[58]If $\dot{W} = a + bU + cU^{-1}$ then $d\dot{W}/dU = b - cU^{-2}$, and so the Phillips curve has a negative slope if $U_o < \sqrt{c/b}$. Substituting for b and c from the 1862-1913 equation we obtain $U_o < 10.2/0.19 = 7.33$. Unfortunately U would have been on the positively sloped section of the curve in 1879, 1885-6, 1893, and 1908-9. Even if this were not the case we feel that a functional form ought to be rejected if it exhibits perverse behaviour over plausible ranges of U (which essentially means for values of U less than about 25 percent).

[59]A number of other formulations were tried. In particular we investigated Phillips' threshold argument by the use of (0-1) dummy variables. Specifically, we set up a dummy variable which took the value of 1 when PDOT (p) was, say, greater than or equal to 5%. For this period none of the values tried (2%, 3%, 4% or 5%) performed any better than PDOT itself.

[60]In both 1921 and 1922 money wage rates fell by over 21% although real wages fell much less precipitously. Hennerberry, et al (1980) contains an interesting discussion of wage rigidity in the U.K. between the wars.

Brown (1955, p. 90) also comments on this period: "In the U.K., between 1880 and 1914, the index of wage rates was strongly influenced by certain industries--most notably coal-mining--in which (especially in the early part of the period) wages were related explicitly to the price of the product." He further observes that about one tenth "of the recorded wage changes in 1919-20 were made in accordance with sliding scales....By the time the slump came, sliding scales had become so popular that more than half the recorded changes in wages in the years 1921-2 were made automatically in accordance with them. Thereafter, they again became of minor importance in effecting wage adjustments" (Ibid, p. 93).

[61]Phillips died in 1975. Lipsey returned to Canada in the early 1970s and his worksheets were lost during the move.

[62]Surprisingly little has been written on the multicollinearity problem in the Phillips curve context. (See Santomero and Seater (1978, pp. 508 and 514)). One of the standard solutions to this problem, recommended by most textbooks on econometrics (see Johnston (1972), Judge, et al. (1982) and Pindyck and Rubinfeld (1981)) is to delete one of the variables which is causing the trouble. Unfortunately this solution will usually introduce mis-specification bias (see Giles (1973)), and so it is often not very appealing. However, in our case, we have a problem because of the collinearity between the terms in our approximating polynomial. It seems not unreasonable then to drop the U, U^{-2} and U^{-4} terms from our equations and to re-estimate with just U^{-1} acting as the excess demand proxy. When we did this the results were somewhat better but we could not detect a well determined, stable, negatively sloped Phillips curve for the 1923-1939 period nor for the post-Second World War period. It is interesting to note that the U^{-1} specification has been frequently employed in Phillips curve work,

although whether this is the result of prior experimentation with alternative functional forms is not usually made clear.

[63]We doubt whether these sliding scale effects can be adequately modelled using annual observations. Of course, we could introduce a dummy variable into the equation but that would just confirm the shift we have already noted.

[64]Of course, we could always argue that we have actually come up with the true (positively sloped) Phillips curve, and that the problem lies with the limitations of our theory (and perhaps our imaginations, too) not with our estimates. We do not find that gambit attractive.

[65]The 1981 data only cover the first two quarters of 1980 and so the 1980 rates of change estimates are only eduated guesses.

[66]See Dicks-Mireaux and Dow (1959) and Lipsey (1960, n. 1, p. 25).

[67]Of course, as the Friedman-Meiselman experiment shows the inter-war period appears to be generally difficult to model.

[68]See Santomero and Seater (1978) for a partial listing.

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CHAPTER 3

EXPECTATIONS, MONEY ILLUSION AND THE ACCELERATION HYPOTHESIS: THE U.K. 1851-1979

"Take it from me, wages have
gone down by twenty percent,
and the cost of living's gone up
by twenty percent: forty percent
that makes."

R. Musil: The Man Without
Qualities, Vol. III

EXPECTATIONS, MONEY ILLUSION AND THE ACCELERATION HYPOTHESIS: THE U.K. 1851-1979

I. INTRODUCTION

At least since the seminal work of Hicks and Samuelson in the late 1930's and early 1940's[1] economists have tended to model markets in disequilibrium in terms of a simple adjustment mechanism in which the rate of change of the relevant price is an increasing (usually linear) function of the level of excess demand in that market. It was therefore natural for A. W. Phillips to adopt this framework for his work during the 1950's on the disequilibrium behaviour of the British economy.[2] Phillips' famous paper on the so-called Phillips curve was a natural empirical extension of this research'[3] and he seems to have regarded the curve he estimated for the U.K. for the period between 1861 and 1913 as the real world analogue of the theoretical disequilibrium adjustment function for "the" U.K. labour market.[4] He writes, for example, in the often quoted opening sentences of his 1958 Economica paper (Phillips (1958, p. 283)):

> When the demand for a commodity or service is high relatively to the supply of it we expect the price to rise, the rate of rise being greater the greater the excess demand. Conversely when the demand is low relatively to the supply we expect the price to fall, the rate of fall being greater the greater the deficiency of demand. It seems plausible that this principle should operate as one of the factors determining the rate of change of money wage rates, which are the price of labour services.

It is, of course, the last sentence of this quotation which causes problems--as we will see below.

Although Phillips with his background in engineering was perfectly at home with disequilibrium processes, economists have traditionally preferred (and have been trained in) equilibrium analysis,[6] and it is perhaps not surprising that Phillips' interpretation of his curve was rapidly superceded by an alternative explanation. This interpretation essentially ignored Phillips' reason for using unemployment in his estimation procedure--that unemployment is a proxy for the unobservable excess demand for labour[7]--and seized upon his mark-up over normal unit labour cost inflation model[8] to arrive at the conventional trade-off between unemployment and inflation view of the Phillips curve, which has dominated macroeconomic theory and policy debates during the last quarter of a century.[9]

On both the theoretical and policy levels these debates have centred around the issue of whether there exists a stable empirical trade-off between inflation and unemployment. The problem of "creeping" inflation had gained increasing prominence in policy discussion during the 1950's[10] and many economists interpreted Phillips' claim to have discovered a stable statistical relationship between the level of unemployment and the rate of change of money wage rates--a claim which was not seriously challenged by Lipsey's replication study[11]--as evidence that there existed exploitable trade-offs between unemployment and inflation. The macroeconomic policy problem during the early 1960's then became one of choosing the optimal combination of inflation and unemployment rather than choosing between them.

This apparently happy state of affairs was rudely disturbed by two developments which occurred at the end of the 1960's. On the theoretical level Professors Friedman (1968) and Phelps (1968) launched an attack on the naive Phillips curve which appears to have been successful.[13] They argued that we should not expect to find a stable statistical relationship between the rate of change of nominal wages and the level of unemployment, except in periods of price stability,[14] because the appropriate decision variable in wage negotiations is the real wage, not the nominal wage. The second development was the apparent statistical breakdown of the original Phillips curve regression.

The Friedman-Phelps theory has been labelled the Acceleration Hypothesis (or sometimes the Natural Rate Hypothesis) and it is the major purpose of this paper to provide additional evidence on the validity of the Acceleration Hypothesis using the longest U.K.[15] sample available annual observations for the years 1851 to 1979.

The remainder of the paper is organised as follows. In Section 2 we review the Acceleration Hypothesis from a theoretical perspective and investigate the roles of the assumptions of rationality and realised expectations in the derivation of the vertical long-run Phillips curve. Section 3 is devoted to a review of the early attempts empirically to test the Acceleration Hypothesis and includes a suggestion for reinterpreting those tests. The fourth section of the paper is devoted to our test of the Acceleration Hypothesis which is essentially a replication of the basic Solow experiment. The final section of the paper contains our conclusions and some suggestions for further research.

2. THE ACCELERATION HYPOTHESIS

Friedman (1976, pp. 215-216) traces the Acceleration Hypothesis back to Fisher's 1926 paper but the earliest post-Phillips references appear to be Friedman's "Newsweek" article (Friedman, 1966) and the comments which he made on Solow's pro-Guideposts conference paper (Friedman, 1966a, pp. 58-59). However, most writers date the accelerationist counter-revolution from 1967-1968 when Phelps published his two versions of the theory and Friedman devoted part of his Presidential address to the American Economic Association to the demolition of the naive Phillips curve.[16]

Friedman launches his attack by asserting--or perhaps reasserting would be a better term since the idea was, of course, a basic tenet of pre-Keynesian monetary theory--that the real economy generates a unique equilibrium level of unemployment, the so-called "natural rate" level of unemployment, where the terminology "natural" is adopted, by analogy with Wicksell's natural rate of interest, to stress that this component of measured unemployment is ground out by the real rather than the monetary forces at work in the economy.[17] Although Friedman's definition of the natural rate of unemployment is well known it is worth repeating:

> The "natural rate of unemployment" ...is the level that would be ground out by the Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of the labour and commodity markets, including market imperfections, stochastic variability in demands and supplies, the cost of gathering information

about job vacancies and labour availabilities, the costs of mobility and so on.[18]

Perhaps the most striking feature of this definition is its lack of operational precision. Obviously there are many features of the real world which impinge on the natural rate,[19] but enumerating them does not necessarily make it easier to determine which unemployment level corresponds to the natural rate. The natural rate of unemployment obviously corresponds closely to the rate of frictional unemployment, but it also seems to encompass some part of what is commonly termed structural unemployment.[20] Evidently we should not expect the level of the natural rate of unemployment to be zero, but to exactly which non-zero rate we should attach our label is not clear.

Friedman then proceeds to argue that "there is always a temporary trade-off between inflation and unemployment" but that "there is no permanent trade-off" (Friedman (1968, p. 11)).

We can outline Friedman's argument with the aid of Figure 3.1. Consider first the top part of the figure labelled (A). Assume that the economy has been in equilibrium for a considerable period of time and that both employers and employees have come to predict that the price level during the next contract period, will be P_o^e. Currently the labour market is in equilibrium at N_o with the equilibrium wage being W_o. Since employers and employees are on their labour demand or supply curves we have a welfare optimum at the initial market configuration. Now let us assume that there is a permanent increase in nominal demand ($N^D(P_o^e)$ to $N^D(P_1^e)$). Employers respond to this drop in the real wage by expanding output and offering increased employment opportunities.

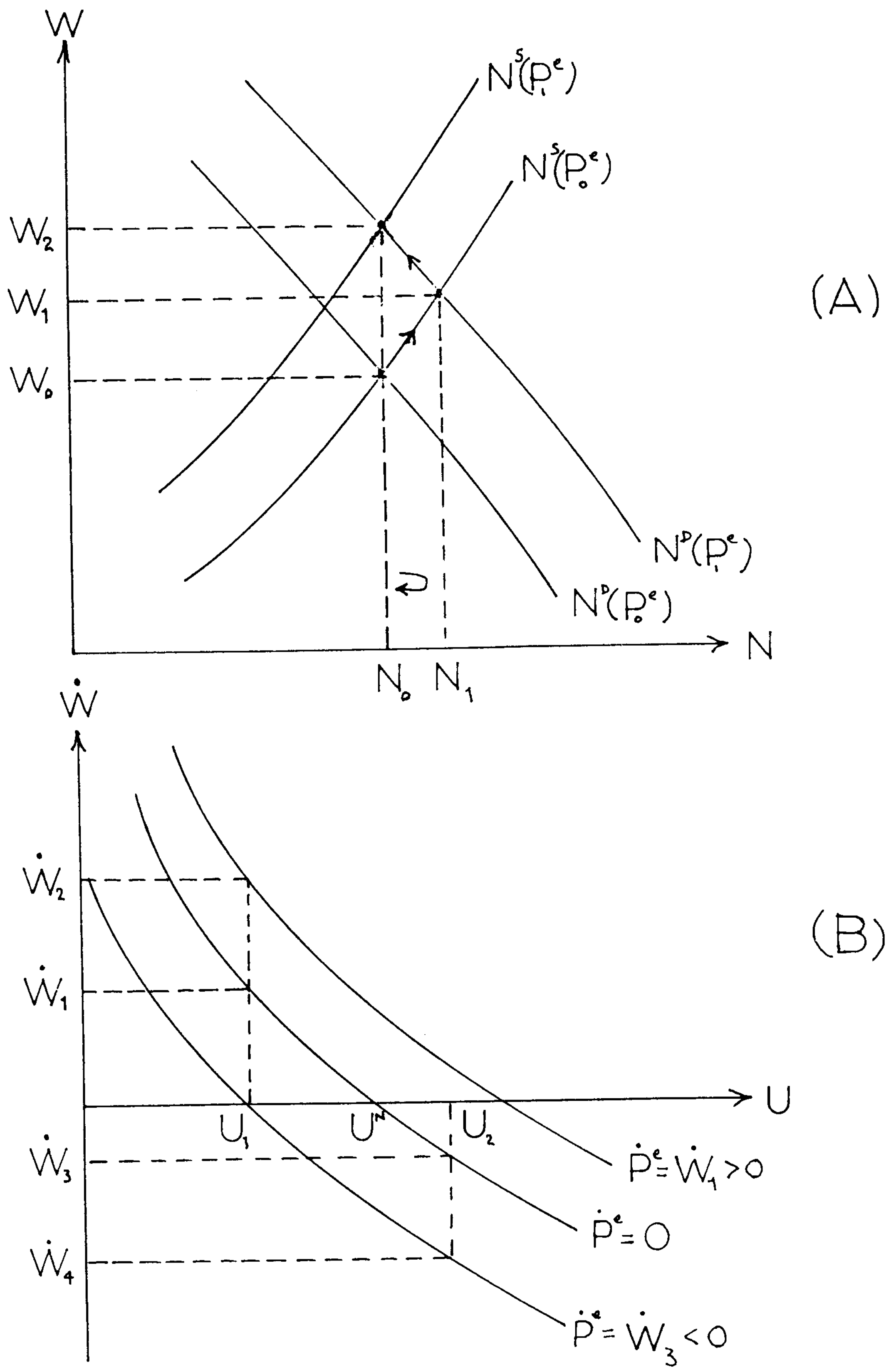

Figure 3.1 Friedman's Natural Rate Argument

Friedman argues that initially output and employment will probably rise, but that, as employees and employers discover that what they had initially interpreted as increased real demand for their particular product and increased real purchasing power is in fact simply an increase in the aggregate price level, the labour market will revert to its initial (natural rate) equilibrium employment level (N_o) at the original (expected) real wage, since $(W_2/P_1^e) = (W_o/P_o^e)$. In equilibrium the labour market reflects only real forces, and the natural rate is associated with employment (unemployment) levels at which the market clears so that all trades are voluntary and optimal.

The lower half of Figure 1, labelled (B), illustrates the argument in the previous paragraph in terms of the Phillips curve. Again assume that the labour market starts from a position of long-run equilibrium. Specifically let us assume that unemployment is at the (unique) natural rate level, U^N, and that the expected rate of inflation is zero. Given our monetary shock the unemployment level is reduced to U_1 since transactors confuse the positive rate of nominal wage change, $\dot{W}_1$, with an increase in their real wages. However, with nominal wages rising at the rate $\dot{W}_1$ (and assuming, for convenience of exposition, that the expected rate of productivity increase is zero) the rate of price inflation (which was initially zero) will also increase by $\dot{W}_1$ (assuming a simple mark-up pricing procedure). If the authorities continue to maintain the increase in money demand so that the economy stays at U_1, employees will eventually learn about the increased rate of price inflation and will demand proper compensation for the lost leisure and search time associated with the reduction in unemployment from U^N to

U_1. They will therefore demand an increase in money wages per period of $\dot{W}_2$, which is equivalent to a rate of increase in expected real wages of $\dot{W}_1$ (i.e. $\dot{W}_1 - \dot{P}_o = \dot{W}_1 - 0 = \dot{W}_1 = \dot{W}_2 - \dot{W}_1$). Unfortunately this increase in nominal wages will cause the rate of price inflation to increase yet further and by an amount no less than the previous increase. If the authorities continue to try to maintain unemployment at U_1 ($< U^N$) then they will lose control of the price level, and it, and the rate of inflation, will increase without bound. The long-run Phillips curve is vertical and, as asserted, there is no permanent trade-off between inflation and unemployment (although the argument obviously requires that there be a short-run trade off between these policy variables). Notice that the argument is perfectly general since the only feature of the unemployment level U_1 which was utilised was that it corresponded to a level less than the natural rate. Although we are not aware of a specific discussion of the issue by Friedman himself, it is usually assumed, at least by economists of a monetarist persuasion, that the previous argument is symmetrical and that raising unemployment above the natural rate (say to U_2) will be associated with a permanent deflation of the price level.[21]

Friedman's argument parts company with the Phillips on one crucial assumption. Friedman writes: "Phillips' analysis...is fallacious because no economic theorist has ever asserted that the demand and supply of labour are functions of the nominal wage rate (i.e. wage rate expressed in dollars). Every economic theorist from Adam Smith to the present would have told you that the vertical axis...should refer not to the nominal wage rate but to the real wage rate" ((Friedman, 1976, p.

218) Emphasis in the original).[22] The Phillips curve was therefore fundamentally misspecified in Friedman's view. We will return to this issue below, but before doing so it will be convenient to discuss the somewhat different route by which Phelps arrives at the Acceleration Hypothesis in his 1968 and 1970 papers.[23]

The basic feature of Phelps derivations is his concentration on the forces which persuade firms to change their wage offers.[24] Phelps posits that each firm determines a "wage differential" which is the "proportionate differential it desires to have...between its wage and the average money wage it expects to be paid elsewhere" (1970, p. 137). Let us write this as $w^d \equiv \frac{w_i - w^e}{w^e}$ where w_i is the ith firm's optimal wage and w^e is the average wage it expects to prevail over the decision period. Phelps argues (1970, pp. 137-138), that the wage differential depends directly upon the aggregate vacancy rate, directly upon its own vacancies, and inversely upon the aggregate unemployment rate. A firm wishing to attract extra labour will raise its wage differential. If it wishes to erode its labour force it will allow its wage differential to narrow. Otherwise it will allow the differential to reamin constant raising its wage at the expected rate, $\dot{w}^e$. In part three of his paper Phelps derives a "mometary augmented Phillips curve" under static expectations of the form

$$\dot{W} = f(U,z)$$

where z is defined as the ratio of N (approximately the rate of change of employment) to L, the size of the labour force, and where U is the unemployment rate (1970, p. 146). Finally, in section four of this paper, Phelps relaxes his static expectations assumption[25] and argues that "we must add the expected rate of wage change" (in our notation $\dot{W}^e$) "to the wage change that would occur under static wage expectations to determine the actual rate of wage change per annum..." (1970, pp. 153,154), i.e.

$$\dot{W} = f(U,Z) + \dot{W}^e.$$

He then, "following Hayek, Lindahl, Harrod, and others..." defines "equilibrium" to be "a path along which the relevant variables work out as people think they will" (1970, p. 154). In other words, like Friedman, Phelps associates equilibrium (long-run stationary or steady states) with realised expectations, specifically with $\dot{W} = \dot{W}^e$ which, of course, reduces the last equation to $f(U,Z) = 0$ which in turn implies that "there exists a unique steady-state equilibrium value of the unemployment rate" (1970, p. 158), say U^N, such that U^N is the unique solution of $f(U,Z) = 0$. We see, therefore, that Phelps' analysis, although based upon quite different initial assumptions leads us to the same conclusion reached by Friedman. We will return to the Phelps model below but let us now turn our attention back to Friedman.

As we have already seen, Friedman's Presidential address presentation of his Natural Rate-Acceleration Hypothesis argument (which was delivered in December, 1967) was purely verbal. It appears to have received its first algebraic treatment by James Tobin at a conference on inflation organised by the Kazanjian Economic Foundation which met on January 31st, 1968.[26] Tobin first defines the rate of change of real wages ($\dot{W} - \dot{P}$) to be equal to the rate of change of the marginal productivity of labour ($\dot{\rho}$):

(1) $\dot{W} - \dot{P} = \dot{\rho}$

He then writes the Phillips curve in "augmented" form as

$$(2) \quad \dot{W} = \alpha \dot{P}^e + f(U)$$

where $0 \leq \alpha \leq 1$ and $f'(U) < 0$.[27] Tobin further assumes that the expected rate of inflation is a "weighted average, with exponentially receding weights of actual price changes, current and past" (1968, p. 50) and derives the rate of change of the expected rate of inflation from this

$$(3) \quad \frac{d\dot{P}^e}{dt} = W.\dot{P} - W.\dot{P}^e$$

hence

$$(4) \quad \frac{1}{W} \frac{d\dot{P}^e}{dt} = f(U) - (1-\alpha) P^e - \dot{\rho}.$$

Tobin observes that "In equilibrium, with $\alpha < 1$, expected and actual price changes are constant and equal, and depend inversely on the unemployment rate" (1968, p. 50)

$$(5) \quad \dot{P} = \dot{P}^e - \frac{1}{1-\alpha} [f(U) - \dot{\rho}].$$

He continues "The dynamics expressed (equation (4)) is that inflation will accelerate (decelerate) so long as unemployment falls short of (exceeds) the amount geared to the prevailing rate of inflation. Thus if aggregate demand policy shifts to a lower unemployment target, the rate of inflation will rise to its new equilibrium level.

However, the situation is quite different if $\alpha = 1$. Equation (4) becomes:

$$(6) \quad \frac{1}{W} \frac{d\dot{P}^e}{dt} = f(U) - \dot{\rho}$$

According to (6) there is a unique equilibrum rate of unemployment U*--Milton Friedman calls it the natural rate such that $[f(U^*) = \dot{\rho}]$. If U is equal to U* inflation will be neither accelerating nor decelerating. It will be occurring at some constant rate. That rate is indeterminate in the above model. That is it is determined by factors wholly outside

the labor market" (Tobin, 1968, p. 50). He then points out that "Deviation of U to either side of U* will mean ever-accelerating inflation or deflation. If $\alpha = 1$, we cannot buy lower unemployment with creeping inflation. The creep will become a gallop" (1968, p. 50).
This is the standard view of the Acceleration Hypothesis and its policy implications. Tobin's argument places great emphasis on what we will call the "alpha coefficient" i.e. the coefficient, α, of the expected inflation term in equation (2). According to his view if alpha equals one then the long-run Phillips curve is vertical and there is no way that we may buy lower unemployment by accepting a higher (steady-state) rate of inflation. This is quite correct, but its relevance to real world policy is less clear.

Two propositions are invoked to obtain the vertical Phillips curve: (1) $\alpha = 1$ or the absence of money illusion, and (2) $\dot{P}^e = \dot{P}$, the economy is in long-run equilibrium. It is the relevance of this latter condition which we wish to question.

Before doing so, however, let us set out the alternatives algebraically.

<u>CASE 1</u>: $\dot{P}^e = \dot{P} \quad \alpha \neq 1$

Then our model has the solution

$$\dot{P} = \frac{1}{1-\alpha}\,[f(u) - \dot{\rho}]$$

and $\dfrac{\partial \dot{P}}{\partial U} = \dfrac{1}{1-\alpha}\, f'(U) < f'(U) \qquad 0 \leq \alpha < 1$

Of course if $\alpha > 1$ then $\dfrac{\partial \dot{P}}{\partial U}$ becomes positive.

<u>CASE 2</u>: $\dot{P}^e = \dot{P} \quad \alpha = 1$

Then, as we have seen, $f(U) = \dot{\rho}$ and we have equilibrum at the natural rate, an indeterminate equilibrium rate of inflation, and a vertical Phillips curve.

CASE 3: $\dot{P}^e = \dot{P} \qquad \alpha \neq 1$

Here the solution for $\dot{P}$ just reverts to

$$\dot{P} = f(U) + \alpha\dot{P}^e - \alpha\dot{P}^e - \dot{\rho}$$

and $$\frac{\partial \dot{P}}{\partial U} = f'(U) + \alpha \frac{\partial \dot{P}^e}{\partial U}$$

$$= f'(U) + \alpha \frac{\partial \dot{P}^e}{\partial \dot{P}} \cdot \frac{\partial \dot{P}}{\partial \dot{W}} \frac{\partial \dot{W}}{\partial U}$$

$$= f'(U) + \alpha \left(\frac{1}{\alpha}\right) \frac{\partial \dot{P}}{\partial \dot{W}} f'(U)$$

$$= f'(U) \left[1 + \frac{\partial \dot{P}}{\partial \dot{W}}\right] < 0$$

CASE 4: $\dot{P}^e \neq \dot{P}$ and $\alpha = 1$

We then have

$$\dot{P} = f(U) - \dot{\rho} + \dot{P}^e$$

and $$\frac{\partial \dot{P}}{\partial U} = f'(U) \left[1 + \frac{\partial \dot{P}}{\partial \dot{W}}\right] < 0$$

Absence of money illusion, $\alpha = 1$, is a necessary, but not a sufficient, condition for a vertical Phillips curve.

Phillips curve research during the early 1970's was very much concerned with "alpha hunting," as we will see below. The reason for this was that some economists wished to pursue activist policies designed to lower the measured unemployment rate but obviously such policies would be frustrated if the Phillips curve were vertical. It was therefore thought to be crucial to demonstrate that alpha was actually less than one--to demonstrate that employees, and perhaps employers (using the Phelps approach), were subject to money illusion. However, the alternative approach of denying the relevance of the long-run, $\dot{P}^e - \dot{P}$, assumption, which we will argue is theoretically more appealing, was largely ignored.[28]

Consider the *gedankenexperiment* which implicitly or explicitly underlies the conventional derivation of the vertical long-run curve. Solow writes, for example: "Any *constant* rate of inflation, high or low, will come to be accurately and confidently expected *if it is maintained long enough*. When that happens, one must suppose that the economy will revert to the real situation that prevailed before the inflationary episode began" (Solow (1970, p. 3) emphasis added). Such a position is difficult to argue with. In the first place this experiment obviously abstracts from shocks (or, at least, assumes that we are tracking the trend inflation rate around which there may be fluctuations associated with random disturbances which are, of course, inherently unpredictable and hence can be ignored) in which case it is indeed difficult to see how economic agents could avoid ultimately perceiving and, unless subject to money illusion, incorporating the systematic behaviour into their calculations. But the relevance of such steady state arguments to the actual forecasts of real world economic actors is difficult to access.[29] All of the empirical evidence suggests that the rate of inflation is a difficult variable to forecast,[30] in which case the assumption that $\dot{P}^e = \dot{P}$ is not very helpful as a guide to modelling the actual reactions of the economy to a policy stimulus. Secondly, the "long-run" is obviously a non-operational and vague concept, and is likely to lead to problems when testing hypotheses because there is always the possibility of recourse to the alibi that the test "came out wrong" because we really weren't in the long-run because insufficient time has elapsed for $\dot{P}^e$ to "zero in" on the true $\dot{P}$.[31]

One can object that in practice we do not need perfect forecasting of inflation, but only the systematic incorporation of expectations into the wage bargain, in order to frustrate attempts to exploit apparent inflation-unemployment trade-offs. The argument is about how steep the Phillips curve is, not whether it is perfectly vertical. But this tack misses the point. In our view an estimated alpha of less than one may be the consequence of money illusion (true alpha less than 1), use of an incorrect proxy for $\dot{P}^e$, or the fact that $\dot{P}^e \neq \dot{P}$ for the sample period, or any combination of these factors. Further, in our opinion, factors two and three[32] are far more likely to be the culprits than factor one, although, as we have seen, the existence of a long-run trade-off is usually attributed to factor one, the presence of money illusion.

We can illustrate our point by a slight modification of the algebraic model we outlined above. Let us now add to a system consisting of equations (1) and (2) an equation which allows $\dot{P}^e$ to be some multiple of $\dot{P}$. We then have

(1) $\dot{P} = \dot{W} - \dot{\rho}$

(2) $\dot{W} = f(U) + \alpha \dot{P}^e \qquad 0 \leq \alpha \leq 1$

(3) $\dot{P}^e = \beta(t)\, \dot{P} \qquad 0 \leq \beta\,(t) \leq 1.$

Let us also assume initially that $\beta(t)$ is a constant β_o, then

$$\dot{P} = f(U) - \dot{\rho} + \alpha\, \beta_o\, \dot{P}$$

or

$$\dot{P} = \frac{1}{1-\alpha\beta_o}\,[f(U) - \dot{\rho}]$$

If $\alpha = 1$, no money illusion, then

$$\dot{P} = \frac{1}{1-\beta} [f(U) - \dot{\rho}$$

and the trade-off remains so long as β_o does not equal one. It is not clear how one would distinguish this model from the traditional one. Further, the obvious question we would wish to ask is: what determines $\beta(t)$? It seems likely that β_o will change over time, being particularly large when there is a shift in the "gearing"[32] of the inflation process and tending to become smaller over time if our information set increases. Although there may be some basis for the supposition that $\beta(t)$ tends to decrease with time it would surely not be correct to believe that it is <u>necessarily</u> smaller in the 1980's than it was in the 1970's, or that the $\beta(t)$ of the 1970's was <u>necessarily</u> less than that of the 1960's. To do so would be to confuse the accelerationist "<u>long</u>-run," which is an analytical construct akin to the use of the term long-run in Marshall's dynamic classification, with a <u>long</u> period of time. Economic agents, in a world in which information is a scarce resource, may be assumed to devote time, effort, and money to improving forecasts only if they obtain a net benefit from doing so at the margin. We will return to this issue in section 3 below.

Let us assume, for sake of argument, that there exists a long-run trade off between inflation and unemployment. Since we are in a steady-state equilibrium expectations are realised and the correctly measured $\dot{P}^e$ is equal to the actual $\dot{P}$. The negative slope of the long-run Phillips curve therefore reflects money illusion--alpha is less than

1. In such a situation a lower equilibrium unemployment level can be purchased at the expense of a lower equilibrium inflation rate since the feedback from inflation to wages is less than one-to-one. But, should we attempt to exploit such a long-run trade-off? Would the resulting equilibrium (say U_e) be optimal? The answer to these questions obviously hinges upon the optimality of the natural rate unemployment level, U^N. When Friedman introduced the idea of the natural rate in his "Guidelines" Comments (1966, p. 60) he did so very briefly without any direct reference to the optimality question. We have seen that in his elaboration of the concept in his 1967 A.E.A. presidential address (1968, p.8) he associates it with the level of (aggregate) unemployment which would be "ground out by the Walrasian general equilibrium equations" which, under very strict assumptions, have well known optimality properties.[33] However, as Tobin observed in his presidential address to the A.E.A. (1972, pp. 5-6) "in fact we know little about the existence of a Walrasian equilibrium that allows for all the imperfections and frictions that explain why the natural rate is bigger than zero, and even less about the optimality of such an equilibrium if it exists." Subsequent research in general equilibrium analysis and welfare economics does not seem to have moved us significantly closer to definitive answers to these questions.[34]

However, Friedman's uncharacteristic appeal to the properties of the Walrasian model [35] may have led him into unnecessary technical problems. Phillips formulated his curve as a macroeconomic construct (in fact as part of the full macroeconomic models whose stabilisation properties were his major concern during most of his professional life). On this level of discourse the economy is conceived as a small set of interrelated markets--usually markets for labour, money, bonds, and a homogeneous and an infinitely malleable consumption-capital good (Ricardo's "corn")--which can be analysed by the familiar supply and demand apparatus. Such a system has the great merit of allowing us to come to grips with the implications of general equilibrium feedbacks, while being sufficiently aggregative to enable us to both comprehend the workings of the model, and to test its implications using available data. In these terms, as we have already seen above, we can conceptualise the natural rate as the equilibrium employment (or unemployment) level generated by the aggregate supply and demand curves for "labour" (where "labour" is another homogeneous artifact).[36]

If the natural rate corresponds to N_o (in Figure 3.1) above then we may argue that it is an optimal state since transactors are on their respective supply and demand curves. This is an example of voluntary exchange which is optimal in the sense that the corresponding real wage is equal to the marginal product of labour and also, at the margin, is just sufficient to compensate labour for the disutility of effort and lost satisfaction from foregone leisure. Similarly, U^N, the difference between N_o and the appropriately measured labour force (L), is at an optimal level and corresponds, according to Friedman, to "frictional" unemployment which takes into account the benefits of search activity. Hence, even if there exists a long-run trade-off we should not attempt to exploit it.

Such a steady-state trade-off exists only because the labour force is subject to money illusion. "Correcting" for such money illusion would obviously be presumptious.[37] However, accelerationists deny the possibility of persistent money illusion, and it is difficult to reconcile money illusion with our definition of the long-run. If the long-run is a state in which expectations are realised then why do economic decision makers go to the trouble of predicting the rate of inflation accurately only to fail to incorporate their calculations "appropriately" into their decisions?

The policy implications of all this are quite clear. If the natural rate level of unemployment is optimal then it is that level of unemployment which policy makers should aim at. Even though a long-run negative trade-off might exist it should not be exploited for to do so would move us away from the welfare maximum. Further, accelerationists would deny that, empirical evidence notwithstanding, a long-run negative trade-off could exist since such a trade-off could only arise from money illusion and money illusion does not seem to be consistent with inflation expectations being realised. At best, on this view, money illusion would be a transitory phenomenon which would gradually fade away as the long-run equilibrium state was approached. Assuming that this learning process takes place in real-time we would expect, historically, to observe that alpha would approach one on the assumption that the price level, or any time derivative of the price level exhibits detectable trends. Through time the optimal policy options become more and more constrained since the economy moves closer and closer to a knife-edge situation in which sustained deviations of unemployment from the natural rate thrust the system into accelerating inflations or deflations.

Why then, given these clear policy implications, have such sophisticated economists as Rees[38] and Tobin advocated reducing the unemployment level when some economists, such as Tullock, have claimed that to do so would move the unemployment level below U^N? The answer to this question requires that we recognize that the Acceleration Hypothesis is but one strand in the great controversy which has always been at the centre of macroeconomics since the inception of the subject with the publication of the "General Theory" in 1937.[39] This controversy is concerned with the self-correcting, homeostatic properties of the economic system, and centres around the issue of the uniqueness of real equilibrium. On one side economists of the classical persuasion argue that the term "equilibrium" should be reserved for situations in which all transactors are on their supply or demand curves, that such an equilibrium is unique and is determined only by real forces so that monetary policy impinges only on the price level (or its time derivatives), and since the absolute level of the aggregate price index may change without altering relative prices (real exchange ratios) the specific value which the index takes is essentially irrelevant. Economists within this group also stress market clearing (wages and prices which are systematically responsive to excess demand or supply), the absence of money illusion (zero degree homogeneity of micro demand and supply functions), and lay great emphasis upon stationary- or steady-state properties of the economy, especially the realisation of expectations in long-run equilibrium.[40] The "Keynesian" faction on the other hand tends to deny the relevance of these long-run propositions for practical policy and stresses downward rigidity of wages and prices as the prime source of underemployment equilibrium. On this interpretation there is no reason to expect that the actual unemployment level existing at any point of time should correspond to the natural rate.[41]

Assuming, for sake of argument, that the natural rate exists and is unique then it would appear that there is agreement that economic policy should be consistent with the economy gravitating towards an unemployment level equal to U^N. But, as we have already argued, the theory provides little guidance as to how to determine the magnitude of U^N. Friedman, although the originator of the term, has devoted remarkably little space in his writings to how to determine its level.[42] We do know that U^N does <u>not</u> correspond to $U = 0$ (see above), and we have also been told that U^N is not constant.[43] The problem with this situation is that it is always open to someone who wishes to oppose expansionary policies to argue that unemployment is already at, or below, the natural rate. Similarly it is always possible for economists and politicians to advocate throwing further fuel on the inflationary fires on the grounds that the present level of unemployment is to the right of U^N.[44] Our only way to combat these arguments is to estimte U^N but, as we have seen, the only guidance that Friedman provides us in this task is to equate $\dot{\rho}$ with $\dot{W} - \dot{P}$. Two points need to be mentioned here. Which $\dot{\rho}$ should we use? Presumably the (expected) long run trend value associated with operating the economy at normal capacity--whatever that is. Secondly, we need to be able to measure $\dot{P}^e$ accurately since it is $\dot{\rho}^e$ that determines the rate of change of expected real wages. (Alternatively we could assume that the economy is already in long-run equilibrium and, hence, that $\dot{P} = \dot{P}^e$ which implies that we need to estimate alpha, otherwise we are already at U^N).

The most interesting aspect of this revival of the Keynes versus the classic debate has yet to be investigated. This concerns Keynes' notions of involuntary unemployment and downward wage rigidity. We now turn our attention to these ideas.

Friedman, unlike some of his followers, has never dismissed Phillips' work on the Phillips curve out of hand but, rather, he has gone out of his way to pay tribute to the general sophistication of Phillips' economics.[45] However, in Friedman's view Phillips' work contains a major flaw: a confusion between real and nominal wages.[46] Friedman attributes this lapse to two features of the Keynesian macroeconomic framework within which Phillips worked and which was the ruling orthodoxy at the time he wrote his paper. These two features were the notion that "prices are rigid" and the belief that "real wages *ex post* could be altered by *unanticipated* inflation." Friedman (1976, p. 220) claims that: "These two components imply a sharp distinction between *anticipated* nominal and real wages and *actual* nominal and real wages. In the Keynesian climate of the time, it was natural for Phillips to take this distinction for granted and to regard anticipated nominal and real wages as moving together."

Let us first deal with the role of anticipations. Phillips, of course, did take prices into account in his analysis and Lipsey incorporated the actual rate of inflation into his regressions. The major achievement of Phelps and Friedman was to distinguish between actual and expected inflation, and to point to the latter as the crucial variable in the wage determination process, because labour markets are not continuous auction markets but are characterised by contractual arrangements which normally extend over a time horizon of at least one year. Given these institutional arrangements (and the implicit employment contracts which some economists have argued are a major feature of the real world) the participants in wage negotiations must give thought to the future, and in particular the future course of prices, since although the nominal wage is known over the life of the contract, the real purchasing power of the nominal wage is not generally guaranteed (unless, of course, wages are indexed).[47]

Friedman's first caveat referred to the assumptions of downward rigidity of wages. A correct appreciation of this assumption is, in our opinion, crucial to a proper evaluation of the policy implications of the Natural Rate Hypothesis. Classical economists argued that workers' refusal to accept cuts in their real wages via cuts in nominal wages implied that the corresponding unemployment was voluntary. Keynes[48] on the other hand argued that the relevant question to ask was did workers also resist general cuts in real wages brought about by increases in the aggregate price level? If the answer to this question was no, then Keynes argued that that part of the observed unemployment which would be removed by an expansion of monetary demand was involuntary. If part of measured unemployment is involuntary then the economy must be operating to the right of the natural rate. In such circumstances exploitation of any long-run trade-off would be legitimate. It is this type of reasoning which underlies the expansionary policy prescriptions of Tobin and Ross in the early 1970's.[49]

Friedman (1976, pp. 213-214) has charged that the rigid wages argument is unsatisfactory because it involves a confusion between nominal and real magnitudes which he seems to associate with money illusion. Tobin, on the other hand, denies that the downward inflexilibity of money wages is evidence of money illusion.[50] He interprets Keynes as claiming that workers are concerned with <u>relative</u> (real) wages, not with absolute real wages. Individuals and small groups cannot lower their money wge rates or fall behind the pattern of increase in other markets without lowering their relative wage rates. Inflation happens to be a neutral and universal way of reducing--or retarding--all workers' real wages without changing relative status."[51] Whatever the source of the phenomenon there does appear to be evidence for its existence[52] and the implications for the Phillips curve are relatively straightforward. To help illustrate these implications we refer to Figure 3.2. Figure 3.2(A) shows a standard aggregate labour market, of the type we used in Figure 3.1. In this case, however, nominal wages have risen to W at some time in the past, but under existing supply and demand conditions, and given that prices are expected to be P_o^e, there is now excess supply (N_o^s - N_o) at the wage floor $\bar{W}$.[53] If the labour market were in equilibrium then the expected real wage (We/P_o) would be consistent with full employment at N_e (and a natural rate of unemployment equal to L-N_e). Unless real wages can be driven down from their present level ($\bar{W}/P_o^e$) the unemployment level will continue above the natural rate level. Classically minded economists would expect that nominal wages would respond to the excess supply (nominal wages changing because it is the nominal wage, not the real wage, which is in fact determined in real world labour markets). On the other hand Keynesians would expect nominal wages to "stick" at $\bar{W}$ and "involuntary" unemployment to persist. The Keynesian solution to this involuntary unemployment is to push up the price level so that the expected price level rises from P_o^e to P_1^e. As a consequence the demand curve for labour will shift towards the left and employment will rise to N_e (unemployment will fall to the natural rate level). Assuming that labour does not suffer from money illusion the supply curve will also shift towards the right and $\bar{W}$ will correspond to the new equilibrium level of the nominal wage rate. Alternatively, if labour was subject to money illusion, some workers would be fooled into remaining in the labour force at the real wage $(\bar{W}/P_1^e)$ which they erroneously believed to be equal to the (higher) real wage $(\bar{W}/P_o^e)$.

There is the possibility that this expansionary policy would be frustrated if labour exhibits "real wage rigidity." In that case, illustrated in part (B) of Figure 3.2, we would expect the nominal wage to always keep step with the price level. Hence, when prices rise (causing P_1^e to increase to P_1) the nominal wage floor would also rise--from $\bar{W}$ to $\bar{W}_1$. In this case the gap $N_o^s - N_o$ is not closed and unemployment continues above the natural rate level.[54]

In any event the implication of nominal wage rigidity is that we would expect the Phillips curve to have a very flat right hand tail. In fact Phillips' original estimate of the pre-World War One U.K. curve yielded a graph similar to part (C)(i) of Figure 3.2, whereas Lipsey's curve estimated using inter-war and post-Second World War U.K. data suggested that the curve would look like that shown in Figure 3.2(C)(ii) (i.e. with a positive asymptote).[55] Alternatively the curve could asymptotically approach the horizontal axis as U increases towards one

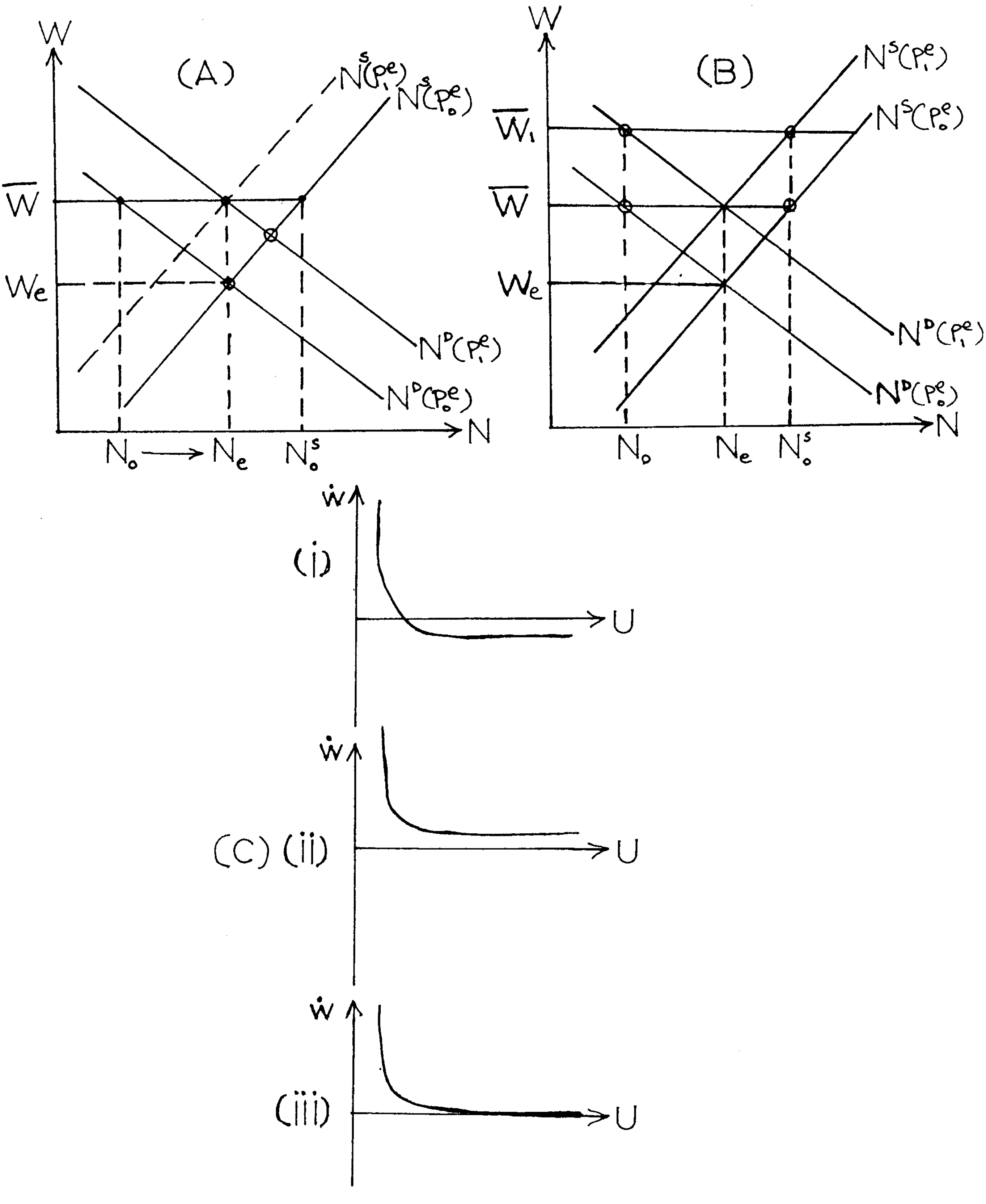

Figure 3.2 Wage Rigidity and the Natural Rate

hundred percent, as in Figure 3.2(C) (iii). In our experience almost all expositions of the Phillips curve, especially by North Americans,[56] show it cutting the horizontal axis and continuing to possess a steep negative slope well below the horizontal axis.

Before we move on to consider the empirical tests of the Acceleration Hypothesis we will summarise our discussions so far. The Acceleration Hypothesis, introduced by Friedman and Phelps in the late 1960's, claims that the Phillips curve trade-off is a purely short-run phenomenon and that it will cease to exist as soon as transactors perceive that the rate of inflation is not constant. Attempts by the authorities to operate the economy at unemployment levels to the right or left of the so-called natural rate level, U^N, will be associated with accelerating deflation or inflation. We argued that the vertical long-run Phillips curve result depends not simply upon the absence of money-illusion (the alpha coefficient being equal to one), but also upon the realisation of expectations ($\dot{P}^e = \dot{P}$), which obviously holds by definition in the "long-run" but whose relevance to any real world situation needs to be demonstrated. Friedman believes that the economy has a unique real equilibrium level corresponding to U^N and that the configuration of the economy is socially optimal in the sense that both suppliers and demanders of labour are on their relevant curves and are therefore satisfied with the employment-real wage bargain which is struck in the market. In this view even if a long-run trade-off exists it should not be exploited.[57] On the other hand economists, such as Tobin, who reflect a more Keynesian approach have argued that there is no reason to associate the actual rate of unemployment with U^N and that the existence of rigid nominal wages may lead to the possibility of multiple equilibria in the labour market. Under these circumstances expansionary policies designed to inflate the price level until, and only until, the real wage has been depressed to the level consistent with natural rate equilibrium are socially optimal. This policy should not be confused with one which claims that the long-run trade-off, if it exists, should be exploited. We are not at liberty to choose any combination of unemployment and inflation, but only the natural rate level and any rate of inflation.

This whole discussion suggests that an accurate estimate of the natural rate should be a major feature of any research programme related to the Phillips curve. Before such an estimate can be made, however, it is, in our opinion, necessary to obtain a good estimate of the augmented Phillips curve. That is the task of section four of this paper, but before we proceed to detail our own experiment we will review some of the early attempts to test the Acceleration Hypothesis.

3. SOME EARLY TESTS OF THE ACCELERATION HYPOTHESIS

Phelps introduced the Acceleration Hypothesis into the academic economics literature in 1967 (Phelps, 1967) and the concept was given additional impetus by its inclusion in Friedman's presidential address to the A.E.A. in December 1967. The alpha equals one hypothesis had to wait barely a month before the first tests were reported in the papers by Cagan (1968) and Solow (1968) at the Kazanjian Foundation's Symposium on Inflation held on the last day of January 1968 (Rousseas, 1968).[58]

Cagan's work involved the use of cycle averages and although it contains the first reported results for the U.K. will not be pursued here. Solow's quarterly data were drawn from the United States. He estimated a price inflation equation using a technique which we will describe in relation to his U.K. study below. He concluded that although his P^e proxy improved the overall fit of his equation "its coefficient never wanders far from 0.4" (Solow (1968, p. 14)). On the basis of his test Solow rejected the Acceleration Hypothesis arguing that: "For time spans that matter, there is no natural rate of unemployment" (loc. cit.).

Solow returned to this issue in a series of lectures which he presented at Manchester University (Solow, 1970). Solow's technique was to proxy inflation expectations by implementing a form of the Adaptive Expectations Hypothesis which had been used by Cagan in his well known study of hyperinflation (Cagan (1956)). The Adaptive Expectations Hypothesis may be written in the form:

$$\dot{P}_t^e - \dot{P}_{t-1}^e = \theta(\dot{P}_{t-1} - \dot{P}_{t-1}^e) \qquad 0 \leq \theta \leq 1$$

which hypothesises that expectations are revised in strict proportion to the expectational error made in the previous period. A simple form of learning is therefore involved. Straightforward re-arrangement of the equation yields

$$\dot{P}_t^e = \theta\dot{P}_{t-1} + (1 - \theta)\,\dot{P}_{t-1}^e$$

and it is in this form that Solow incorporates this proxy for $\dot{P}_t^e$ into his estimated price inflation equation. Specifically he constructed a set of proxies, one for each of the values of θ from 0.1 to 0.9 and then chose between them on the basis of the maximisation of $\bar{R}^2$ (which was the procedure Cagan had adopted fifteen years before). Solow's estimating equation was chosen to achieve comparability with his U.S. results (Solow (1970, p. 18)). For his annual data (covering the period 1948 to 1966) Solow used the percentage change in the "price index for final product" as his dependent variable, unit labour cost (defined as "the wage bill divided by real GDP") in annual proportional change form, the annual rate of change of the "index of prices of imported raw materials," and two incomes policies dummies (one for the Cripps 1948-1949 period, and one for 1961--the Selwyn Lloyd dummy) as independent variables in addition to his expectational dummy. Solow also experimented unsuccessfully (the coefficient was insignificant and with the wrong sign) with Paish's capacity utilisation measure. His regression results suggest a value of alpha close to 0.2 with the optimal theta being 0.6.

Solow ran quarterly regressions for the U.K., using four-quarter overlapping proportional changes, for the period 1957 (3) to 1966 (4). In this case the capacity variable did have a significant, correctly signed, coefficient. He found that the optimal value of theta was 0.7 which led to an alpha coefficient of 0.8.[59] Solow notes (loc. cit., p. 23) that: "These equations are thus much more favorable to the strict expectations hypothesis." He therefore re-ran his annual regression using the 1956-1966 sample, but found that dropping the earlier observations did not materially alter his results and so he concluded that there was no evidence to suggest that expectations had altered subsequent to 1956. Summarising his two sets of results Solow (loc. cit., p. 24) concludes: "I have no ready explanation for the inconsistency of the quarterly and annual regression coefficients. My inclination is to wonder if the quarterly figures are very good." It would appear that neither his U.S. or U.K. regressions provide strong support for the Acceleration Hypothesis if the assumption that expectations are formed adaptively holds.

Both Laidler (1970) and Friedman (1976, p. 228, n. 17)[60] criticised Solow's original American study on the grounds that it mis-specifies the test of the Acceleration Hypothesis. They point out that Solow's inclusion of a wage term (unit labour cost) on the right hand side of his price inflation equation will affect the interpretation of the alpha coefficient since this will only pick up "effects of anticipated inflation on the current rate of inflation that were not being transmitted through the labour market" (Laidler (1970, p. 120)). As Friedman notes: "In such an equation there is no reason to expect b (Friedman's notation for alpha) to be unity even on the strictest acceleration hypothesis."[61]

Solow's study appears to have been the only one to use his grid search technique to generate estimates for alpha. Subsequent studies have tended to use the Koyck transformation to obtain expectational proxies from the Adaptive Expectations Hypothesis, or to use proxies obtained from survey data or more complicated techniques such as the Box-Jenkins procedure. The Koyck transformation approach to the Adaptive Expectations Hypothesis has been criticised on the grounds that the alpha coefficient is often not uniquely determined, and usually involves inducing a moving average error term into the equation.[62] Santomero and Seater (1978, pp. 526-7) review many of the empirical studies and conclude that although the results are mixed there is evidence that the estimated alpha tends to approach unit value as the samples are extended into the 1970's. This finding is particularly important in the U.K. case since there is evidence that a distinct shift, or set of shifts, occurred in the Phillips curve after 1966 which is, of course, the end point of Solow's sample.[63,64]

At this point we wish to consider a difficulty in interpreting these tests which is well known but which, in our opinion, has not been satisfactorily resolved. Santomero and Seater point out that:

> Unfortunately, the job of econometric verification is no mean task. It requires the analysis of perceived as well as actual variables. Expected wages and prices rest at the heart of the theory and cannot be avoided. Accordingly, as noted by researchers in the area, any hypothesis testing includes a joint test of the underlying model and the expectations-generating mechanism.[65]

Unfortunately economics is largely a non-experimental discipline where the researcher seldom has control over the factors to be tested. When testing the Acceleration Hypothsis there are a number of reasons, therefore, why we might end up with alpha estimates of less than one: the Acceleration Hypothesis may be incorrect and the true alpha is less than one; our inflation expectations proxy may be poor; our sample may not refer to a situation for which expectations are realised; the whole Phillips curve construct which underlies the theory may be false; the data series used may not correspond to the theoretical variables (e.g. our price index may be defective and our unemployment proxy for excess demand may be inadequate); and, of course, our estimation procedure may be inappropriate (e.g. because we have not taken account properly of simultaneities, or we have failed to model the equation or disturbance dynamics correctly). All this says, of course, is that applied econometrics is a complicated discipline and Nature's experimental designs are often inadequate or perverse. This is a fact of life which economists have learned to live with. In this case, however, the problem is particularly acute because, as the quotation from Santomero and Seater points out, the whole basis of the interpretation of our test rests on the correctness of our choice of a proxy for $\dot{P}^e$, important policy prescriptions have been drawn from the results of these tests.

However, it is not clear that the conventional interpretation is necessarily the best one available to us. Why should we assume that we know more about the process of expectatons formulation than we do about the "rationality" of economic decisions? If the estimated alpha does not equal one then the conventional approach asserts that economic agents are subject to money illusion in their labour market decisions, but this inference requires that we <u>assume</u> that our $\dot{P}^e$ proxy is correct.[66] Obviously, if we are to use the standard test of the Acceleration Hypothesis then we must assume something.[67] The issue is: <u>what</u> should we assume? Now, in our view, the conventional approach is odd, because it assigns the Adaptive Expectations Hypothesis (or some other expectations generation mechanism) to what Lakatos called the "hard core," and allocates money illusion to the "protective belt" where it must "bear the brunt of tests and get adjusted and re-adjusted, or even completely replaced."[68] But such an allocation of concepts surely reverses the economists usual presumption concerning the likely plausibility of the two constructs, and also fails to reflect also the amount of empirical evidence we possess about them.

Tobin has observed (1972, p. 3) that "An economic theorist can, of course, commit no greater crime than to assume money illusion."[69] The whole of neoclassical economics is predicated upon a conception of rational decision making which abjures any possibility of systematically fooling economic agents. Demand functions, supply functions, consumption functions, demand for money functions, etc. are all conventionally assumed to be free of money illusion, because otherwise it would be possible for some units to make economic gains by persuading other units to transact at false prices. Further, such money illusion would deny the possibility that households and firms learn from experience and that they would ultimately come to realise that their real purchasing power was less than that apparently implied by their nominal incomes. Of course, in a dynamic world of uncertainty, it may be argued that determining the true "real" state of affairs may be difficult,[70] but this argument only implies that the outcomes of the economic process may not (with 20-20 hindsight) be consistent with full rationality (at least in short-run disequilibrium situations), it does not necessarily imply that the intentions were subject to money illusion.

It might, however, be objected that this position converts the absence of money illusion into a tautology. However, there is ample evidence that laymen, as well as professional economists, are aware of the implications of price inflation for the purchasing power of wages, and even formulate hypotheses concerning this phenomenon. Phillips[71] after all, was much concerned with the so-called "wage-price spiral"--the belief, widespread in Britain in the 1950's that wage increases immediately lead to one-to-one price increases which in turn cause further one-to-one wage increases and so on--and also devoted considerable space in his paper to discussing the possible impact of changes in prices (especially import prices) on wage claims.[72] Phillips was also aware (Phillips (1958, pp. 292-4)) of the existence of the sliding-scale and automatic cost-of-living adjustment agreements which had been a feature of some industries even before the First World War and which showed a rapid growth during and immediately after that conflict.[73]

Finally let us note that we have no theory to explain why, if absence of money illusion is abandoned in labour market modelling, it should not also be overthrown elsewhere in economic theory and application. But to attack the no money illusion doctrine more widely like this brings us up against the problem that models incorporating this assumption have apparently had some success in explaining real world phenomena. The alternative of assuming symmetry in the homogeneity specifications of individual behaviour is therefore much more palatable, but we would argue that even it should not be swallowed without good reason.[74]

Our alternative is to cast a jaundiced eye on the assumption that the $\dot{P}^e$ proxy is correct. The first thing to note is that many proxies have in fact been used in empirical work: naive proxies (such as simple extrapolative and autoregressive schemes), error learning mechanisms (such as the Adaptive Expectations Hypothesis), sophisticated statistical procedures (such as the use of Box-Jenkins forecasts), various proxies constructed along Rational Expectations lines (such as using the model's own inflation forecasts as the surrogate) and also the use of direct evidence on expectations obtained from surveys.[75] The fact that there is no unique procedure for modelling expectations, although the Rational Expectation approach is becoming dominant, suggests that we are on less firm ground here. It is also true that the preoccupation with expectations is a relatively new feature of economics being largely associated with the 1970's and the interest in testing the Acceleration Hypothesis and so we are not attempting to overthrow some great established tradition when we cast doubt upon the expectations generation process.[76]

Solow and Cagan both adopted the Adaptive Expectations procedure when they devised their initial tests of the Acceleration Hypothesis in 1968. The reasons for this are straightforward. In the first place, as Laidler (1976, p. 61) has observed, "...the natural first step was to take over research initially generated in studies of the demand for money and apply to (the) new problem." Since the model was known to have had some success elsewhere economy of effort could be achieved by utilising it in the new experiment. Secondly, the Adaptive Expectations procedure had the advantage of plausibility. The simple error-correction process was both easy to grasp and intuitively appealing. It was the sort of simple rule of thumb technique which one could imagine businesses and individuals actually operating. Thirdly, and related to this last point, in the guise of exponentially weighted moving average forecasts the Adaptive Expectations procedure was known to be used in real world business forecasting, as well as being advocated by statisticians interested in the problems of business forecasting. Fourthly, the Adaptive Expectations formulation had been shown by Muth (1960) to be an optimal forecasting technique if the process being forecast was a random walk with superimposed noise.[77] Finally, the Adaptive Expectations Hypothesis probably had two technical features which increased its appeal to economists in the early 1970's. Repeated lagging and substitution into the basic $\dot{P}^e$ equation above shows that this mechanism leads to a proxy which is a distributed lag equation in terms of current and past inflation rates.[78] Distributed lags and their estimation were a particularly fashionable brand of applied econometrics at this time. Further there already existed two tried techniques--the Cagan grid search procedure and the Koyck transformation[79] for reducing the intractably large (and highly collinear) set of lag coefficients to manageable form. In these circumstances it is hardly surprising that the Adaptive Expectations Hypothesis became the dominant model for the expectations generation process.[80]

Nonetheless the Adaptive Expectations Hypothesis has a number of disadvantages, one of which was surprisingly overlooked, or at least was not commented upon, in the early tests of the Acceleration Hypothesis. There is an obvious affinity between Friedman's permanent income concept and the $\dot{P}^e$ proxy generated by the Adaptive Expectations Hypothesis. In fact the proxies are generated by the same mechanism adopted from Cagan's hyperinflation study. However, Friedman notes (Friedman (1957, p. 144)) that the technique will not work well in the case where the variable being tracked, in our case $\dot{P}$, is trended. As is now well known if the rate of inflation shows a positive trend then the expected rate of inflation will systematically underestimate it, in fact diverging by larger and larger absolute amounts.[81] This feature of the Adaptive Expectations Hypothesis makes it a suspect model for testing a theory which predicts a continual acceleration of the rate of inflation or deflation.

It has also been argued that any simple endogenous mechanism of expectations formation is a priori implausible since it assumes that the future is in some sense an extrapolation of he past whereas expectations, despite their overall tendency towards inertia, are likely to show a certain waywardness which Keynes (1936) attempted to capture in his term "animal spirits."[82]

On a more technical level Sargent (1971) asserted that distributed lag schemes, such as the Adaptive Expectations model, which constrain the lag weights to be equal to one impose a downward bias on the coefficient and are therefore not suitable vehicals for testing the Acceleration Hypothesis. Further Bierwag and Grove (1966) have argued that only if all economic agents possessed identical alphas--a not very plausible assumption--will the lag coefficients decline geometrically.[83]

Our conclusion from all this is that the usual treatment of the two hypotheses which are jointly tested in the conventional investigation of the Acceleration Hypothesis should be reversed. The standard procedure is to presume that the assumed expectations formation mechanism is correct, and that the absence of money illusion postulate is open to question. We propose that the standard tests should be interpreted as throwing light upon the validity of the $\dot{P}^e$ proxy, and that the zero degree homogeneity assumption should be shifted to the "hard core"[84] to be brought into question only if strong, independent, evidence concerning the correctness of our expectations modelling procedure becomes available.[85] Admittedly even this interpretation is far from satisfactory since we do not know that decisions in the labour market are free from money illusion. But there is little that we can do, except to throw up our hands in horror and relinquish the field to those with more robust constitutions, since we are confronted with too many degrees of freedom (and this is before we take into account any of the other complicating factors we have already listed above). At least our proposed interpretation is consonant with the mainstream of economic analysis during the last century.

This approach has the additional merit that it should be possible to make some progress by further empirical investigation. For example, we would expect some proxies to be better than otghers and that replacing the inferior by the superior proxy should lead to better fits and forecasting behaviour for our equation. We would also expect that there would be a systematic relationship between the tracking ability of a proxy and its actual, continued, use by forecasters. This fact should also be amenable to empirical analysis. On the other hand the conventional interpretation of the Acceleration Hypothesis tests does not seem to offer much scope for further development.[86]

We now propose to review our own experiment and to comment on our results.

4. THE EXPERIMENT

Our experiment is essentially a replication of Solow's basic experiment (Solow (1970)), but using a different data base, a different formulation of the regression equation, and suggesting a different interpretation of the results. There are a number of reasons why such an experiment is worth undertaking. Solow's study was one of the first tests of the Acceleration Hypothesis[87] and is, therefore, of considerable historical interest. However, ours is not simply an antiquarian exercise but addresses a number of issues which Solow could not, or did not, pursue.

As we have seen above both Friedman and Laidler have argued that the form of the test Solow conducted was inappropriate. In their view the use of a price inflation equation incorporating wage effects on the right hand side biases the Alpha coefficient downwards. One way one might avoid this problem would be to drop the rate of change of unit labour costs term from the regression, but we have preferred to circumvent the difficulty by re-casting the test in terms of the standard Phillips-Lipsey wage inflation equation. One obvious advantage of this procedure is that it means we conduct our test in the mainstream of the Phillips curve literature--at least in its British contribution. A further advantage of this formulation is that it allows us to consider whether the temporal instability of our previously reported experiments with the U.K. Phillips curve (Sleeman (1983)) was the consequence of incorrectly modelling inflationary expectations˙

It should also be remembered that Solow's British test yielded contradictory results between his annual and quarterly regressions. The alpha coefficients produced by his best annual equations were 0.18 and 0.21, whereas his quarterly results yielded a statistically significant alpha of 0.81 (which is consistent with a null hypothesis of alpha equals one at a ten percent level). Solow attributes these inconsistencies to the inadequacy of the quarterly data available to him, but he also conducted an experiment to see if there was any evidence of a break in the expectations formation mechanism after 1956. He concludes that there was no such break. However, with all the advantages of hindsight, we may observe that the really crucial discontinuity in the behaviour of the U.K. wage, price and unemployment series seems to have occurred in 1966, which corresponds to the end point of Solow's sample. There seems to be good reason to replicate the experiment but with a more extensive sample.

Finally, our experiment allows us to explore some additional aspects of the Acceleration Hypothesis, such as the relative merits of different formulations of $\dot{P}^e$[88] and the relative advantages of the Friedman and Phelps approaches. And, of course, we are also able to try out the alternative interpretation of the results of the test which we discussed in section 3.

The form of Solow's test is straightforward, consisting of adding to the standard Phillips and Lipsey formulation of the Phillips curve ($\dot{W} = f(U,\dot{U})$) a $\dot{P}^e$ proxy term. Solow chose to generate this proxy by using the Adaptive Expectations Hypothesis (which he refers to (Solow (1970, p. 4)) as the "generally favored mechanism"). The Adaptive Expectations Hypothesis leads, of course, to a $\dot{P}^e$ equation of the form

$$\dot{P}^e_t = \theta\dot{P}_{t-1} + (1- \theta)\dot{P}^e_t \qquad 0 \leq \theta \leq 1$$

where $\dot{P}^e_t$ is the expected rate of price inflation, and $\dot{P}_t$ is the actual rate.[89] Theta is a measure of the speed with which expectations are currently adjusted to discrepancies between the actual and expected inflation rates in the previous time period. A theta value close to zero suggests very slow adjustment and a process with a very long memory (in the limiting case, where theta is zero, $\dot{P}^e$ is a constant). Alternatively, theta values close to unity correspond to a very rapid adjustment to recent errors and the process has a very short memory (in the limiting case, where theta equals one, $\dot{P}^e_t$ reduces to $\dot{P}_{t-1}$ and so the previous inflation rate is extrapolated into the present period).[90]

The Adaptive Expectations Hypothesis is, as we have already observed, equivalent to generating $\dot{P}^e$ from a particular form of distributed lag on past inflation rates. This formulation, usually associated with Koyck's early monograph on the investment function (Koyck, 1954), assumes that the weights on the lagged inflation terms form a (declining) geometric progression and sum to unity.[91] Thus $\dot{P}^e$ satisfies a first-order difference equation" (ibid.) Hence "For a given choice of theta , a whole time series of [$\dot{P}^e_t$] can be constructed by iteration, starting with a single initial value and using the observed time series of [$\dot{P}_t$] as raw material." (ibid.) Solow, following Cagan (1956), proceeded to calculate nine $\dot{P}_t$ series (one for each of the theta values from 0.1 to 0.9) and to choose between them (i.e. to choose the optimal theta coefficient) on the basis of the goodness of fit of the augmented Phillips curve regression. He initialised the process by setting $\dot{P}^e$ equal to zero in 1929[92] and argues that "Since I use the resulting series only for post-war years, the choice of an initial value is unimportant." (ibid.)

The data base used in our experiment consists of annual observations on wages, prices and unemployment for the United Kingdom from 1850 to 1980 inclusive. The wage series is an index of hourly wage rates. The price series is a consumer price index (in fact the official Retail Price Index from 1920). The unemployment data are an attempt to measure the annual average national unemployment rate, initially using trade union returns and then the official series.[93]

In order to ensure comparability with the Lipsey study and our own previous efforts along these lines, we have used three functional forms for the augmented Phillips curves. The first, which we call the theoretical formulation, takes the form

$$\dot{W} = a + bU^{-1} + cU + d\dot{U} + e\dot{P}^{e} \qquad (1)$$

The other two specifications are the ones used by Lipsey in his seminal <u>Economica</u> paper (Lipsey (1960)) and may be written as

$$\dot{W} = a + bU^{-1} + cU^{-2} + d\dot{U} + e\dot{P}^{e} \qquad (2)$$

$$\dot{W} = a + bU^{-1} + cU^{-4} + d\dot{U} + e\dot{P}^{e} \qquad (3)$$

We proxied the $\dot{P}^{e}$ variable in two basic ways: the adaptive proxies ($\dot{P}^{e}$, $PCHP^{e}$, $P\dot{F}D^{e}$ and $\dot{W}^{e}$) and the naive proxies involving lags of $\dot{P}$, PCHP, $P\dot{F}D$ and $\dot{W}$. The first adaptive proxy, $\dot{P}^{e}$, uses the first central proportional differences of the consumer price level series to generate an inflation series. That series was then subjected to the Solow procedure in order to obtain a set of proxies (one for each value of the theta from 0.1 to 0.9). The second adaptive series, $PCHP^{e}$, is similar to the first but uses the first difference approximation rather than the first central difference approximation.[94] We tried this proxy on the intuitively appealing grounds that households (and perhaps firms) are likely to attempt to reduce the information costs of their inflation forecasts[95] by using the official inflation series which, at least since the Second World War, are widely reported in the media. This series reports the percentage change in the price level over the previous year.

Our choice of the third adaptive proxy, $\dot{PFD}^e$, was similarly motivated. PFD refers to the food component of the Retail Price Index (or an analogous series). It seems not implausible that consumers would be particularly sensitive to fluctuations in food prices since they are usually monitored at least weekly (probably more frequently on a historical basis) and, therefore, involve lower "storage and retrieval" costs than the general price index (called, in Britain, the All Items Retail Price Index). Certainly Phillips singled out food prices in the late 1930s as an important factor influencing the cost of living (Phillips (1958, p. 295)).[96] The only systematic treatment of this issue with which we are familiar is the excellent article by Van Duyne (1981) which concludes, however, that the American data are not consistent with the view that food prices are particularly influential for price expectation.

Our final adaptive proxy, $\dot{W}^e$, was introduced in order to distinguish between the Friedman and Phelps formulations of the Acceleration Hypothesis. $\dot{W}^e$ simply uses the first central proportional differences of the wage series to generate the inflationary expectations variable. Admittedly our formulation is somewhat crude, but it was adopted it to ensure comparability with our other results.[97] We have also conducted some experiments with a $PCHW^e$ variable, analagous to $PCHP^e$, but we do not report these below, although they would add little to our conclusions they would add rather a lot to the bulk of the paper.

We therefore have thirty-six adaptive proxies: nine (one for each value of theta) for each of the four price or wage series. All of these proxy series were initialised by assuming that $\dot{P}^e$ in 1850 was constant and either zero, or plus or minus one percent. The initialisation at these levels was determined after examining evidence concerning the behaviour of prices in Britain between the beginning of our period and the end of the Napoleonic Wars. This evidence[98] seems to be consistent with Friedman's observation that: "For two centuries before World War II for the United Kingdom...prices varied about a roughly constant level, showing substantial increases in time of war, then post war declines to roughly pre-war levels" (Friedman (1977, p. 465)). Some experimentation suggested that there was little to choose between the three initial values and so we in fact confined our calculations to a starting value for $\dot{P}^e$ of zero in 1850.

In addition to the adaptive proxies we have also run regressions using naive proxies. These proxies utilise the basic series, $\dot{P}$, PCHP, $\dot{P}$FD and $\dot{W}$ either in contemporaneous form (lag = zero) or with a one period lead (lag = plus one) or a one period lag (lag = minus one). The last choice is straightforward and corresponds, as we have already noted, to the case of alpha equals one, and is a not implausible rule of thumb procedure for forecasting inflation. The zero lag may be interpreted as indicating that economic agents do in fact observe, collect, and process price etc. data over a much shorter time horizon than a year. It would also be consistent with the view that the Rational Expectations Hypothesis is equivalent to using the actual outcome of the series to be forecast as the expected value.[99] The lead value was used simply to see how well it performed--as a bench mark for other results.

Each equation was run for each of nine sample periods and using both ordinary least squares (OLSQ) and the Cochrane-Orcutt (CORC) estimation procedures. The CORC estimation technique was used because we expected, both on past experience and on theoretical grounds, that the OLSQ equations would show serially correlated residuals. The CORC approach to generalized least squares estimation was used in preference to, for example, a Hildreth-Lu type grid search, in order to reduce the amount of computer time used.[100]

For each of our nine time periods we estimated 288 equations,[101] giving a grand total of 2,592 equations.[102] In order to keep the length of the paper within reasonable bounds we have resisted reporting all of these results. Instead we have selected the most "interesting" results for display and discussion using a simple selection procedure. For each time period we present four tables, one for each of the main proxy variables: $\dot{P}^e$, $PCHP^e$, $\dot{PF}^e$, and $\dot{W}^e$. We thus have thirty-six tables in all. There were initially seventy-two potential equations for inclusion in each table: each of the three functional forms was estimated by both the OLSQ and the CORC technique yielding six standard equations, each of which could be estimated with any one of the twelve sub-proxies (nine adaptive proxies associated with the nine theta values, and three naive proxies associated with the three lag structures). We reduced these seventy-two original equations to eight (or less) by the expedient of selecting the four "best" equations (two OLSQ and two CORC) using the R^2 maximisation criterion adopted by Solow, and the four "best" equations (two OLSQ and two CORC) according to our own criterion of minimising the difference between the alpha coefficient and unity. In many cases equations tied according to one of the criteria in which case we report the equation with the better Durbin-Watson statistic. This procedure yielded 224 equations (out of a potential 288) which we actually report.

There are eight possible $\dot{P}^e$ equations, labelled 1-4 for the adaptive proxies and 17-20 for the naive proxies. Similarly there are eight possible $\dot{P}F^e$ equations (labelled 5-8 for the adaptive and 21-24 for the naive proxies); eight possible $PCHP^e$ equations (9-12 being associated with the adaptive and 25-28 with the naive proxies); and eight potential $\dot{W}^e$ equations (13-16 reporting adaptive, and 29-32 associated with naive proxies). Within each set of eight equations: (1) the odd numbered equations correspond to R^2 maximisation and the even numbered to the Alpha criterion; and (2) the OLSQ equations are the first two in both the adaptive and the naive proxy categories, while the second two equations in each category are the CORC equations. This rather complicated numbering system is illustrated in Figure 3.3. For example we see that the "best" $\dot{W}^e$, naive proxy, CORC equations are labeled 31 (for the R^2 maximisation criterion) and 32 (for the alpha criterion), while the "best" $PCHP^e$, adaptive proxy, OLSQ estimate equations are labelled 9 (R^2) and 10 (alpha).

Let us now turn our attention to the tables themselves. Each table is divided vertically into a maximum of eight rows: each row presenting the results from one of the preferred equations. The extreme, left hand side column of each table has two sets of numbers identifying the equation in each row: the upper number gives the equation number (or numbers, in the event of a tie) following the Figure 3.3 classification, while the lower number indicates the theta value associated with the

FIGURE 3.3 EQUATION CLASSIFICATION SCHEME

Proxy Type	Variable	Estimation Procedure	Criterion R^2	Criterion Alpha
A	$\dot{P}^e$	OLSQ	1	2
D		CORC	3	4
A	$P\dot{F}D^e$	OLSQ	5	6
P		CORC	7	8
T	$PCHP^e$	OLSQ	9	10
I		CORC	11	12
V	$PCHP^e$	OLSQ	9	10
E		CORC	11	12
	$\dot{W}^e$	OLSQ	13	14
		CORC	15	16
N	$\dot{P}^e$	OLSQ	17	18
A		CORC	19	20
I	$P\dot{F}D^e$	OLSQ	21	22
V		CORC	23	24
E	$PCHP^e$	OLSQ	25	26
		CORC	27	28
	$\dot{W}^e$	OLSQ	29	30
		CORC	31	32

adaptive proxies (or the lag type associated with the naive proxies). For example the numbers in the first four rows of Table 1 tell us that the "best" four adaptive proxy equations (numbered 1 and 2 for the OLSQ estimation and 3 and 4 for the CORCs) had theta values of 0.9, 0.3, 0.6, and 0.1 respectively. Similarly, the last two rows of Table 1 indicate that using either the OLSQ or the CORC estimation procedure yielded a unique equation according to both criteria, and that in these cases it was the contemporaneous naive proxy (i.e. the one with the zero lag) which was preferred.

The next seven columns of each table are reserved for coefficient values and their corresponding absolute t-statistic values. The first of these columns always reports the value of the estimated constant term. The next four columns are reserved for the excess demand proxies. If the preferred equation had the "theoretial" functional form then columns three and four will contain entries; if the equation uses Lipsey's pre-World War One specification then columns four and five will be filled; whereas if Lipsey's post-World War One specification is chosen then columns four and six will contain numbers. An inspection of columns four and six therefore tells us which of the three specifications applies to the equation (row) in question. Column seven always contains the coefficient on the $\dot{U}$ term (which may be interpreted as measuring the expected rate of change of the excess demand for labour). In column eight we have the estimated coefficient of the expected inflation proxy: our alpha coefficient (its t-statistic refers to the conventional null hypothesis that the true population value is actually zero).

The last five columns of each table present the relevant equation statistics: the corrected coefficient of determination (R^2); the F-statistic (with k-1 and N-k degrees of freedom: where k, which is always five, is the number of estimated coefficients and N is the sample size) for testing the null hypothesis that the coefficients of all of the independent variables are simultaneously zero; the Durbin-Watson statistic (DW) for testing for first-order serial correlation; RHO the value of the estimated autocorrelation coefficient generated by the CORC procedure; and, finally, the standard error of the regression.

We will now review our statistical results for each of the nine time periods.

(1) 1851-1979 (TABLES 3.1-3.4)

This is our longest sample period. However, it also, of course, includes two world wars and the Korean "police action," periods during which the exchange rate was fixed or followed a "dirty-float" regime, major structural shifts in the economy (from an initial situation in which the British economy was dominated by agriculture and heavy manufactures and was the world's major exporter, we progress to a situation in which agricultural production occupies less than three percent of the labour force, where the great nineteenth century staples have withered almost to nothing, and in which Britain's balance of payments is kept healthy only by North Sea oil), and a massive change in the role of both the government and trade unions in economic affairs. We should, therefore, be surprised if we get anything at all like a Phillips curve--and highly skeptical about the possible temporal stability of any such observed relationship.

1851-1979 N=129 INFLATION PROXY=PEDOT TABLE 3.1

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,124)	DW	RHO	SER
1)	.01		6.31	-2.05		-.01	.82	.56	40.35	1.31		4.28
(.9)	(.02)		(1.98)	(1.08)		(.64)	(10.20)					
2)	-.47		6.51		-.61	-.01	.98	.46	28.53	.96		4.90
(.3)	(.64)		(3.25)		(1.65)	(1.00)	(8.05)					
3)	7.36	-.72	-1.11			-.01	.29	.65	59.59	1.46	.70	3.80
(.6)	(4.11)	(4.23)	(.62)			(.82)	(.29)					
4)	-1.03	11.44	-4.73			-0.00	1.09	.61	50.69	1.41	.62	4.00
(.1)	(.72)	(2.93)	(2.28)			(.35)	(2.99)					
17-18)	-.12		4.72		-.49	.02	.95	.75	99.51	1.25		3.17
(0)	(.24)		(3.50)		(1.98)	(3.34)	(17.02)					
19-20)	.29		3.91		-.50	.01	.92	.79	122.12	1.65	.41	2.92
(0)	(.43)		(2.51)		(2.06)	(2.35)	(13.10)					

1851-1979 N=129 INFLATION PROXY=PFEDOT TABLE 3.2

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,124)	DW	RHO	SER
5)	-.06		8.07	-2.78		-.01	.64	.48	30.39	1.17		4.62
(.8)	(.07)		(2.37)	(1.37)		(.75)	(8.49)					
6)	-.77		9.60	-3.16		.92	.92	.42	24.60	.88		4.85
(.2)	(.83)		(2.70)	(1.49)		(.93)	(7.32)					
7)	8.09	-.79	-1.27			-.01	.19	.65	58.90	1.44	.74	3.81
(.4)	(4.29)	(4.64)	(.70)			(.72)	(1.15)					
8)	-.75		11.53	-4.78		-0.00	.95	.61	50.81	1.42	.62	4.00
(.1)	(.54)		(2.96)	(2.31)		(.36)	(3.04)					
21-22)	1.09	-.06	1.53			.19	.96	.79	92.93	1.19		3.25
(0)	(1.33)	(.67)	(1.39)			(2.89)	(16.25)					
23-24)	2.20	-.16	.49			.01	.90	.78	119.34	1.57	.45	2.95
(0)	(1.99)	(1.42)	(.38)			(1.41)	(11.51)					

1851-1979 N=129 INFLATION PROXY=PCHPE TABLE 3.3

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,124)	DW	RHO	SER
9-10)	2.55	-.24	2.92			-.01	.63	.40	21.59	1.03		4.99
(.7)	(2.05)	(1.85)	(1.74)			(.85)	(6.38)					
11)	9.08	-.85	-1.29			0.00	-.06	.65	58.83	1.42	.80	3.82
(.9)	(4.27)	(4.89)	(.73)			(.37)	(.71)					
12)	.65		6.81		-.65	-0.00	.61	.58	46.76	1.41	.66	4.10
(.1)	(.45)		(2.88)		(2.00)	(.13)	(1.47)					
25-26)	.37		5.63	-1.59		0.00	.77	.58	45.44	1.55		4.14
(0)	(.46)		(1.82)	(.87)		(.53)	(10.96)					
27-28)	1.03		7.43	-3.11		-0.00	.36	.64	56.57	1.64	.60	3.87
(0)	(.79)		(1.89)	(1.51)		(.33)	(4.43)					

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,124)	DW	RHO	SER
13)	-.49		4.17		-.26	-.02	.75	.60	48.03	1.34		4.07
(.9)	(.76)		(2.35)		(.80)	(2.70)	(11.25)					
14)	-2.54		9.64		-.81	-.01	1.03	.35	18.43	.81		5.14
(.1)	(2.88)		(4.57)		(1.99)	(.66)	(5.72)					
15)	5.16	-.52	.17			.01	.35	.66	63.08	1.56	.62	3.73
(.9)	(3.07)	(3.15)	(.09)			(1.38)	(3.75)					
16)	-.09		5.16		-.40	-.01	.56	.65	59.27	1.62	.44	3.81
(.9)	(.10)		(2.47)		(1.27)	(1.69)	(6.69)					
29-30)	-.36		3.91	-.64		-.02	.76	.62	53.34	1.41		3.94
(-1)	(.47)		(1.32)	(.36)		(2.89)	(12.06)					
31)	8.22	-.84	-3.34			0.00	.36	.69	71.72	1.62	.69	3.57
(+1)	(5.11)	(5.40)	(1.89)			(.50)	(4.58)					
32)	.61		4.50		-.59	.01	.46	.63	55.58	1.62	.49	3.89
(+1)	(.62)		(2.02)		(1.85)	(1.37)	(5.56)					

Table 3.1 presents the results obtained using the basic $\dot{P}^e$ proxy. The first four equations report the optimal adaptive proxy equations using $\dot{P}$ as the generating series. Equations 1 and 2 are for the OLSQ estimates, and equations 3 and 4 are for the CORC results. According to the R^2 maximisation criteria the $U^{-1}U^{-2}$ specification is best with OLSQ, but is replaced by UU^{-1} for the CORCs. However, our alpha criterion singles out the Lipsey post-1919 specification, $U^{-1}U^{-4}$, as the best functional form under OLSQ (and this is also the preferred form for the naive-proxies), but the theoretical UU^{-1} specification under the CORC transformation. Notice that there is also wide variation in the values of the estimated speed of adjustment coefficients, thetas, which vary from 0.1 and 0.3 (using alpha) to 0.6 and 0.9 (using R^2).

As far as the naive proxies (equations 17-20) are concerned, we see that, whether using OLSQ or CORC, our criteria choose the same equations (in each case the $U^{-1}U^{-4}$ specification) with no lag in the effect of the variable (i.e. the preferred equation is just the Lipsey post-World War One functional form down to the choice of $\dot{P}$ as the inflation proxy).

Comparing the naive and the adaptive proxies we notice that the former seem to show considerably better fits with generally better determined coefficients. Notice also that the constant terms in these equations are not significantly different from zero, which is also true of equations 1, 2 and 4--but note the highly significant positive constant term for equation 3. It is also interesting to notice that the $\dot{U}$ terms are small, positive (consistent with clockwise loops) and statistically significant.

However, before we make too much of these results we should observe the very low Durbin-Watson statistics. While the CORC procedure leads in every case to a higher Durbin-Watson statistic none of these results are satisfactory according to usual criteria--only the last equation (19-20) even reaches the indeterminate range of the Durbin-Watson statistic at the 5% significance level.

Finally notice that, except for equation 3, the alpha values yielded by these estimates are all consistent with the Acceleration Hypothesis. According to our criterion this would mean that none of the proxies in Table 1--whether generated by the Adaptive Expectations Hypothesis or not--are poor enough to provide evidence of mis-specification.

Comparing the results in Table 3.1 with those in the other three tables for this time period, we notice immediately that the poor Durbin-Watson statistics phenomenon is common to all the tables. We report 24 regressions in all, of which only numbers 16, 19-20, 27-28, 31 and 32 have Durbin-Watson statistics even in the indeterminate range. Bearing this in mind--with its implication of inflated t-values and artificially high R^2s--we will chance a few general observations.

None of the equations as a whole have especially high R^2s (particularly given the Durbin-Watson statistics). Equations 17-18, 19-20, 21-22, and 23-24 (the naive proxy equations associated with $\dot{P}$ and $\dot{P}F$) have the best overall fits. The first three of these equations also have satisfactory alphas, but only equation 19-20 (as we have seen) achieve anything like an acceptable Durbin-Watson statistic. Although there is not much to choose between the $\dot{P}^e$ and the $\dot{P}F^e$ equations the marginally better t-statistics of the former might lead us to discount our hypothesis concerning the advantage of food prices as an expectational proxy. There is also no evidence to suggest that people use the percentage change of prices rather than the central difference formulation. Finally, the Phelps version of the Acceleration Hypothesis seems to perform least well on either criterion.

We conclude, somewhat tentatively given the nature of our sample and the poor Durbin-Watson statistics, that there is little evidence in Tables 1-4 to suggest that the original Phillips-Lipsey specification of the Phillips curve should be supplanted by a more thorough going accelerationist formulation, and that we cannot reject the Acceleration Hypothesis--on either criterion--using this sample.

(2) 1851-1913 (TABLES 3.5-3.8)

This is the longest pre-World War One sample available to us. As we have seen, Friedman and others have observed that this was a period of relatively stable prices which may account for the original, pre-augmented, Phillips curve working rather well. Once again the most striking feature of all of the equations is the low Durbin-Watson statistics.

Starting with the $\dot{P}^e$ results reported in Table 5 we observe that in all four cases (the two criteria always generated the same preferred equations with this proxy) the preferred specification is UU^{-1}--the theoretical specification. The results are very much what we would expect from Phillips' and Lipsey's papers. We have a significant (negative) constant term, well determined excess demand coefficients, and well determined coefficients for the $\dot{U}$ term (which has a negative sign, indicating counter-clockwise looping) and the inflation proxy term

1851-1913 N=63 INFLATION PROXY=PEDOT TABLE 3.5

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,58)	DW	RHO	SER
1-2)	-3.37	.28	9.99			-.02	.27	.69	35.52	1.33		1.25
(.7)	(3.45)	(2.24)	(6.62)			(5.31)	(3.20)					
3-4)	-2.69	.25	8.28			-.01	.22	.73	43.78	1.59	.50	1.16
(.6)	(2.63)	(2.00)	(5.03)			(3.95)	(1.94)					
17-18)	-3.58	.30	10.46			-.01	.29	.72	40.97	1.38		1.19
(0)	(3.84)	(2.50)	(7.29)			(2.71)	(4.21)					
19-20)	-2.58	.25	8.07			-.01	.25	.77	50.72	1.64	.52	1.10
(0)	(2.67)	(2.11)	(5.21)			(1.83)	(3.29)					

1851-1913 N=63 INFLATION PROXY=PFEDOT TABLE 3.6

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,58)	DW	RHO	SER
5-6)	-3.17	.23	10.26			-.02	.11	.65	30.42	1.35		1.32
(.8)	(3.08)	(1.72)	(6.43)			(5.03)	(1.82)					
7)	-.20		1.48	5.43		-.01	-.27	.73	41.89	1.50	.61	1.18
(.1)	(.31)		(.56)	(1.99)		(3.14)	(.84)					
8)	-2.56	.21	8.55			-.01	-.01	.72	40.57	1.49	.58	1.19
(.8)	(2.41)	(1.07)	(5.02)			(3.06)	(.15)					
21-22)	-3.13	.23	10.19			-.01	.17	.66	30.39	1.22		1.32
(0)	(3.05)	(1.73)	(6.39)			(3.75)	(1.81)					
23-24)	-2.49	.22	8.24			-.01	.11	.73	42.12	1.50	.56	1.18
(0)	(2.38)	(1.78)	(4.94)			(2.93)	(1.29)					

1851-1913 N=63 INFLATION PROXY=PCHPE TABLE 3.7

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,58)	DW	RHO	SER
9-10)	-.69		3.29	5.06		-.02	.16	.67	31.64	1.23		1.30
(.6)	(1.24)		(1.15)	(1.73)		(5.19)	(2.04)					
11-12)	-2.56	.21	8.53			-.01	.10	.73	41.89	1.55	.53	1.18
(.6)	(2.45)	(1.67)	(5.14)			(3.65)	(1.29)					
25-26)	-.74		3.18	5.75		-.01	.19	.71	38.41	1.31		1.22
(+1)	(1.44)		(1.20)	(2.09)		(2.73)	(3.05)					
27-28)	-.35		2.35	4.94		-.01	.13	.76	49.69	1.63	.53	1.11
(+1)	(.62)		(.92)	(1.89)		(2.07)	(2.96)					

1851-1913 N=63 INFLATION PROXY=WEDOT TABLE 3.8

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,58)	DW	RHO	SER
13-14)	.13		-.90	4.86		-.02	.51	.72	41.68	1.51		1.18
(.9)	(.73)		(.32)	(1.83)		(6.23)	(4.21)					
15-16)	-.20		2.18		2.59	-.02	.39	.75	45.97	1.65	.37	1.14
(.9)	(.42)		(1.21)		(1.98)	(4.71)	(2.89)					
29)	-2.70	.14	8.37			-.01	.47	.79	61.27	1.58		1.02
(+1)	(3.43)	(1.42)	(6.65)			(1.56)	(6.74)					
30)	-.06		1.22		2.53	-.02	.55	.74	44.59	1.62		1.15
(-1)	(.13)		(.71)		(1.92)	(6.33)	(4.72)					
31-32)	-1.33		5.77		1.23	-0.00	.51	.81	67.89	1.55	.15	.98
(+1)	(4.07)		(5.34)		(1.07)	(1.27)	(6.57)					

(but with a very small coefficient which is inconsistent with the Acceleration Hypothesis). There is no evidence here for believing that the Adaptive Expectations Hypothesis formulation of the proxies does any better than the naive (unlagged) version. The optimal theta values (0.6 to 0.7) are consistent with a fairly rapid speed of adjustment. The overall fit, as indicated by the R^2s and the F-statistics is reasonably satisfactory, but once again the low Durbin-Watson statistics--even after correction--are cause for alarm.

As with the previous sample the results for the fit of the $\dot{PF}^e$ and $PCHP^e$ equations (reported in Tables 3.6 and 3.7 respectively) do not suggest that there is any mileage to be obtained from replacing $\dot{P}^e$ by these variables as proxies. Notice, however, that the $\dot{PF}^e$ alphas seem to be consistent with a zero value for the expectations series which, if one accepts the Friedman view of the period, gives some grounds for suggesting that the PFD series might be the most appropriate basis for constructing an inflationary expectations proxy. Further, with the exception of equation 7, the optimal theta values are all quite high (0.6 or larger). Also observe that in this period there is not much to choose between the naive and adaptive expectation proxies.

Finally notice that the Phelps equations all yield much larger alphas than those obtained with the other proxies. In general the value is around one-half. But also notice that two of the Phelps naive proxy equations used the lead form (i.e. W_{t+1}) and the interpretation of this result is not very clear.

(3) 1862-1913 (TABLES 3.9-3.12)

This period corresponds to that used by Lipsey in his original

1862-1913 N=52 INFLATION PROXY=PEDOT TABLE 3.9

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,47)	DW	RHO	SER
1)	-2.75	.18	9.73			-.02	.22	.80	48.86	1.28		1.00
(.6)	(3.36)	(1.71)	(7.71)			(6.03)	(2.18)					
2)	-2.48	.13	9.71			-.02	.31	.78	45.86	1.20		1.03
(.1)	(2.96)	(1.21)	(7.46)			(5.96)	(1.48)					
3-4)	-2.33	.11	9.09			-.01	.11	.83	62.79	1.87	.48	.91
(.5)	(2.75)	(1.09)	(6.57)			(4.14)	(.77					
17-18)	-2.92	.19	10.20			-.01	.22	.81	53.44	1.14		.97
(0)	(3.68)	(1.87)	(8.43)			(4.17)	(2.94)					
19-20)	-2.18	.11	8.73			-.01	.20	.86	73.99	1.80	.53	.84
(0)	(2.74)	(1.19)	(6.84)			(3.05)	(2.74)					

1862-1913 N=52 INFLATION PROXY=PFEDOT TABLE 3.10

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,47)	DW	RHO	SER
5-6)	-1.29		7.59		1.41	-.02	.26	.78	46.30	1.23		1.02
(.1)	(3.02)		(6.46)		(1.15)	(5.93)	(1.51)					
7)	-1.32		6.20	2.38		-.01	-.08	.83	63.15	1.92	.55	6.90
(.6)	(2.39)		(2.66)	(1.05)		(3.52)	(.86)					
8)	-1.44		7.54		.94	-.01	-.03	.83	61.87	1.90	.52	.91
(.1)	(3.00)		(5.99)		(.89)	(3.87)	(.89)					
21-22)	-2.71	.16	9.89			-.02	.19	.79	50.42	1.16		.99
(0)	(3.37)	(1.58)	(7.99)			(4.76)	(2.46)					
23-24)	-2.06	.09	8.58			-.01	.16	.85	69.04	1.85	.52	.87
(0)	(2.49)	(.93)	(6.41)			(3.60)	(2.10)					

1862-1913 N=52 INFLATION PROXY=PCHPE TABLE 3.11

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,47)	DW	RHO	SER
9-10)	-1.30		7.46		1.53	-.02	.23	.77	45.08	1.20		1.03
(.1)	(3.56)		(6.16)		(1.23)	(5.85)	(1.11)					
11-12)	-2.31	.09	9.250			-.01	-.02	.82	62.23	1.88	.53	.91
(.9)	(2.70)	(.87)	(6.75)			(3.85)	(.40)					
25-26)	-2.86	.18	10.06			-.02	.13	.79	49.03	1.20		1.00
(0)	(3.48)	(1.71)	(8.04)			(5.22)	(2.11)					
27-28)	-2.42	.13	9.13			-.01	.83	.83	66.52	1.87	.50	.88
(0)	(2.91)	(1.28)	(6.90)			(3.87)	(1.69)					

1862-1913 N=52 INFLATION PROXY=WEDOT TABLE 3.12

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,47)	DW	RHO	SER
13)	-2.42	.17	12.35			-.01	-1.21					
(.1)	(3.37)	(1.85)	(10.08)			(4.00)	(4.41)	.83	66.07	1.44		.88
14)	-.62		3.71		1.82	-.02	.39					
(.9)	(1.43)		(2.04)		(2.04)	(6.67)	(2.80)	.80	52.86	1.44		.97
15)	-1.84	.12	10.93			-.01	-1.18					
(.1)	(2.33)	(1.25)	(8.45)			(3.08)	(3.18)	.86	76.48	1.92	.39	.83
16)	-1.11		5.86		1.25	-.02	.19					
(.9)	(2.34)		(3.29)		(1.15)	(4.61)	(1.40)	.84	64.19	1.92	.42	.90
29-30)	-2.29	.09	7.88			-0.00	.47					
(+1)	(3.57)	(1.13)	(7.52)			(.86)	(6.06)	.87	86.27	1.93		.79
31-32)	-2.30	.09	7.91			-0.00	.47					
(+1)	(3.58)	(1.11)	(7.46)			(.88)	(5.65)	.87	84.64	1.80	-.02	.79

replication of the Phillips paper. For this period all of the OLSQ equations (except 29-30) have Durbin-Watson statistics in the indeterminate range (at the 5 percent significance level), while all of the CORC Durbin-Watson statistics move into the acceptable region beyond the upper bound.

Once again the $\dot{P}^e$ proxy yields a clearly preferred functional form--the theoretical specification, UU^{-1} (not, as one might have expected, Lipsey's own preferred form for this period, $U^{-1}U^{-2}$). There is little to choose between any of the equations in any of the tables in terms of overall fit--all of the R^2s are between 0.77 and 0.87--although the fit seems to be somewhat better than in the previous time periods.

Equation 3-4, which is the best fitting of the adaptive proxies, has an alpha coefficient which is not significantly different from zero and a satisfactory Durbin Watson statistic (achieved, of course, after application of the CORC transform). Again this may suggest that inflation expectations were in fact zero during the pre-World War One period.

Turning to Table 3.10, which contains the $\dot{P}F^e$ results, we observe again evidence that the true $\dot{P}^e$ may have been zero and also the suspicion that food prices may have been a better proxy for inflationary expectations during the nineteenth and early part of the twentieth centuries. On the other hand the $PCHP^e$ results are perhaps a little less attractive than those for $\dot{P}^e$. We would expect that our argument in terms of the widespread availability of the percentage change measure is inappropriate for such a remote period of time and, hence, we would only expect that proxy to come into its own after the Second World War.

The Phelps equations are most remarkable for the alpha values--significantly smaller than minus one--for equations 13 and 15 (which were selected on the R^2 maximisation criterion). Notice the very erratic behaviour of the optimal thetas which take the values 0.1 or 0.9 (the thetas for the other proxies are also bi-modal). Again the naive proxies have much larger alpha values, but they are also (as in the previous sample) generated by the W_{t+1} form, which suggests simply that the equation is picking up the correlation between the dependent variable and that variable led one period.

(4) 1919-1938 (TABLES 3.13-3.16)

This sample covers the whole inter-war period for the British economy. It was, of course, a period of deep depression with unemployment rising rapidly after the post-World War One boom and staying above ten percent for almost the whole period. The collapse of the world economy after 1929 exacerbated the already grim situation. This period has always proved difficult to model. One important feature of our sample, compared with the next one we will consider, which is based on Lipsey's exclusion of 1919 to 1922 because of the extreme volatility of the price level during those years, is that we now are considering a period in which price expectations may be expected to be important.

What is immediately apparent in all of our tables is the "blowing up" of the coefficients on the excess demand terms. We have previously noted this phenomenon and have tentatively associated it with problems of multicollinearity.[99] Equations 1 and 2 have reasonable overall fits but their low Durbin Watson statistics suggest the need to take account

1919-1938 N=20 INFLATION PROXY=PEDOT TABLE 3.13

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,15)	DW	RHO	SER
1)	-10.15		145.17		446.65	-.04	-3.11	.95	81.57	1.19		2.12
(.1)	(5.30)		(5.81)		(1.07)	(2.33)	(10.23)					
2)	-15.96	.33	137.51			-.13	.25	.65	7.72	1.25		5.78
(.9)	(1.79)	(.71)	(3.80)			(2.95	(.83)					
3)	-21.24	.61	223.29			-.04	-1.22	.88	31.31	2.20	.90	2.20
(.3)	(3.02)	(2.10)	(10.34)			(2.97)	(3.91)					
4)	6.81		-212.81	1661.15		-.07	.10	.87	35.98	2.03	.44	2.07
(.9)	(1.72)		(3.18)	(6.85)		(3.29)	(.79)					
17-18)	-11.99	.43	87.91			-.06	1.04	.90	43.09	1.34		2.84
(0)	(2.73)	(1.93)	(4.62)			(3.07)	(7.06)					
19-20)	-29.17	.91	231.57			-.08	.58	.88	31.76	1.78	.60	2.19
(0)	(3.64)	(2.69)	(4.57)			(5.35)	(2.73)					

1919-1938 N=20 INFLATION PROXY=PFEDOT TABLE 3.14

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,15)	DW	RHO	SER
5)	-12.65		154.57	313.06		-.05	-2.75	.94	73.72	1.16		2.22
(.1)	(6.22)		(5.86)	(.71)		(2.55)	(9.68)					
6)	-17.22	.39	143.97			-.13	.22	.66	7.83	1.26		5.75
(.9)	(1.96)	(.84)	(4.13)			(2.99)	(.91)					
7)	-5.29		91.23		2381.87	.03	-.84	.92	55.23	1.53	.79	1.70
(.4)	(1.94)		(3.52)		(4.63)	(1.22)	(4.74)					
8)	7.58		-227.90	1732.98		-.07	.11	.89	35.97	2.07	.43	2.07
(.9)	(1.89)		(3.36)	(6.96)		(3.63)	(1.06)					
21-22)	-12.09	.44	87.47			-.06	1.04	.91	44.11	1.32		2.83
(0)	(7.76)	(1.96)	(4.61)			(3.07)	(7.11)					
23-24)	4.03		-53.04		16689.	-.04	.67	.95	92.09	1.31	.23	1.53
(0)	(7.53)		(2.43)		(7.12)	(3.08)	(6.69)					

1919-1938 N=20 INFLATION PROXY=PCHPE TABLE 3.15

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,15)	DW	RHO	SER
9)	-9.08		120.42		744.20	-.05	-2.78	.95	92.56	1.23		1.99
(.1)	(5.04)		(5.17)		(1.88)	(2.67)	(10.96)					
10)	-18.84	.38	153.39			-.11	-.17	.65	7.72	.72		5.78
(.9)	(2.07)	(.82)	(4.21)			(2.59)	(.83)					
11)	-1.07		63.07		2524.53	.02	-.73	.95	104.51	1.79	.84	1.25
(.5)	(.43)		(3.14)		(6.71)	(1.28)	(8.05)					
12)	-29.62	.83	261.84			-.07	-.17	.86	25.39	1.99	.74	2.42
(.9)	(4.46)	(2.43)	(8.67)			(4.85)	(1.93)					
25)	2.40		-22.91		912.51	.08	1.11	.95	83.00	2.05		2.10
(+1)	(1.08)		(.82)		(2.18)	(3.08)	(10.33)					
26)	-5.37	.20	42.29			.05	1.07	.94	67.31	2.08		2.32
(+1)	(1.42)	(1.09)	(2.34)			(1.96)	(9.07)					
27-28)	.17		13.96		-4249.34	.17	1.24	.93	67.65	2.67	-.03	1.54
(+1)	(.10)		(.63)		(2.99)	(5.54)	(14.71)					

1919-1938 N=20 INFLATION PROXY=WEDOT TABLE 3.16

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,15)	DW	RHO	SER
13)	-10.71	.20	168.05			-.03	-2.74	.94	84.18	1.23		2.09
(.1)	(3.30)	(1.23)	(13.08)			(2.19)	(10.26)					
14)	-8.84		105.84		-123.21	-.16	.41	.64	8.90	1.41		5.50
(.9)	(1.77)		(1.65)		(.11)	(2.75)	(1.66)					
15.16)	-1.24		14.54		17499.	-.03	.23	.92	53.28	1.63	.29	1.73
(.9)	(.59)		(.55)		(9.86)	(1.30)	(2.69)					
29)	-10.44	.19	82.17			.14	1.63	.83	25.11	1.27		3.64
(+1)	(1.82)	(.65)	(3.23)			(2.49)	(4.95)					
30)	-8.04		97.63		-106.01	-.17	.49	.67	10.57	1.58		5.17
(-1)	(1.70)		(1.62)		(.10)	(3.18)	(2.26)					
31)	3.86		-152.49	1299.32		0.00	.42	.90	42.51	2.43	.45	1.92
(+1)	(.99)		(2.26)	(4.65)		(.10)	(1.48)					
32)	-32.45	.92	257.78			.02	.73	.87	29.48	2.46	.60	2.26
(+1)	(4.16)	(2.61)	(5.48)			(.40)	(2.47)					

of serial correlation. This improves the situation somewhat as can be seen by comparing equations 1 and 3. Equation 4, also corrected, has an alpha coefficient not significantly different from zero, and, indeed none of the adaptive proxies give any support for the Acceleration Hypothesis--unless one believes that the whole of the inter-war period was characterised by a belief in zero or negative inflation. On the other hand the naive proxies (with zero lags) offer much more support for the Acceleration Hypothesis, but they also exhibit low Durbin Watson statistics.

The equations reported for the $\dot{PFD}^e$ and $PCHP^e$ proxies (Tables 3.14 and 3.15) do not suggest that these variables are noticably superior to the traditional, $\dot{P}^e$, formulation. These regressions, especially those for $\dot{PFD}^e$, show rather less consistency with respect to the preferred specification than do the $\dot{P}^e$ equations. One should also notice that the naive proxies for the $PCHP^e$ variable all utilise the lead (t+1) formulation. Finally, there is, again, no particular pattern in the theta values with 0.9 the dominant figure (the other figures being 0.15 or less).

The Phelps specification is bedevilled by evidence of autocorrelation in the residuals. None of the adaptive proxies have acceptable Durbin Watson statistics, while the two naive proxies with better (corrected) behaviour are both of the lead (t+1) type.

Once again this inter-war period has resisted satisfactory modelling. In particular the large (in absolute value) negative alphas which were produced by some of the equations suggests serious specification problems, as do the abnormal coefficients on the U terms which we have already noted. We now turn to the Lipsey inter-war period in the hope that by dropping the 1919 to 1922 observations we will obtain superior results.

(5) 1923-1939 (TABLES 3.17-3.20)

Our hopes are quickly dashed. Only two equations amongst these tables (those being equations 19-20 and 23-24) have acceptable Durbin Watson statistics. Further, for this sample the coefficients on the U terms are even less acceptable than for those obtained from the inclusive inter-war sample. The only exception to these conclusions is equation 29-30 for the $\dot{W}^e$ variable, but once again this naive-proxy involves W_{t+1} and so it really signifies very little concerning the explanatory power of the Acceleration Hypothesis.

We again conclude that the inter-war period is extremely difficult to model using the conventional approach introduced by Phillips and Lipsey.

(6) 1948-1957 (TABLES 3.21-3.24)

This time period corresponds to the post-Second World War sample available to Phillips and Lipsey. Their model used to the $\dot{P}^e$ specification of the naive proxy with P unlagged. As can be seen from Table 3.21 this is by far the best fitting of the $\dot{P}^e$ variables, and also possesses satisfactory residuals (as indicated by the Durbin Watson test) after application of the CORC procedure. These equations (19 and 20) have alpha coefficients around 0.85, which compares with the 0.13 and 0.15 alphas of equations 1 and 2. These results give some distinct support for the Acceleration Hypothesis, but none at all for the Adaptive Expectations mechanism of expectations formation which is

1923-1939 N=17 INFLATION PROXY=PEDOT TABLE 3.17

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,12)	DW	RHO	SER
1)	-.60	42.23	-19770.30			-.60	.76	.65	7.28	1.32		1.32
(.3)	(.15)	(.59)	(.53)			(2.78)	(3.06)					
2)	.29		60.66		-528.45	-.65	1.19	.49	4.08	1.23		1.59
(.2)	(.03)		(.23)		(.32)	(2.47)	(1.73)					
3)	-2.40		189.20		-5259.40	-.01	-.65	.69	14.26	1.61	.95	1.03
(.4)	(.43)		(2.43)		(1.72)	(.38)	(1.42)					
4)	8.86		-222.13	1492.94		-.05	.73	.72	10.12	1.34	.40	1.18
(.7)	(.89)		(.87)	(.95)		(2.34)	(2.34)					
17)	-1.16		40.49		-23324.30	.02	.63	.84	24.75	1.02		.80
(0)	(.51)		(.97)		(1.06)	(1.20)	(6.70					
18)	5.82	-.16	-34.86			.02	.65	.89	23.25	.93		.83
(0)	(.77)	(.64)	(.65)			(1.22)	(6.69)					
19-20)	2.37		-23.02		3993.22	.06	.83	.94	69.97	2.27	.16	.50
(0)	(2.37)		(.77)		(.27)	(3.91)	(10.39)					

1923-1939 N=17 INFLATION PROXY= PFEDOT TABLE 3.18

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,12)	DW	RHO	SER
5)	.08		32.88		-16263.70	-.06	.55	.65	7.41	1.29		1.31
(.3)	(.02)		(.45)		(.43)	(2.89)	(3.10)					
6)	6.33	-.06	-40.07			-.06	1.04	.58	5.46	1.43		1.46
(.2)	(.46)	(.13)	(.42)			(2.71)	(2.51)					
7)	6.68		-158.50	1121.95		.54	.54	.72	10.16	1.41	.47	1.18
(.5)	(.67)		(.64)	(.74)		(2.19)	(2.04)					
8)	-3.99		110.09		-25260.00	-.03	.03	.75	11.69	1.41	.96	1.11
(.9)	(.77)		(1.61)		(.91)	(1.31)	(.32)					
21-22)	-.58		28.62		-16272.80	.02	.64	.84	24.99	1.20		.80
(0)	(.25)		(.68)		(.73)	(1.15)	(6.79)					
23-24)	2.92		-34.80		11992.90	.05	.83	.94	57.62	2.42	.11	.55
(0)	(1.58)		(1.04)		(.73)	(3.95)	(9.65)					

1923-1939 N=17 INFLATION PROXY=PCHPE TABLE 3.19

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,12)	DW	RHO	SER
9)	-3.31		85.78		-37481.	-.06	.53	.58	5.33	1.36		1.47
(.3)	(.79)		(1.15)		(.93)	(2.80)	(2.30)					
10)	12.89	-.40	-76.55			-.07	.75	.46	3.35	1.19		1.68
(.2)	(.84)	(.76)	(.71)			(2.55)	(1.32)					
11)	-.68		158.12		-44774.60	-.01	-.49	.80	16.30	1.62	.95	.97
(.4)	(.12)		(2.65)		(1.79)	(.74)	(1.89)					
12)	-3.59		119.77		27823.10	-.02	-.02	.75	11.65	1.53	.93	1.12
(.9)	(.67)		(1.85)		(1.03)	(1.01)	(.27)					
25-26)	4.59	-.15	-21.29			-.05	.39	.60	5.99	.72		1.41
(+0)	(.34)	(.33)	(.23)			(2.23)	(2.73)					
27-28)	-2.84		122.69		-521.93	-.03	.16	.77	13.02	1.36	.93	1.07
(+0)	(.41)		(.81)		(.58)	(1.65)	(1.22)					

1923-1939 N=17 INFLATION PROXY=WEDOT TABLE 3.20

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,12)	DW	RHO	SER
13-14)	-2.73		63.15		-28874.10	-.05	1.15	.61	6.61	1.33		1.37
(.3)	(.71)		(.88)		(.76)	(2.37)	(2.82)					
15)	-2.19		122.90		-29206.80	-.02	-.25	.75	11.75	1.45	.95	1.11
(.3)	(.35)		(1.85)		(1.06)	(1.18)	(.34)					
16)	-2.21	0.00	38.13			-.04	.88	.71	9.55	1.45	.51	1.21
(.4)	(.19)	(0.00)	(.50)			(1.75)	(1.81)					
29-30)	4.22	-.21	-18.09			.01	.60	.77	14.25	1.90		1.02
(+1)	(.44)	(.65)	(.27)			(.25)	(5.03)					
31-32)	4.11	-.19	20.38			-.03	.05	.74	11.01	1.53	.92	1.14
(-1)	(.43)	(.61)	(.35)			(1.32)	(.48)					

1948-1957 N=10 INFLATION PROXY=PEDOT TABLE 3.21

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 5)	DW	RHO	SER
1)	-49.54	15.38	46.22			.01	0.13	0.50	2.89	2.36		1.15
(.5)	(2.25)	(2.25)	(2.61)			(.31)	(0.36)					
2)	13.07		-20.27		23.38	0.01	0.15	0.46	2.31	2.35		1.24
(.5)	(1.62)		(1.35)		(1.91)	(0.51)	(0.41)					
3)	-21.50		35.58		-11.04	-0.03	1.31	0.75	36.39	2.55	-0.70	0.85
(.9)	(1.66)		(1.64)		(0.77)	(1.50)	(3.08)					
4)	-10.93	-0.06	18.03			-0.01	1.03	0.75	5.81	1.85	-0.61	0.89
(.8)	(0.47)	(0.01)	(1.02)			(0.74)	(2.50)					
17-18)	-38.01	11.73	35.57			000.00	0.37	0.77	6.30	1.64		0.85
(0)	(2.21)	(2.22)	(2.53)			(0.03)	(2.09)					
19)	-14.63	5.40	15.61			-0.03	0.83	0.95	32.43	2.24	0.88	0.40
(0)	(2.19)	(2.69)	(2.78)			(3.57)	(8.60)					
20)	6.55		-6.91		7.24	-0.03	0.86	0.92	21.65	2.15	0.87	0.49
(0)	(2.59)		(1.65)		(1.91)	(2.66)	(7.50)					

1948-1957 N=10 INFLATION PROXY=PFEDOT TABLE 3.22

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 5)	DW	RHO	SER
5)	-47.33	14.66	44.40			0.01	0.11	0.51	3.28	2.56		1.10
(.6)	(2.24)	(2.24)	(2.61)			(0.25)	(0.79)					
6)	12.16		-18.61		22.12	0.01	0.12	0.50	2.68	2.63		1.18
(.7)	(1.69)		(1.32)		(1.90)	(0.43)	(0.83)					
7)	-19.61	4.43	24.00			0.01	0.37	0.88	14.56	2.85	-0.49	0.59
(.9)	(1.45)	(0.99)	(2.29)			(0.73)	(4.19)					
8)	-1.76		5.23		6.19	0.01	0.38	0.87	13.06	2.63	-0.43	0.62
(.8)	(0.32)		(0.51)		(0.80)	(1.16)	(4.22)					
21)	-58.12	18.23	52.36			0.01	0.14	0.52	3.15	2.37		1.12
(+1)	(2.47)	(2.56)	(2.86)			(0.71)	(0.68)					
22)	16.97		-28.07		28.96	0.02	0.15	0.50	2.50	2.37		1.21
(+1)	(2.34)		(1.75)		(2.20)	(1.01)	(0.66)					
23)	-27.61	8.90	26.18			-0.02	0.63	0.91	18.29	2.40	0.80	0.53
(0)	(3.35)	(3.54)	(3.80)			(1.72)	(6.14)					
24)	8.18		-12.01		13.03	-0.01	0.66	0.87	12.29	2.30	0.76	0.63
(0)	(2.78)		(2.15)		(2.69)	(1.05)	(5.29)					

1948-1957 N=10 INFLATION PROXY=PCHPE TABLE 3.23

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 5)	DW	RHO	SER
9)	-48.00	15.65	44.90			0.02	-0.13	0.51	3.15	1.62		1.12
(.9)	(2.24)	(2.44)	(2.60)			(0.81)	(0.67)					
10)	-51.08	16.11	47.56			0.01	0.01	0.49	2.79	2.18		1.17
(.4)	(2.31)	(2.42)	(2.70)			(0.51)	(0.05)					
11)	-35.43	12.99	34.64			0.01	-0.43	0.76	4.78	1.55	0.52	0.96
(.9)	(2.13)	(2.64)	(2.56)			(0.39)	(2.38)					
12)	10.93		-17.23		22.16	0.02	0.25	0.50	2.01	1.22	-0.33	1.33
(.6)	(1.08)		(0.93)		(1.55)	(1.12)	(0.71)					
25)	30.03		-86.52	69.68		0.01	0.31	0.76	5.80	1.93		0.88
(+1)	(3.46)		(3.14)	(3.30)		(0.77)	(2.12)					
26)	3.75		-3.03		9.50	0.00	0.37	0.56	3.66	2.05		1.06
(0)	(0.39)		(0.17)		(0.65)	(0.08)	(1.45)					
27)	29.13		-70.35	55.34		0.02	-0.39	0.76	4.72	1.53	0.51	0.97
(-1)	(3.37)		(2.78)	(2.73)		(0.78)	(2.51)					
28)	-6.58		22.61	-12.63		-0.05	0.75	0.59	3.88	2.51	0.51	1.05
(0)	(0.39)		(0.45)	(0.33)		(1.45)	(2.19)					

1948-1957 N=10 INFLATION PROXY=WEDOT TABLE 3.24

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 5)	DW	RHO	SER
13)	-45.38	17.38	48.04			0.01	-1.38	0.77	5.99	2.69		0.87
(.3)	(2.73)	(3.47)	(3.66)			(0.41)	(1.99)					
14)	21.74		-32.57		31.98	0.02	-0.32	0.50	2.71	2.50		1.18
(.9)	(2.14)		(1.85)		(2.29)	(1.12)	(0.86)					
15)	-41.37	16.67	46.38			0.02	-1.70	0.86	11.51	1.55	-0.38	0.65
(.3)	(3.21)	(4.33)	(4.66)			(1.54)	(3.53)					
16)	26.85		-40.86		38.47	0.04	-0.51	0.56	3.07	1.59	-0.44	1.15
(.9)	(2.75)		(2.35)		(2.77)	(1.87)	(1.53)					
29)	-57.48	18.02	50.37			0.02	0.30	0.59	4.17	2.70		1.01
(+1)	(2.94)	(3.04)	(3.29)			(0.96)	(1.31)					
30)	16.92		-29.72		29.01	0.02	0.33	0.51	3.39	2.72		1.09
(+1)	(2.79)		(2.22)		(2.68)	(1.31)	(1.31)					
31)	-55.81	17.11	47.40			0.04	0.60	0.89	14.79	1.74	-0.34	0.58
(+1)	(4.96)	(4.96)	(5.32)			(3.61)	(4.05)					
32)	15.33		-29.86		28.59	0.05	0.65	0.86	11.92	2.11	-0.34	.64
(+1)	(4.09)		(3.77)		(4.41)	(4.01)	(3.42)					

inferior on both of our criteria.

The results for the $\dot{PF}^e$ and the $PCHP^e$ variables are generally inferior to those obtained with $\dot{P}^e$ both in terms of poorer fits and of non-significant alpha coefficients. Once again there appears to be no support for the view that people use food prices or the published percentage inflation rate variables in the generation of their inflation anticipation.

The results for $\dot{W}^e$ are also inferior to those for $\dot{P}^e$. All of the preferred equations for the naive proxies use the lead W formulation. All of the adaptive proxies have negative alphas (some of which are non-significant). The high values of the Durbin Watson statistic in equations 13 and 14, and the negative rho's for the corrected equations, suggest that negative serial correlation may have been a problem.

All of the results for this first post-World War Two period show one very important improvement relative to those generated by the two inter-war samples. This is the marked reduction in the size of the coefficients on the excess demand for labour variables. These are now quite large relative to the estimates we obtained from our first three samples, but not so large as to suggest serious collinearity problems. Further, at least for the naive $\dot{P}^e$ formulation, these coefficients are well determined (and remain so after the application of the CORC transformation). Also the $\dot{U}$ term regains its negative (and statistically significant) coefficient. Overall we conclude that the Phillips-Lipsey formulation of the Phillips curve works quite well for the period to which they had immediate access.

(7) 1948-1979 (TABLES 3.25-3.28)

Our largest post-Second World War sample extends from the beginning of Phillips' and Lipsey's period to the end of the 1970's. It also has been a period of considerable turmoil: a period which includes the Korean and Vietnam Wars, the OPEC oil price hikes of 1973-74 and 1979, two devaluations of the pound (in 1949 and 1967), the "dirty float" of sterling after June 1972, periods of Incomes Policy (which in the 1970's became almost continuous), periods of great industrial unrest, and last, but not least, the apparent structural shift in the U.K. labour market which occurred about 1966.

The first point to observe concerning the $\dot{P}^e$ results reported in Table 3.25 is that all of the preferred equations involve the theoretical specification, UU^{-1}. Also notice the generally poor Durbin Watson statistics. When the CORC transformation was applied to equations 1 and 2 the resulting regressions (3 and 4) showed some improvment in the Durbin Watson statistics. Observe that equations 1 and 3, which were chosen on the R^2 maximisation criterion, have unacceptably large alpha coefficients.[103] Equations 2 and 4 (which have optimal theta values of 0.6 and 0.4 respectively) have alphas insigificantly different from one (those equations, of course, were chosen using the alpha criterion). The overall fit of equations 2 and 4 is inferior to that of the naive proxy equations (17-18 and 19-20). These equations also have alpha values consistent with the strict Acceleration Hypothesis, an acceptable Durbin Watson statistic (for equation 1920 after correcting for serial correlation) and approximately jointly significant U terms (although the coefficients, like those for

1948-1979 N=32 INFLATION PROXY=PEDOT TABLE 3.25

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	(F(NN,MM)	DW	RHO	SER
1)	25.51	-5.87	-29.54			0.06	2.40	0.57	10.88	1.16		3.64
(.2)	(3.35)	(2.62)	(3.04)			(1.60)	(3.29)					
2)	16.55	-2.43	-16.88			0.06	0.98	0.53	9.52	1.21		3.78
(.6)	(2.45)	(1.58)	(2.00)			(1.45)	(2.82)					
3)	14.75	-5.17	-18.31			0.09	3.67	0.69	17.24	1.85	0.56	3.11
(.1)	(1.99)	(2.21)	(1.90)			(2.55)	(2.80)					
4)	13.85	-2.49	-11.60			0.08	1.08	0.63	13.66	1.63	0.52	3.38
(.4)	(1.72)	(1.18)	(1.20)			(2.11)	(1.82)					
17-18)	10.16	-1.28	-10.45			0.04	0.96	0.79	28.17	1.61		2.58
(0)	(2.30)	(1.65)	(1.88)			(1.44)	(6.93)					
19-20)	10.04	-1.23	-10.13			0.04	0.93	0.79	28.03	1.89	0.20	2.58
(0)	(2.00)	(1.38)	(1.63)			(1.36)	(5.96)					

1948-1979 N=32 INFLATION PROXY=PFEDOT TABLE 3.26

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,27)	DW	RHO	SER
5)	11.99		-16.27		12.01	0.07	0.37	0.53	9.88	1.14		3.74
(.9)	(2.60)		(1.58)		(0.85)	(1.75)	(2.09)					
6)	21.40	-2.94	-23.47			0.07	0.89	0.52	9.49	1.16		3.79
(.3)	(2.87)	(1.75)	(2.51)			(1.89)	(2.80)					
7)	14.50	-4.04	-15.81			0.09	2.48	0.67	16.29	1.82	0.63	3.17
(.1)	(1.87)	(1.87)	(1.63)			(2.78)	(2.39)					
8)	3.37		0.41	-1.24		0.09	1.00	0.63	13.60	1.70	0.63	3.38
(.1)	(0.29)		(0.12)	(0.04)		(2.70)	(1.14)					
21-22)	10.07	-1.26	-10.34			0.04	0.95	0.79	28.33	1.61		2.58
(0)	(2.28)	(1.63)	(1.86)			(1.57)	(6.95)					
23-24)	9.97	-1.21	-10.01			0.04	0.93	0.79	28.22	1.90	0.20	2.57
(0)	(2.00)	(1.36)	(1.61)			(1.43)	(6.00)					

1948=1979 N=32 INFLATION PROXY=PCHPE TABLE 3.27

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,27)	DW	RHO	SER
9)	20.89	-3.38	-22.80			0.08	1.35	0.46	7.57	1.10		4.03
(.3)	(2.44)	(1.41)	(2.13)			(2.10)	(1.93)					
10)	18.71	-2.51	-19.70			0.08	0.99	0.44	7.18	1.12		4.09
(.4)	(2.25)	(1.14)	(1.91)			(2.09)	(1.70)					
11)	29.09	-1.87	-9.35			0.09	-0.53	0.67	16.18	2.21	0.95	3.18
(.7)	(1.99)	(1.02)	(1.13)			(3.17)	(1.56)					
12)	6.27		-6.88		5.05	0.10	0.91	0.62	13.08	1.71	0.64	3.43
(.1)	(0.49)		(0.21)		(0.17)	(2.73)	(0.74)					
25)	11.53		-18.02		14.68	0.07	0.61	0.68	11.43	1.51		3.10
(+1)	(3.89)		(2.57)		(1.40)	(2.20)	(4.31)					
26)	11.41	-1.11	-11.91			0.03	0.87	0.63	14.25	1.35		3.33
(+0)	(2.00)	(1.08)	(1.66)			(0.90)	(4.25)					
27)	12.51		-19.47		16.38	0.09	0.51	0.70	18.19	1.69	0.28	3.05
(+1)	(3.86)		(2.48)		(1.45)	(2.63)	(3.31)					
28)	10.25	-0.84	-9.04			0.03	0.75	0.68	16.52	1.79	0.39	3.16
(+0)	(1.52)	(0.67)	(1.10)			(0.65)	(3.13)					

1948-1979 N=32 INFLATION PROXY=WEDOT TABLE 3.28

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,27)	DW	RHO	SER
13)	15.54	-4.04	-20.97			0.09	1.84	0.57	11.60	1.37		3.56
(.2)	(2.49)	(2.41)	(2.55)			(2.47)	(3.52)					
14)	11.39	-2.01	-12.61			0.08	1.02	0.56	11.03	1.45		3.62
(.4)	(1.84)	(1.55)	(1.61)			(2.34)	(3.34)					
15)	38.87	-2.88	-11.96			0.09	-0.44	0.67	15.63	1.88	0.97	3.22
(.5)	(1.94)	(1.69)	(1.43)			(3.11)	(1.30)					
16)	9.84	-1.56	-9.24			0.09	0.89	0.61	12.81	1.77	0.41	3.45
(.3)	(1.31)	(0.87)	(1.00)			(2.45)	(1.82)					
29)	14.31		-36.27	27.73		0.09	0.45	0.63	14.49	1.57		3.31
(+1)	(3.60)		(2.25)	(1.68)		(2.74)	(3.88)					
30)	9.01		-18.40	13.50		0.06	0.53	0.56	10.74	1.62		3.65
(-1)	(1.51)		(0.91)	(0.69)		(1.58)	(2.77)					
31)	13.48		-23.31		22.37	0.11	0.38	0.68	16.58	1.74	0.23	3.15
(+1)	(4.25)		(3.05)		(1.98)	(3.04)	(3.15)					
32)	15.35		-39.14	30.11		0.11	0.39	0.66	15.69	1.73	0.23	3.22
(+1)	(3.52)		(2.19)	(1.67)		(3.06)	(3.13)					

all of the other equations in Table 3.25, are both negative). Once again there appears to be no reason to prefer the equations generated by the Adaptive Expectations Hypothsis over the equations incorporating the naive proxies.

The results presented in Table 3.26, for the $\dot{P}F^e$ proxy, are broadly similar to those for $\dot{P}^e$. Once again the naive proxies appear to be no worse than the more sophisticated adaptive proxies. Also the overall fit of the equations is comparable, as are the alpha values. Inspection of the Durbin Watson statistic, however, suggests that these food price proxies may be worse than the usual All Items Retail Price Index variable. On the other hand this is not a problem with equation 23-24--the naive proxy estimates using the CORC procedure.

Comparing the $PCHP^e$ results (Table 3.27) with those for $\dot{P}^e$ we also have reason to prefer the latter which generally exhibit better fits, superior Durbin Watson statistics and comparable or better alpha values--especially in the naive proxy versions. Finally there appears to be no evidence favouring the Phelps $\dot{W}^e$ formulation over the Friedman $\dot{P}^e$ variant.

Taken as a whole the results for the complete post-Second World War period are compatible with the existence of an augmented Phillips curve, with a coefficient of alpha close to one, and with the naive $\dot{P}^e$ proxy outperforming other proxies.

<u>(8) 1948-1966 (TABLES 3.29-3.32)</u>

We have broken the post-war period into two parts, with the break coinciding with the year 1966, at the end of which the structural shift is supposed to occur. The first thing which strikes one about all the

1948-1966 N=19 INFLATION PROXY=PEDOT TABLE 3.29

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,14)	DW	RHO	SER
1)	14.65		-15.14		18.82	0.07	-1.13	0.16	1.81	2.13		2.49
(.1)	(1.69)		(0.97)		(1.21)	(2.20)	(0.88)					
2)	-14.93	5.10	18.44			0.06	0.05	0.08	1.34	2.07		2.61
(.9)	(0.57)	(0.69)	(0.81)			(1.77)	(0.13)					
3)	12.48		-13.49		17.78	0.07	-0.71	0.18	1.83	1.88	-0.09	2.54
(.1)	(1.31)		(0.83)		(1.10)	(2.27)	(0.49)					
4)	-17.23	5.61	20.77			0.07	0.03	0.14	1.58	1.88	-0.07	2.61
(.5)	(0.05)	(0.78)	(0.90)			(2.14)	(0.06)					
17)	9.74		-13.32		15.15	0.05	0.26	0.13	1.69	2.09		2.52
(0)	(0.48)		(0.64)			(1.92)	(0.67)					
18)	-12.61	4.54	14.77			0.05	0.28	0.10	1.50	2.09		2.56
(0)	(0.48)	(0.62)	(0.64)			(1.88)	(0.69)					
19-20)	9.25		-12.08		15.24	0.07	0.17	0.19	1.80	1.93	-0.07	2.55
(0)	(1.30)		(0.76)		(0.97)	(2.05)	(0.42)					

1948-1966 N=19 INFLATION PROXY=PFEDOT TABLE 3.30

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,14)	DW	RHO	SER
5)	18.69		-45.37	40.41		0.06	-0.42	0.11	1.61	2.10		2.53
(.1)	(1.35)		(1.01)	(1.08)		(2.07)	(0.65)					
6)	-14.27	4.95	17.82			0.06	0.04	0.08	1.35	2.07		2.60
(.9)	(0.54)	(0.67)	(0.77)			(1.89)	(0.20)					
7)	8.92		-10.89		15.10	0.07	0.06	0.17	1.77	1.90	-0.07	2.56
(.9)	(1.23)		(0.69)		(0.95)	(2.18)	(0.37)					
8)	-16.11	5.29	19.41			0.07	0.08	0.14	1.63	1.89	-0.07	2.59
(.5)	(0.61)	(0.71)	(0.84)			(2.20)	(0.36)					
21-22)	-13.43	4.77	15.17			0.06	0.33	0.11	1.59	2.09		2.54
(0)	(0.52)	(0.66)	(0.67)			(1.92)	(0.87)					
23-24)	-15.95	5.32	18.26			0.07	0.22	0.16	1.70	1.93	-0.07	2.57
(0)	(0.61)	(0.73)	(0.79)			(2.06)	(0.57)					

1948-1966 N=129 INFLATION PROXY=PCHPE TABLE 3.31

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,14)	DW	RHO	SER
9)	13.97		-14.63		18.04	0.07	-1.02	0.17	1.85	2.13		2.48
(.1)	(1.74)		(0.95)		(1.17)	(2.22)						
10)	15.74		-37.24	32.96		0.06	-0.15	0.11	1.55	2.02		2.55
(.9)	(1.21)		(0.85)	(0.91)		(2.02)	(0.49)					
11)	12.15		-13.28		17.34	0.07	-0.65	0.18	1.84	1.89	-0.08	2.54
(.1)	(1.36)		(0.82)		(1.09)	(2.24)	(0.52)					
12)	17.06	5.63	20.82			0.07	-0.03	0.14	1.59	1.88	-0.07	2.61
(.5)	(0.64)	(0.76)	(0.91)			(0.91)	(0.07)					
25-26)	9.77		-13.12		15.96	0.07	0.17	0.18	1.82	1.93	-0.08	2.55
(+1)	(1.37)		(0.81)		(1.02)	(2.25)	(0.47)					

1948-1966 N=19 INFLATION PROXY=WEDOT TABLE 3.32

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4,14)	DW	RHO	SER
13)	39.77		-26.49		26.99	0.06	-4.64	0.47	4.10	1.83		2.08
(.1)	(3.18)		(1.91)		(2.01)	(2.56)	(2.67)					
14	-21.24	7.36	24.19			0.06	-0.17	0.09	1.44	1.85		2.58
(.9)	(0.75)	(0.89)	(0.98)			(1.98)	(0.57)					
15)	41.75		-26.00		26.10	0.06	-5.08	0.46	3.87	1.83	0.13	2.15
(.1)	(2.93)		(1.82)		(1.90)	(2.22)	(2.49)					
16)	17.46		-24.29		26.07	0.08	-0.41	0.23	2.22	1.80	0.20	2.45
(.9)	(2.04)		(1.43)		(1.61)	(2.51)	(1.49)					
29)	13.43		-18.03		20.91	0.06	-0.15	0.13	1.65	1.84		2.53
(-1)	(1.49)		(0.99)		(1.20)	(2.06)	(0.59)					
30)	11.06		-15.35		18.40	0.06	0.07	0.11	1.55	2.15		2.55
(+1)	(1.37)		(0.80)		(1.03)	(1.98)	(0.25)					
31)	-31.97	10.72	33.49			0.08	-0.35	0.19	1.90	1.78	0.17	2.53
(-1)	(1.15)	(1.32)	(1.37)			(2.47)	(1.28)					
32)	4.69	0.83	-4.65			0.12	0.38	0.64	1.45	1.71	0.27	3.34
(+1)	(0.68)	(0.74)	(0.55)			(3.12)	(2.93)					

equations in this sample is the very low adjusted coefficient of determination--very low-not simply with respect to the entire 1948 to 1979 period, but also much lower than that achieved for the Phillips-Lipsey post-war sample. This suggests that it is the years 1959 to 1966 which cause problems for the Phillips curve. None of the F statistics for the equations selected for this period are significant at the 5 percent level. Surprisingly, however, the Durbin Watson statistics show a marked improvement over the previous periods.

The coefficients on the explanatory variables are also peculiar for these equations. The excess demand variables, the Us, and the inflation proxies have statistically insignificant coefficients, whereas the U term, which is always positive, achieves statistical significance for most of the equations.

The above pattern is consistent across the three price proxies and again we can find no evidence for preferring PF^e or $PCHP^e$ to P^e. In particular we note that there is no evidence that the increased coverage of inflation by the media in the post-war period--with its emphasis on the percentage change in the price level--has led to households using $PCHP^e$ to form inflation expectations.

The W^e results follow the pattern of the other proxies. The only equations which exhibit significantly superior fits compared with P^e are numbers 13, 15 and 32, but each of these equations would have to be discarded either because of unrealistic alpha coefficients or, in the case of equation 32, because it corresponds to the W_{t+1} formulation which works for quite spurious reasons.

What is so curious about these results, which correspond to those reported in Sleeman (1983), is that it would appear that just at the time when the Phillips curve was sweeping the field in macroeconomics it was also becoming less well established empirically--at least as far as the annual data is concerned. We also note that the results for the whole post-World War Two period in conjunction with those just discussed suggest that the Phillips curve is not temporally stable between 1948 and 1979, and that some sort of break in behaviour occurred between 1958 and 1966.

(9) 1967-1979 (TABLES 3.33-3.36)

This is the period for which we would expect to find strong evidence for the Acceleration Hypothesis since there seemed to be a systematic upwards trend in the inflation rate, and in which we might expect the Adaptive Expectations Hypothesis to be overthrown as its predictions develope larger and larger errors because of the trend in the inflation rate.

Turning to Table 3.33 which contains the results for the P^e proxy we first of all note that it is the naive proxy (with zero lag) that generates the best results. Equations 17 and 18 have Durbin Watson statistics close to the upper bound of the indeterminate region (and the Durbin Watson statistic does not show any marked improvement after the application of the CORC transform--see equations 19 and 20). Close to 90 percent of the variation of $\dot{W}$ is explained by the independent variables which are well determined except for the insigificant U variable (which would be retained in the equation using the standard

1967-1979 N=13 INFLATION PROXY=PEDOT TABLE 3.33

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 8)	DW	RHO	SER
1)	-73.34		283.51		-1954.10	0.01	4.60	0.96	99.35	2.56		0.91
(.1)	(13.64)		(17.12)		(17.21)	(0.52)	(13.53)					
2)	-24.36		145.04		-1191.29	-0.01	0.93	0.54	4.37	1.10		3.62
(.6)	(1.99)		(3.21)		(2.97)	(0.10)	(2.00)					
3)	-115.09		663.55	-1009.48		-0.01	5.17	0.97	196.30	2.35	-0.77	0.59
(.1)	(37.19)		(42.62)	(41.58)		(1.23)	(32.91)					
4)	-8.43		-190.74		-1327.95	0.05	0.35	0.88	20.99	1.93	0.94	1.74
(.3)	(0.36)		(3.30)		(3.30)	(1.23)	(0.42)					
17)	-11.61		79.42		-710.48	-0.04	0.93	0.89	25.20	1.90		1.75
(0)	(3.00)		(3.85)		(3.39)	(1.08)	(6.58)					
18)	45.03	-5.44	-72.61			-0.06	0.99	0.87	19.58	1.94		1.97
(0)	(2.57)	(2.73)	(2.27)			(1.26)	(6.54)					
19)	-14.58		344.02	-525.03		0.09	0.16	0.92	35.82	1.60	0.94	1.35
(+1)	(1.47)		(5.26)	(4.84)		(2.97)	(1.85)					
20)	-12.83		-84.47		-769.46	-0.05	0.96	0.88	17.11	1.95	0.02	1.81
(0)	(2.91)		(3.72)		(3.72)	(1.22)	(6.11)					

1967-1979 N=13 INFLATION PROXY=PFEDOT TABLE 3.34

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 8)	DW	RHO	SER
5)	-100.46		616.82	-951.00		-0.01	3.71	0.96	95.63	2.29		0.92
(.1)	(15.22)		(17.07)	(16.59)		(0.56)	(13.99)					
6)	-49.63		375.69	-608.00		-0.01	1.02	0.65	6.16	1.08		3.20
(.4)	(3.26)		(3.73)	(3.49)		(0.08)	(3.01)					
7)	-100.79		619.02	-954.56		-0.02	3.71	0.96	72.23	1.88	-0.26	0.96
(.1)	(16.14)		(17.99)	(17.28)		(0.83)	(14.92)					
8)	-42.76		455.24	-692.45		0.04	0.81	0.91	28.32	2.20	0.94	1.51
(.2)	(1.78)		(4.63)	(4.36)		(1.21)	(1.19)					
21)	-11.51		78.71		-700.42	-0.04	0.93	0.89	24.95	1.93		1.76
(0)	(2.96)		(3.80)		(3.32)	(1.05)	(6.54)					
22)												
(0)												
23)	-12.64		83.37		-755.08	-0.05	0.96	0.87	18.81	1.96	0.01	1.83
(0)	(2.87)		(3.67)		(3.22)	(1.18)	(6.09)					
24)	45.51	-5.52	-73.87			-0.06	1.01	0.83	13.88	1.90	-0.00	2.09
(0)	(7.36)	(2.50)	(2.07)			(1.16)	(5.72)					

1967-1979 N=13 INFLATION PROXY=PCHPE TABLE 3.35

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 8)	DW	RHO	SER
9)	-122.77		726.85	-1102.29		0.03	4.13	0.96	92.61	2.05		0.94
(.2)	(15.12)		(17.23)	(17.15)		(1.80)	(18.77)					
10)	86.93	-10.94	-138.01			0.03	0.99	0.42	2.21	1.17		4.45
(.6)	(2.38)	(2.40)	(2.04)			(0.31)	(1.38)					
11)	-121.80		717.34	-1089.02		0.03	4.13	0.96	77.79	1.56	-0.36	0.93
(.2)	(18.13)		(20.64)	(20.30)		(1.97)	(16.43)					
12)	85.06										0.91	
(.6)												
25)	-11.82		-91.63		-813.60	-0.06	0.83	0.61	5.38	1.55		3.36
(0)	(1.54)		(2.33)		(1.98)	(0.68)	(2.43)					
26)	46.14	-5.44	69.50			-0.07	0.93	0.57	4.19	1.64		3.67
(0)	(1.33)	(1.42)	(1.09)			(0.81)	(2.56)					
27)	-17.08		372.88		-573.45	0.06	0.14	0.91	33.06	1.47	0.94	1.40
(+1)	(1.66)		(5.67)		(5.21)	(2.20)	(1.61)					
28)	95.39	-9.04	-81.64			0.07	0.17	0.94	27.32	1.81	0.93	1.54
(+1)	(5.63)	(4.61)	(3.05)			(2.27)	(1.71)					

1919-1938 N=20 INFLATION PROXY=PCHDE TABLE 3.36

EQU/ THETA	C	U	U^{-1}	U^{-2}	U^{-4}	$\dot{U}$	ALPHA	$\bar{R}^2$	F(4, 8)	DW	RHO	SER
13)	-60.44		222.98		-1565.37	0.01	3.39	0.92	36.77	1.70		1.47
(.1)	(8.06)		(10.16)		(9.34)	(0.16)	(8.07)					
14)	-13.69		99.15		-889.70	0.01	0.66	0.54	4.25	1.27		3.65
(.6)	(1.54)		(2.36)		(2.02)	(0.14)	(1.95)					
15)	-61.03		225.70		-1590.95	0.01	3.40	0.90	26.52	1.80	0.14	1.56
(.1)	(6.43)		(7.67)		(6.73)	(0.20)	(6.75)					
16)	-1.02		167.86		-1179.37	0.07					0.93	
(.6)	(0.10)		(4.66)		(3.85)	(1.83)						
29)	-7.64		75.49		-722.02	-0.01	0.56	0.50	3.98	1.41		3.74
(-1)	(0.94)		(1.61)		(1.44)	(0.07)	(1.81)					
30)	-1.17		56.36		-742.56	0.13	0.39	0.46	3.55	1.04		3.87
(+1)	(0.13)		(1.02)		(1.41)	(1.45)	(1.59)					
31-32)	97.13	-9.06	84.06			0.10	0.19	0.92	32.90	1.58	0.94	1.41
(+1)	(6.18)	(5.05)	(3.43)			(3.30)	(2.18)					

rule for maximising R^2). The alpha coefficients for these equations are indistinguishable from one.

However, the adaptive proxies perform considerably less well. In particular the estimated alphas are unacceptable--either too large or too small. These equations also exhibit "explosive" coefficients, a problem which was also present, although less marked, in the naive regression results. We conclude that yet again the Adaptive Expectations Hypothesis is not consistent with the data.

As usual there is little evidence to suggest that either $\dot{PF}^e$ or $\dot{PCHP}^e$ are better proxies for inflation anticipation than $\dot{P}^e$. Again the naive formulation, at least for $\dot{PF}^e$, seems to be superior. Finally the $\dot{W}^e$, Phelps formulation, does least well amongst the four specifications and yields unacceptable values for the alpha coefficients.

For this period the best proxy was undoubtedly $\dot{P}^e$. The estimates of the augmented Phillips curve obtained using this construct are consistent with the Acceleration Hypothesis, although the results do not indicate any support for the Adaptive Expectations Hypothesis.

In the final section of the paper we will summarise the results of our experiment and draw some general conclusions.

5. CONCLUSIONS

Let us first summarise the results of the empirical experiment. We conclude that the $\dot{P}^e$ proxy outperforms the other two price inflation proxies and is clearly superior to the $\dot{W}^e$ form. We could find no support for the view that households might be particularly sensitive to food prices or that, because they obtained their information about inflation from the media, they paid more attention to percentage price changes than to rates measured using first central proportional differences. We were also unable to find any strong support for the Adaptive Expectations Hypothesis. In most cases the naive proxy (in the unlagged form) gave the best fit and also the most acceptable alpha coefficients. We observed that the two criteria for assessing augmented Phillips curve regressions--goodness of fit and how close alpha was to one--seldom coincided. However, our results were usually either directly consistent with the Acceleration Hypothesis or, as in the pre-World War One case were interpretable in terms of that hypothesis and so there was little conflict between the criteria.

Perhaps the two most important points about our experiment were the evidence of serial correlation in the residuals. Given this serious statistical problem any conclusions drawn from the regressions must be regarded as extremely tentative.

Let us now briefly, since this is already a very long paper, mention some problems which need to be addressed in this area. First of all we wish to raise the issue of whether the fact that we have obtained alphas indistinguishable from one can really be regarded as satisfactory evidence in favour of the Acceleration Hypothesis. There are a number of factors which need to be taken into account when answering this query. One of which is concerned with the type of price index we, and most other researchers in this area, have adopted. This index is a consumer price index and it is not at all clear whether the range of commodities included or the weights attached to their prices are necessarily correct. If, for example, housing and oil are disproportionately represented in the index then rational individuals may not form their expectations of inflation with the index. Under these circumstances the fact that estimated alpha is indistinguishable from unity may not be a cause for congratulation. Further, as we have noted above, Sargent has argued that tests using lag schemes where the weights are constrained to unity yield downward biased coefficients--which suggest that if the estimated alpha equals one than the true alpha value may be larger than one. Finally we note that our use of annual data to generate the inflationary expectations proxies may cause problems if agents actually monitor inflation more frequently. It therefore seems desirable to repeat the various tests of the Acceleration Hypothesis using monthly data.

FOOTNOTES

[1]Hicks (1939) and Samuelson (1947). Samuelson's Nobel Prize was awarded specifically for his work on economic dynamics, and although Hicks' Nobel Prize singled out his contributions to general equilibrium and welfare economics his formulation of the adjustment mechanism was a major component of that research. Of course, earlier economists, such as Alfred Marshall and Leon Walras, had used similar techniques in their work. See, for example, the discussions in Newman (1961, 1965) and Arrow and Hahn (1971).

[2]Phillips (1954, 1956, 1957).

[3]See Lipsey (1979).

[4]Professor Solow, one of the first economists to do research on the Phillips curve says (in a letter to the author dated 11/1/82): "From the very beginning I regarded the Phillips curve as analogous to any price adjustment equation driven by excess supply or demand." Later in the same letter he writes "I have always thought of...the Phillips curve as a model of disequilibrium states with causality running from RHS to LHS."

[5]See Blythe (1979).

[6]Solow (1978, p. 206) remarks: "Deep down I wish Lucas and Sargent are right, because one thing I know how to do well is equilibrium economics." This equilibrium mental set has often, in the past, hampered economists such as Marshall and Keynes when they were attempting to grapple with real world problems which were intrinsically dynamic

(see, for example, Tobin's comments on Keynes' concept of under-employment equilibrium (Tobin (1972, p. 4)) and the concluding remarks in Sleeman (1982).

[7]The last two sentences of the first paragraph of Phillips' 1958 article provide an implicit bridge between the excess demand for labour and the level of unemployment (Phillips, 1958, p. 283)). Lipsey (1960, pp. 13-14) makes this assumption explicit and provides, in secton II.1 of his paperf (written jointly with Professor G. C. Archibald) a more elaborate specification of the connection between these variables.

[8]The author remembers Phillips spelling out the mechanisms of his mark-up theory during Phillips' lectures on macroeconomics given to the M.Sc. programme at the London School of Economics in the early 1960's.

[9]See Tobin and Ross (1971, p. 23), Rees (1970, p. 227), Friedman (1976, p. 221), and Friedman (1977, p. 454).

[10]Bowen and Berry (1962, p. 163) remark on the fact that in both the U.S. and the U.K. "the economics literature of recent years has been replete with discussion of the compatability of price level stability and high employment." The Phillips curve undoubtedly struck most economists as a providential tool to refocus the discussion of this issue.

[11]Lipsey (1960. But see Sleeman (1983) who argues that the evidence produced by Phillips and Lipsey was perhaps less compelling than most contemporary readers seem to think. Bowen and Berry (163, p. 170) seem to have had similar doubts somewhat earlier since they observe "we suspect that a number of persons in the United States have a misimpression concerning the tightness of the relationship that has been

found between unemployment conditions and the rate of change of money wages in the United Kingdom."

Friedman (in a letter to the author dated 10/22/1982) notes that he "thought of the original curve simply as a mistake, an erroneous statistical relationship...."

[12]See Lipsey (1965), Brechling (1968), Rees (1970), Tobin and Ross (1971). Tobin (1972, n. 2, p.4) notes that "Phillips himself is not a prophet of the doctrine associated with his curve. His 1958 article was probably the most influential macro-economic paper of the last quarter century. But Phillips simply presented some striking empirical findings, which others have replicated many times for many economies. He is not responsible for the theories and policy conclusions his findings stimulated." Indeed Phillips eschews policy discussion until the last page of his paper where he uses his fitted curve to estimate the levels of unemployment which would be consistent with zero wage and price inflation (i.e. natural rate estimates). In his penultimate paragraph, however, he might be interpreted as advocating keeping unemployment constant rather than allowing it to fluctuate "because of the strong curvature of the fitted relation in the region of low percentage employment" (1958, p. 299, emphasis added) would mean a lower average rate of wage inflation in the former case.

Lipsey's 1960 paper also seems to be free of the trade-off interpretation.

[13]Friedman (1976, p. 232) says, correctly in our view, that "there is essentially no economist any longer who believes in the naive Phillips curve of the kind originally proposed."

[14]Friedman, in the letter already referred to in n.11 above, argues that Phillips' statistical relationship "held up as long as it did because it was calculated for a period during which the price level was relatively stable and hence there was a high correlation between changes in nominal wages and changes in real wages."

[15]It seems very likely that this is in fact the longest Phillips curve sample which is available for any country.

[16]Phelps (1967, 1968) and Friedman (1968).

[17]While one may sympathise with Friedman's desire to bring out the analogy between his concept and Wicksell's the epithet "natural" does have unfortunate connotations of desirability. Just as one hesitates to embrace irrationality so one also would be reluctant to espouse unnatural unemployment levels.

[18]Friedman (1968, p. 8).

[19]Friedman (1968, p. 9) lists some of those factors which are relevant for the United States. This list includes: legal minimum wage rates, the Walsh-Healy and Davis-Bacon Acts, and the strength of labour unions, improvements in employment exchanges and in availability of information about job vacancies and labour supply. In his Nobel Lecture Friedman adds two further items to the list--the composition of the labour force, especially the proportions of part-time, female and young workers, and "unemployment insurance and other forms of assistance to unemployed persons" (both with respect to the amount and duration of such payments) (Friedman (1977, p. 458)).

Of course, armed with such a list and appropriate data it is possible to use regression analysis to attempt to attach a specific figure to the natural rate, but we would not be excessively sanguine about the uniqueness of the estimates which different researchers might obtain.

[20]In his 1974 London lectures Friedman seems to identify the natural rate with the level of frictional unemployment. He writes (referring to the point of intersection of conventional demand and supply curves in employment/real-wage space): "Unemployment is zero--which is to say, as measured, equal to 'frictional' or 'transitional' unemployment" (Friedman (1976, p. 2176)). But a number of the items listed in the previous footnote, e.g. minimum wage laws and the demographic composition of the labour force, would usually be categorised as structural unemployment components. Perhaps all this indicates is the general lack of precision and exclusivity in economists' unemployment classifications. Pursuing the terminology into an essentialist labyrinth is not likely to be very fruitful.

[21]Non-monetarists are perhaps less convinced as we will see below. Professor Solow, however, asserts that "nobody believes the deflationary half of the proposition. I don't know anybody who would even lie out in the sun, let alone be burned at the stake, for the belief that if the unemployment rate is U* (which is Solow's notation for the natural rate) plus epsilon and we wait long enough, there would be accelerating deflation. That part no one believes" (Solow (1978, p. 207)). This may, however, tell us more about the sophistication of Solow's circle of acquaintances, or the strength of Solow's own convictions, than it does about the prevalence of this belief amongst economists at large.

[22]Friedman is, of course, referring to a diagram like Figure 1A,

but in which the demand and supply functions are _not_ functions of expected prices.

[23]In a letter to the author (undated, but received early in November 1982) Professor Phelps describes the development of his research as follows: "As you know my first try at formulating the disequilibrium process tacked on $\dot{p}^e$ to the Phillips term $\phi(u)$, hence $\dot{p} = \phi(u) + \dot{p}^e$. I wrote this up between January and April 1966 at LSE, later published in _Economica_. That summer, in Cambridge, I tried to rethink the thing in terms of wages along the lines of $\dot{w} = \phi(u) + \dot{p}^e$. But I knew that was not right either. It implied a different rate, u*, for each different productivity growth rate($\lambda \equiv \dot{w} - \dot{p}$). More important, why should the individual firm pay a higher wage just because it expects a higher CPI or because it believes its employees expect a higher CPI--what matters is their alternatives, hence $\dot{w}^e$. This last formulation, $\phi(u, \dot{u}) + \dot{w}^e$, was "born" at Penn in the fall of 1966. I'm sure it must be in the Feb. 1967 discussion paper you mentioned. This was reworked for the Aug. 1967 AEA Conference at Montauk Ft. L.I....the proceedings of which were published, Aug. 1968 in the JPE supplement. As you know the 1970 version in the "Macroeconomic Foundation" volume is a slight reworking." We will actually refer to the final, 1970, version of Phelps paper which, as he notes, contains some reworking of the 1968 material.

[24]Rees (1970, p. 233) notes "that in the great majority of labour markets, employers take the initiative. The employer quotes the wage, which the job seeker accepts or rejects. The employer, except in a few cases where he hires through unions, sets hiring standards...it is

employer expectations which are crucial to expectations theory."

[25]By static expectations Phelps means that "each firm expects other firms to pay the same wage on average over the future that was known (or believed) to have been paid in the recent past" (1970, p. 153).

[26]Tobin (1968). It was at this conference that Solow presented his initial empirical work on the Acceleration Hypothesis (Solow (1968)). In what follows we have modified Tobin's notation to make it consistent with the remainder of our paper. Tobin provided a rather more elaborate version of his model in his overview paper for the Econometrics of Price Determination Conference organized by the Federal Reserve in October, 1970 (see Tobin (1972)), but the earlier paper is quite sufficient for our purposes. Another early, and very clear, exposition of the analytics of the Acceleration Hypothesis can be found in Smith (1970).

[27]Tobin includes the rate of change of the marginal productivity of labour in his wage inflation equation but we have dropped that term. This does not lead to any major modification of the results.

[28]Laidler (1971, p.83 and 1976, p. 60) has stressed that the Phillips curve trade-off only vanishes if inflation is perfectly anticipated and that the real world may lack the nice properties of our theoretical models.

[29]See, for example, Archibald (1974, p. 121).

[30]See Alt (1979 and Formby (1982). It would appear that large sums of money are spent constructing, and purchasing, forecasts for various rates of change of price indexes and that the track record of such forecasts is far from perfect. This is difficult to reconcile with the

view that the economy is in, or approaches closely, a natural rate long-run equilibrium position.

[31]There may also be an implicit assumption that given sufficient time, we can always ultimately learn how to forecast a process in which we are interested (or, perhaps, at least we can pass our knowledge on to future generations who can in turn pass our accumulated wisdom to posterity). This seems unobjectionable, although not necessarily of great interest to those of us who are not banking on much more than three score years and ten, but it assumes that the process we are studying is not itself evolving or, at least is evolving only in a predictable fashion--and so on, ad infinitum.

[32]See Flemming (1976, Ch. 7 and Appendix).

[33]See Arrow and Hahn (1977). Hahn (1965, 1971, 1973, 1973a, 1977, 1980).

[34]Hahn (1982).

[35]Friedman in his earlier writings seems to have had a healthy skepticism towards the claims of the Walrasian general equilibrium formulation of economics which was so fashionable amongst mathematicians in the 1950's.

[36]Phillips in fact seems to have conceived of the labour sector of the economy, and of the economy itself, as a set of interconnected sub-markets (see Lipsey (1979, p. 49)) and presumably used the single macro labour market scheme as a model for determining the final state which would result from the reconciliation of all the complex interrelationships which such a system implies. His macro labour market is then, in some sense, a reduced-form akin to Marshall's "representative firm."

When Lipsey and Archibald set about the task of formalising Phillips' theory they did so in terms of such such a multi-market system. Similarly, when Tobin described his view of the theoretical underpinnings of the Phillips curve (Tobin (1972, Section IV, pp. 9-13)) he did so in terms of a stochastic, disequilibrium, multi-market model. None of these authors, however, provide a detailed algebraic presentation of their theory. For such a presentation one needs to consult the strnagely neglected paper by Baumol in the Phillips memorial volume (Baumol (1979)).

[37]Tobin and Ross (1971) got themselves into some difficulties by being rather vague about this issue. See the exchange with Tullock in the Journal of Money, Credit and Banking (Tullock (1972, 1973) and Tobin and Ross (1971, 1972).

[38]See Rees (1970, p. 270).

[39]Smith (1970, p. 776) observes that "This view (the Acceleration Hypothesis) bears a marked family resemblance to the classical theory. It suggests that economy policy cannot affect the unemployment rate, except temporarily, and that, therefore, monetary policy should be directed at attaining a suitable behaviour of the price level" (Parenthesis added). Friedman (1966, p. 92) makes the following policy recommendation in the "Newsweek" column which contained his first formulation of the Acceleration Hypothesis: "The right policy...is to let the quantity of money increase at a rate that can be maintained indefinitely without inflation...and to keep taxes and spending at levels that will balance the budget at high employment." The whole of section 2 of Tobin's presidential address is devoted to an analysis of

"Keynesian and Classical Interpretation of Unemployment" (Tobin (1972, pp. 2-5)).

[40]The new classical economics, sparked, at least in part, by the so-called Rational Expectations Revolution, is the latest manifestation of this approach. Tobin seems to be the leading opponent of this view in the United States. In the United Kingdom there appears to have been greater resistance to the classical approach. References to the contemporary debate can be found in Sleeman (1982).

[41]Tobin and Ross (1972, p. 432) argue that Tullock uses the abstract arguments of the Acceleration/Natural Rate Hypotheses to draw inappropriate policy inferences concerning concrete real world situations, and that his opposition to expansionary policies in the U.S. in 1971 on these grounds involved the same logic that "led his intellectual predecessors to oppose expansionary measures in 1931-1933."

[42]Friedman (1966, p. 60) says "For any given labour market structure, there is some level of unemployment at which real wages would have a tendency to behave in accordance with productivity." This is, of course, the definition which was derived from our previous algebraic exercise. Friedman (1968, p. 8, n. 3) observes that the "natural rate need not correspond to equality between the number unemployed and the number of job vacancies." Later in the same paper (loc. cit., p. 10) he argues that "the monetary authorities...cannot know what the 'natural' rate is. Unfortunately, we have as yet devised no method to estimate accurately and readily the natural rate of...unemployment." In his London lectures Friedman (1976, p. 218) also defines U^N as the unemployment level corresponding to real wages rising with the "rate of

productivity growth," i.e., $\dot{W} - \dot{P} = \dot{\rho}$. While (loc. cit., p. 228) he later comments that the natural rate "does not correspond to some irreducible minimum of unemployment. It refers rather to that rate of unemployment which is consistent with the existing real conditions in the labor market" (Emphasis in the original). Finally in his Nobel lecture, after enumerating a number of factors--"the effectiveness of the labor market, the extent of competition or monopoly, the barriers on encouragements to working in various occupations, and so on"--which determine the natural rate, and briefly discussing why he feels that U^N had been increasing in the U.S., he exhorts us to do more research on the topic (1977, p. 458).

[43]See the references in the previous footnote, and Laidler (1976, pp. 59-60).

[44]Of course Friedman is an opponent of fine tuning believing that a free enterprise economy is essentially self regulating and that the proper course of economic policy is to pursue an appropriate monetary rule. He was at pains in his "The Role of Monetary Policy" address to remind his audience that "even if the monetary authority knew the 'natural' rate, and attempted to peg the market rate at that level, it would not be led to a determinate policy. The 'market' rate will vary from the natural rate for all sorts of reasons other than monetary policy. If the monetary authority responds to these variations, it will set in train longer term effects tht will make any monetary growth path it follows ultimately consistent with the rule of policy. The actual course of monetary policy will be analagous to a random walk, buffeted this way and that by the forces that produce temporary departures of the

market rate from the natural rate" (Friedman, 1968, pp. 10-11)).

[45]In his A.E.A. address he says "Phillips' analysis of the relation between unemployment and wage change is deservedly celebrated as an important and original contribution" (Friedman (1968, p. 8)) while in his London lectures (Friedman (1976, p. 219)) he comments that Phillips "was certainly a highly sophisticated and subtle economist."

[46]Friedman (1968, p. 8; 1976, pp. 218-219; 1977, p. 455).

[47]In his Nobel lecture (Friedman (177, p. 455) Friedman says "Some of us were skeptical from the outset about the validity of a stable Phillips curve, primarily, on theoretical rather than empirical grounds" and in his letter to the author (after due allowance for imperfections of his memory) he observes "the mis-specification was immediately obvious to me. I say this very definitely because I recall having a long conversation with Bill Phillips about this question though I cannot date it except that I am almost certain it occurred after the article had appeared. That means it must have occurred on a subsequent trip which I made to Great Britain. In that conversation I remember pointing out to Bill that his argument should have been stated in terms of real wages and not nominal wages. My recollection also is that he was persuaded that that was the case though I do not know that he ever stated so in print. Under the circumstances I suspect, though here again I cannot say so definitely, that I interpreted the Phillips/Lipsey inflation term as an attempt to go from nominal wages to real wages. That means that it reflected neither inflationary expectations nor the simultaneity problem."

What is interesting about this quotation is the ambiguity remains cncerning the distinction between actual and expected real wages. It is also interesting to contemplate what would have happened if "truth" about the Acceleration Hypothesis had been "revealed" in the early or mid-1960's. If, as has sometimes been claimed, the present difficulties of the world economy are attributable to the failure of economists and politicians to grasp the import of expectations it is surely odd that those in the know did not disabuse us of our delusions earlier (See Sleeman (1983) for a brief discussion and references.)

Professor Solow's recollections (see n. 4 above) will also be of interest to macro economists. He also first reminds us that his "reconstruction of (his) mental processes of a time more than 20 years ago may be affected by hindsight" and then continues: "I think a reading of our (i.e. Samuelson and Solow's) AEA paper (which started off by worrying about cost-push vs. demand-pull) will suggest that we already realized that both past and expected future price movements could have an influence on wage behavior. We thought, and I still think, that the distinction is very hard to disentangle in practice. So I certainly did not and do not regard the Phillips formulation as a clear mis-specification, and I still think it is an open question whether expectation or inertia plays a greater role. When I turned to empirical work it was not so much that question that I was addressing as the slope of the long-run Phillips curve. On the expectations version, I suppose its bound to be vertical; on the inertia version it could be almost anything in the medium run. I think my Manchester lectures (I no longer have a copy) say that it 'must' be vertical in some ultimate long-run sense, but question whether that has any real-time meaning. I phrased all that in terms of expectations simply in reference to Friedman. I haven't the vaguest idea whether I had then read Phelps' paper. It's possible; we knew each other from Golden Rule days, but I have no recollection. (This response may be affected by self-serving hindsight. It rings true to me because I am _still_ quite uncertain about the expectations-augmented natural-rate verion of he Phillips curve.)" (Emphasis in original.)

[48]Keynes (1936, pp. 9, 14, 15). The relevant passages are quoted in Friedman (1976, p. 220, n. 7).

[49]See Tobin (1972, p. 3) and Tobin and Ross (1972, pp. 433-434).

[50]Tobin and Ross (1972, p. 433) "These asymmetries of the adjustment process seem to us facts of common observation. They do not betray any permanent or fundamental money illusion and they are entirely consistent with the propositions stated above regarding the invariance of long-run equilibrium to proportional variations of monetary parameters." Tobin (1967, pp. 103-4) also contains an excellent discussion of the relativities argument.

As to wage rigidity being a widely observed phenomenon Rees (1970, p. 234) argues that "wages are, next to house rents, the stickiest general class of prices in the economy, seldom adjusted more frequently than once a year. This stickiness may be reinforced by unionisation and collective bargaining, but it was present long before unions arrived."

[51]Tobin and Ross (1972, p. 433). See also Tobin (1972, p. 3), Trevithick (1977, pp. 53-4), Solow (1978, p. 208), Solow (1980), Worswick (1976), Hawkins (1979, p. 72). See also Webb and Webb (1926, pp. 693-4 and 696-7) quoted in Tarling and Wilkinson (1982, p. 22).

[52]Phillips (1958, p. 295), when discussing the deflationary policy which accompanied the return to the Gold Standard in 1925, argued that the predictions from his estimated wage equation (using 1861 to 1913 data) accounted for the actual behaviour of money wage rates quite well. He says "Thus the evidence does not support the view, which is sometimes expressed that the policy of forcing the price level down failed because of an increased resistance to downward movements of real wages." (Emphasis added). (See also Henneberry (1980)) for a discussion of this isue.)

[53]We have two characterisations of the same empirical magnitude. Classical economists refer to the gap $N_o^s - N_o$ as "voluntary" unemployment believing that the failure of nominal wages to adjust is the result of workers not wishing to cut real wages. Keynesians call the same gap, $N_o^s - N_o$, "involuntary" unemployment on the grounds that workers would accept a general cut in real wages but would, quite rationally, resist cuts in nominal wages of an equivalent magnitude on the grounds that they would disturb relativities. (What is optimal for labour as a whole is not optimal for any individual group of workers. Allowing your fellow workers to restore full employment by cutting their wages relative to yours is always strategically superior to cutting your wages and hoping they will magnaminously cut theirs in turn.) Notice that, whichever interpretation is adopted, part of the $N_o^s - N_o$ gap is accounted for by some workers (their number equal to $N_o^s - N_e$ but, unfortunately, their membership is indistinguishable from the other unemployed) being attracted into the labour force by the real wage $(\bar{W}/P_o^e)$. This part of the unemployment gap is presumably not a social problem on

either interpretation. Tobin and Ross (1972, p. 433) highlight the difference between the two approaches when they point out that "Evidently Mr. Tullock believes it (the 6 percent U.S. unemployment rate) is voluntary....Why does he believe it is voluntary? Presumably because of the failure of money wage rates to decline or to rise less rapidly. We find this criterion to be tautological. It does not prove that all of the unemployment compatible with zero inflation is voluntary; it just defines it so." They then proceed to propose a definition of involuntary unemployment which is equivalent to that of Keynes but in terms of the path of the rate of change of real wages ($\dot{W} - \dot{P}$) rather than the level of the real wage (W/P). (Loc. cit., p. 434.) They also point to a number of characteristics of unemployment at the 6 percent level which suggest that it is involuntary.

[54]Hicks (1975) has called this "real-wage resistance." Such a state of affairs may be the consequence of the role of unions in the British labour market. The phenomenon is also consistent with the fact that most researchers using quarterly data for the construction of wage equations for the U.K. post 1960 find that some form of target net real wage specification usually outperforms the augmented Phillips curve model. See the surveys by Henry (1983) and Dawson (1982).

[55]In our opinion one of the most puzzling aspects of the Phillips curve literature is the comparative neglect of the flatness of Phillips' and Lipsey's estimated U.K. curves at high unemployment levels.

[56]It is possible, of course, that the flatness of the Phillips curve is a uniquely British phenomenon. Our, somewhat cursory, acquaintance with the literature for the U.S. does not bear this out.

One problem with interpreting the evidence on this issue is that most of it refers to samples during which the unemployment level has been well below 10 percent and as a consequence the highly nonlinear shape we are assuming may not be readily apparent.

[57]One of the more curious aspects of the Accelerationist debate is why its policy prescriptions are necessary at all. If the economy is at U^N, and if expectations are realised, and if U^N is the social optimum, why then is there agitation from the unemployed for expansionary policies?

[58]The remarkable speed with which the Acceleration Hypothesis was put to the test is probably accountable by the fact that, as we have seen, Friedman had used the idea in his comments on Solow's Guidelines paper and that Cagan is, of course, a long standing associate and friend of Friedman.

[59]Using the figures reported on p. 23 of Solow's monograph we obtain a t-value of 0.19 for the test of the null hypothesis that alpha = 1. With 35 degrees of freedom we cannot reject the null on the basis of these sample data.

[60]Friedman's criticism is repeated in Friedman and Schwartz (1982, p. 446, n. 29).

[61]Crossley argues that Solow's quarterly experiments are also at fault because his geometrically declining weights only decline geometrically after the third quarter (Crossley, 1971, p. 96).

[62]See Reid (1979), Henry (1974), and Desai (1981).

[63]If the true alpha is not constant (as opposed to our <u>estimates</u> improving over time) then this fact should be taken into account in the

estimation procedure. See Kirby (1981), Raj and Ullah (1981), and Parrikh and Raj (1979).

[64]Friedman has raised a fundamental objection to all of these attempts at testing the Acceleration Hypothesis by estimating that the value of alpha in wage or price inflation equations incorporating an expected inflation term. He writes: "A somewhat more subtle statistical problem...is that, if the acceleration hypothesis is correct, the results are either estimates of a short-run curve or are statistically unstable. Suppose the true value of alpha is unity. Then when current inflation equals anticipated inflation, which is the definition of a long-run curve, we have

$$f(U) = -a. \qquad (4)$$

This is the vertical long-run Phillips curve with the value of U that satisfies it being the natural rate of unemployment. Any other values of U reflect either short-term equilibrium positions or a stochastic component in the natural rate. But the estimation process used, with $1/P \frac{dP}{dt}$ on the left-hand side, treats different observed rates of unemployment as if they were exogenous, as if they could persist indefinitely. There is simply no way of deriving equation 4 from such an approach. In effect, the implicit assumption that unemployment can take different values begs the whole question raised by the accelerationist hypothesis" (Friedman (1976, p. 229)). Friedman suggests running U as the dependent variable. A number of studies have used this approach--see, for example, Peel and Sherrif (1976) for test using U.K. data. However, this simple re-arrangement of the causation of the equation does not come to grips with the issue of whether expectations are in fact realised. Friedman's position seems to deny the possibility of obtaining correct estimates except in long-run equilibrium.

[65]Santomero and Seater (1978, p. 25). See also Flemming (1976, p. 58 and pp. 67-68) and Friendman (1976, p. 229).

[66]It is worth noting that the augmented Phillips curve equation raises important estimation problems because <u>all</u> of the right hand side variables are proxy terms, and, of course, the dependent variable is undoubtedly subject to measurement error (both because it is a transformation of a far from perfect index number, and because the transformation itself involves a discrete approximation to a continuous rate of change). Unemployment is a proxy for the unobservable excess demand for labour, the rate of change of unemployment is a proxy for the unobservable rate of change of excess demand, and P^e is a proxy for the unobservable inflationary expectations term. Under these circumstances it would appear that we should use an errors in variables formulation. To our knowledge only Parrikh and Allen (1982) have utilized this estimation technique in the context of the Phillips curve.

[67]Friedman (1976, p. 220) observes that: "Science is possible only because at any one time there is a body of conventions or views or ideas that are taken for granted and on which scientists build. If each individual writer were to go back and question all the premises that underlie what he is doing, nobody would ever get anywhere." While methodologists and philosophers of science will no doubt object to this conventionalist approach, the research worker will readily grasp at this straw as a way out of this dilemma.

[68]See Lakatos (1978, pp. 48-49).

[69]See also Johnson's comments in his well known survey articles (Johnson (1962) and (1970, p. 114)). As we saw above one of the major objections to Keynes rigid wage doctrine was that it violated rationality which has always been associated with zero degree homogeneity of demand and supply functions with respect to the set of all relative prices. The introduction to Solow's lectures (Solow (1970, pp. 2-3) strongly suggests that he would not reject the absence of money illusion assumption on general grounds.

[70]See Wilton (1980, p. 46).

[71]See Phillips (1958, pp. 285, 291, 299).

[72]Dicks-Mireaux and Dow refer to the hypothesis in Dow (1956) that "full compensation for price increases is something which trade unions aim at and which both sides to wage negotiations accept as a standard of reference...." (Dicks-Mireaux and Dow (1959, p. 145, para. 38)). They note that they were forced by their own research to drop the one-to-one assumption. Champernowne (1959, p. 175) expressed grave doubts concerning the less than unit elasticity of wage-movement with respect to price movement result and argued that "the long-term elasticity...should be nearer unity than one half."

[73]Also note that Phillips and Lipsey were fully aware of the need to take account of the feed-back from prices to wages in their wage inflation equation. See Sleeman (1983) and Lipsey (1963, Appendix). The innovations associated with the Acceleration Hypothesis, therefore consisted of the distinction between actual and expected prices, and the emphasis on the long-run, steady-state solution of the model. Even this latter point seems to be quite explicit in Lipsey's (1963) exposition.

The evidence up to the early 1970's, however, consistently pointed to alpha coefficients of about one-half, which was not consistent with an explosive process and indeed suggested a long run relationship between price and wage changes of about two. Lipsey's "Banker" article (Lipsey (1961)) and his piece in the Lloyd's Bank Review (Lipsey (1960a)) were popular expositions apparently designed to combat the view that any positive level of inflation must inevitably lead to hyperinflation.

[74]Also notice that, as we have already observed above, the concept of expectations being realised in the "long-run" seems to logically entail the absence of money-illusion. Why would economic agents wish to generate accurate inflation forecasts and then fail to incorporate them into their calculations and decisions? Surely empirical observations of alpha less than one are more likely to be the failure of forecasts to hit the target in a world in which the target is moving erratically, than indications of a failure to appreciate the need for such forecasts.

[75]There is, of course, an extensive literature on expectations theories in economics. Good surveys with extensive, up-to-date, bibliographies may be found in Chan-Lee (1982), Hudson (1982, Ch. 3) and Begg (1982). Santomero and Seater (1978) also contains a good discussion, and Laidler (1976), although somewhat older, is still worth consulting.

On the purely statistical approach to forecasting, and hence to the construction of expectational proxies, there are also a number of good surveys. Pindyck and Rubinfeld (1982, Ch. 15) provides a convenient list of formulas in a very brief compass, while the books by Makridakis and Wheelwright (1978) and Wheelwright and Makridakis (1977) have extensive lists of references to the major techniques.

[76]As is well known, Irving Fisher was a student of expectations as a consequence of his work on interest rates at the turn of the century (see Friedman (1976)). Cagan (1956) formulated a theory of expectations formation in conjunction with his study of hyperinflations. It is nonetheless true that theories of expectations formation have only received extensive notice in the last fifteen years and that relative to the absence of money illusion postulate they are definitely "Johnnies Come Lately" in economics.

[77]See Saunders and Nobay (1972).

[78]We have seen that according to the Adaptive Expectations Hypothesis

$$\dot{P}_t = \theta \dot{P}_{t-1} + (1-\theta)\, \dot{P}_{t-1}$$

Lagging this equation one period yields

$$\dot{P}^e_{t-1} = \theta \dot{P}_{t-2} + (1-\theta)\dot{P}^e_{t-2}$$

which we may then substitute into the previous equation to obtain

$$\begin{aligned} \dot{P}^e_{t-1} &= \theta \dot{P}_{t-1} + (1-\theta)\,[\,\theta \dot{P}_{t-2} + (1-\theta)\,\dot{P}^e_{t-2}\,] \\ &= \theta \dot{P}_{t-1} + \theta(1-\theta)\,\dot{P}_{t-2} + (1-\theta)^2\, \dot{P}^e_{t-2} \end{aligned}$$

Repeating these steps we finally arrive at

$$\dot{P}^e_t = \theta \dot{P}_{t-1} + (1-\theta)\, \dot{P}_{t-2} + (1-\theta)^2\, \dot{P}_{t-3} + \ldots + (1-\theta)^{n+1}\, \dot{P}^e_{t-n-1}.$$

Only the last term of this equation is unobservable and we may shrink it until it becomes arbitrarilly small by increasing the number of times the lagging/substitution process is repeated. Since $0 \leq \theta \leq 1$ and $\dot{P}^e_{t-n-1} < \infty$, $(1-\theta)^{n+1} \to 0$ as $n \to \infty$). Notice that the last equation expresses $\dot{P}^e$ as a weighted average of past prices $\dot{P}_{t-1}$ with the weights decaying geometrically and summing to one.

[79]See Koyck (1954).

[80]Solow (1970, pp. 3-4), Tobin (1975, p. 4), Hudson (1982, p. 107) and Begg (1982, pp. 23-4) all comment on the appeal of a procedure that relies upon readily observable past inflation rates, which obviously lowers the information costs of the forecasting process.

[81]See especially Flemming (1976, Ch. 7) and his suggestion for overcoming this problem by using an adaptive Adaptive Expectations Hypothesis in which the expectations formation process is conceptualized as experiencing a change of "gear" each time a new (higher) time derivative of the inflation process acquires a trend.

[82]See Chan-Lee (1982, p. 53), Tobin (1972a, p. 14) and Hudson (1982, p. 111). Alt (1979, Ch. 4) presents some interesting survey information concerning the British public's ignorance about inflation (pp. 58-59).

[83]See also Saunders and Nobay (1972).

[84]One procedure would be to impose the restriction alpha equals one on the regressions. We have not done so in the experiment reported below in order to be able to compare our results with those obtained in previous tests.

[85]We have only been able to locate one reference in the literature to this interpretation. Friedman (1976, p. 229) argues that "Even on their own terms, then, these results are capable of two different interpretations. One is that the long-run Phillips curve is not vertical but has a negative slope. The other is that this (the Adaptive Expectations Hypothesis) has not been a satisfactory method of evaluating people's expectations for this purpose (i.e., testing the

Acceleration Hypothesis)." (Parentheses added.) Sumner may have had this approach in mind when he observes that "Rejection of Friedman's hypothesis is, however, contingent on acceptance of the Adaptive Expectations mechanism...." (Sumner (1972, p. 169)).

[86]It is possible that part of the appeal of the Acceleration Hypothesis--its apparent offer of a hostage to fortune--is really no sacrifice at all since the likelihood that any developed economy would exhibit systematic money illusion is vanishingly small. Proponents of the hypothesis are then in the happy position of carrying the day essentially by default. The point we have argued above concerning the reliability of the assumption that expectations are actually realised for significant segments of time never becomes a matter for question.

[87]The only prior studies with which we are familiar are Cagan (1968), Phelps (1968) and Solow (1968). Of these, only Cagan's study refers to U.K. data and it, as we have previously observed, uses cycle average data and it is therefore not obvious how to interpret his results. The first U.K. studies were probably the Solow study we are presently concerned with, and the papers by Archibald (1974) (although this paper was not published until 1974 the research appears to have been completed by the summer of 1970 (See n. 1, p. 109)) and Parkin (1970). The Archibald paper includes some annual results for the 1892-1913 period (all of which have alpha coefficients which are considerably less than one (0.16 to 0.64). Otherwise the Archibald and Parkin studies were concerned with quarterly data.

[88]Parkin (1970) suggests that the autocorrelation observed in the residuals of the regressions contained in his well known study on the

effects of income policy in the U.K. (which he jointly authored with Lipsey) might be accounted for by a mis-specification of the $\dot{P}^e$ term. But see Henry (1974) and Wallis (1971).

[89]The discussion in this paragraph follows closely Solow's exposition (Solow (1970, pp. 4-8)) although similar commentaries on the Adaptive Expectations Hypothesis may be found nowadays in most accounts of the Acceleration Hypothesis.

[90]With alpha equal to one we arrive at a version of the Phillips curve equation which is very similar to that of the original Lipsey specification.

[91]Solow (1968, p. 13) comments that "I can imagine trying other weighting schemes, though in this instance, where we are not dealing with a friction or delay, I should think the weights ought to fall steadily, rather than rise first and then fall." Solow (1970, p. 8) checked the sensitivity of his results to the geometrically declining weights assumption by constructing $\dot{P}^e$ proxies using "20-period and 10-period averages of past $\dot{P}$'s, with weights falling linearly to zero. The results were statistically a bit less good than with adaptive expectations, but yielded qualitatively similar implications." Archibald, on the other hand (1974, p. 138) conducted some experiments with alternative lag structures which suggested that "the Koyck structure is inappropriate." One problem with this approach is the possibility that multicollinearity may make coefficients difficult to pin down.

[92]The initialisation in 1929 was presumably originally chosen for his test using American data. We assume that Solow's British series

were also initialised from 1929, but his account is not clear on this point.

[93]The data, especially before 1920, leave much to be desired and there are a number of problems of comparability. However, mendicants must be constrained optimisers and we know of no better data set. More details concerning the series is provided in the appendix.

[94]Phillips (1958). See also Sleeman (1983a) for a discussion of alternative ways of measuring rates of change.

[95]See Feige and Pearce (1976) and Laidler (1976) on the important distinction between statistical and economic optimality in the context of expectations formation.

[96]Of course, Phillips also laid great stress on the importance of import prices (he in fact makes ten references to import prices (Phillips (1958, passim.)). One possible reason for this emphasis may have been the large proportion of imported foodstuffs in British consumption.

[97]See Reid (1976) and Rao (1977) on the correct statistical formulation of Phelps' hypothesis. Neville (1975, p. 133) had some problems with Parkin's original Australian test of the Phelps formulation (Parkin (1973)) but was corrected by Parkin (1975).

[98]See, for example, the data displayed in "The Economist" (1975) which, although before World War One the series refer to wholesale rather than consumer prices, are undoubtedly indicative of broad trends. These series suggest that prices tended to fall during the 1840's. See also Sumner (1972, n. 11, p. 175) and Saunders (1978).

[99]See Pagan (1981).

[100]As is well known the CORL procedure is far from ideal. See Sleeman (1983) for references.

[101]All of the regressions were run on the IBM4341 computer at Western Washington University's Computer Center using the ESP software package.

[102]We have also run 648 $PCHW^e$ regressions which we do not report at all.

[103]Of course it is possible that the British worker is deeply imbued with "money disillusion" and expects to be compensated several times over for any expected rise in the price level. Why the British businessman should acquiesce in such a scheme is less clear.

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CHAPTER 4

RATES OF CHANGE AND PHILLIPS CURVE ESTIMATES: U.K. 1922-1978

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1. INTRODUCTION

Although there exist a number of interpretations of the Phillips curve the equations which have been used to specify, estimate and test the hypothesis all involve a relationship between the rate of change of a dependent variable and levels and/or rates of change of a set of independent variables. For example Lipsey's specification of Phillips' hypothesis took the form[1]

$$\dot{W} = f(U,\dot{U},\dot{P}) \qquad f_1 < o,\ f_2 \gtrless o,\ f_3 > o$$

where $\dot{W}$ is a measure of the rate of change of nominal wage rates (a proxy for the nominal price of labour, P_L), U and $\dot{U}$ are, respectively, the level and rate of change of a measure of the percentage rate of unemployment (proxying the excess demand for labour, E_L), and $\dot{P}$ is a measure of the rate of change of an aggregate price index (perhaps acting as a proxy for the expected rate of inflation, $\dot{P}^e$). The basic data series which are available to empirically model the equations measure the levels (of index numbers) of certain economic variables. Time series for the rate of change variables must be obtained by transforming the levels data. Phillips' and Lipsey's approach to this problem is well known. They were concerned to estimate Phillips curves for the U.K. economy and, both as a matter of historical interest and in order to maximise degrees of freedom, they pushed their sample back to 1860. However, most of the nineteenth century data are only available in annual form (either averages of twelve monthly observations or observations which were designed in some sense, to be representative of the average behaviour of the variable over a calendar year).[2] Phillips therefore calculated rate of change series as first central proportional differences for the period 1860 to 1920, i.e., he approximated the rate of change of a variable, by transforming the level series for that variable, X, using the transformation

$$\dot{X} = 100\ [(dX/dt)/X]$$

$$\doteq 100[1/2(X_{t+1} - X_{t-1})/X_t]$$

$$= 50\ [(X_{t+1} - X_{t-1})/X_t\ ].$$

Unfortunately the post 1921 wages series available to Phillips when he wrote his paper in 1958 refers to the end of December of each year rather than to the annual average. Phillips (and subsequently Lipsey) therefore calculated his rate of change series from 1921 onwards as the percentage rate of change, i.e., using the transformation

$$\dot{X} = 100\ [(dX/dt)/X\ ]$$

$$= 100\quad (X - X_{t-1})/X_{t-1}$$

which, of course, corresponds to standard usage of the term rate of change (i.e., when the media informs us that the rate of inflation is down to an annual rate of, say, 5 percent, what this usually means is that the difference between the latest CPI value and its value one year ago, expressed as a percentage of the value one year ago, is 5 percent).

Both Phillips and Lipsey seem to have regarded these two different measures of the rate of change of a variable as being essentially equivalent except for minor variations caused by the different data sets associated with the different sampling intervals used to produce the series. According to this view, the pre-World War One, inter-war, and post-World War Two regressions all have the same left hand side variable and therefore the fits of the various estimated equations may be evaluated by comparing their $\bar{R}^2$s.[3] In his critique of Phillips' paper, Professor Routh argued that the different measures would not, in principle, generate equivalent results, although he further argued that Phillips' data was of such poor quality that the differences were irrelevant.

The primary task of this paper is to provide empirical evidence concerning the claim that the method of calculating the rates of change (so long as it is done consistently and all of the series used in the regressions are properly centred) is irrelevant. That is, the different measures will lead to essentially the same parameter estimates, except for minor variations associated with differences in the samples used.[4] The method adopted in this study is to compare parameter estimates obtained from equations with identical functional form but where the rate of change series have been calculated by different procedures depending upon whether the relevant series refers to an annual average, the end of December or the end of June of the corresponding year. In addition to comparing the coefficient values of the equations, traditional econometric criteria are used to investigate the goodness of fit of the estimated equations. This experiment is only possible for the period from 1922 because U.K. data on a monthly basis for all of the variables considered do not stretch back as far as the end of the First World War.

The remainder of this paper is organised as follows. The second section discusses the so-called "Alignment Problem." The third section examines various ways in which rates of change may be calculated and the advantages and disadvantages of the most important approaches. Section four describes the experiment and the empirical results. The fifth section of the paper is concerned with the possibility that spurious serial correlation may be introduced into the equation residuals by certain types of rates of change calculations. This section also reports the results of various attempts to investigate the problems empirically. The final section provides a summary and also discusses the optimal way of calculating rates of change, and possible avenues for further research.

2. THE ALIGNMENT PROBLEM

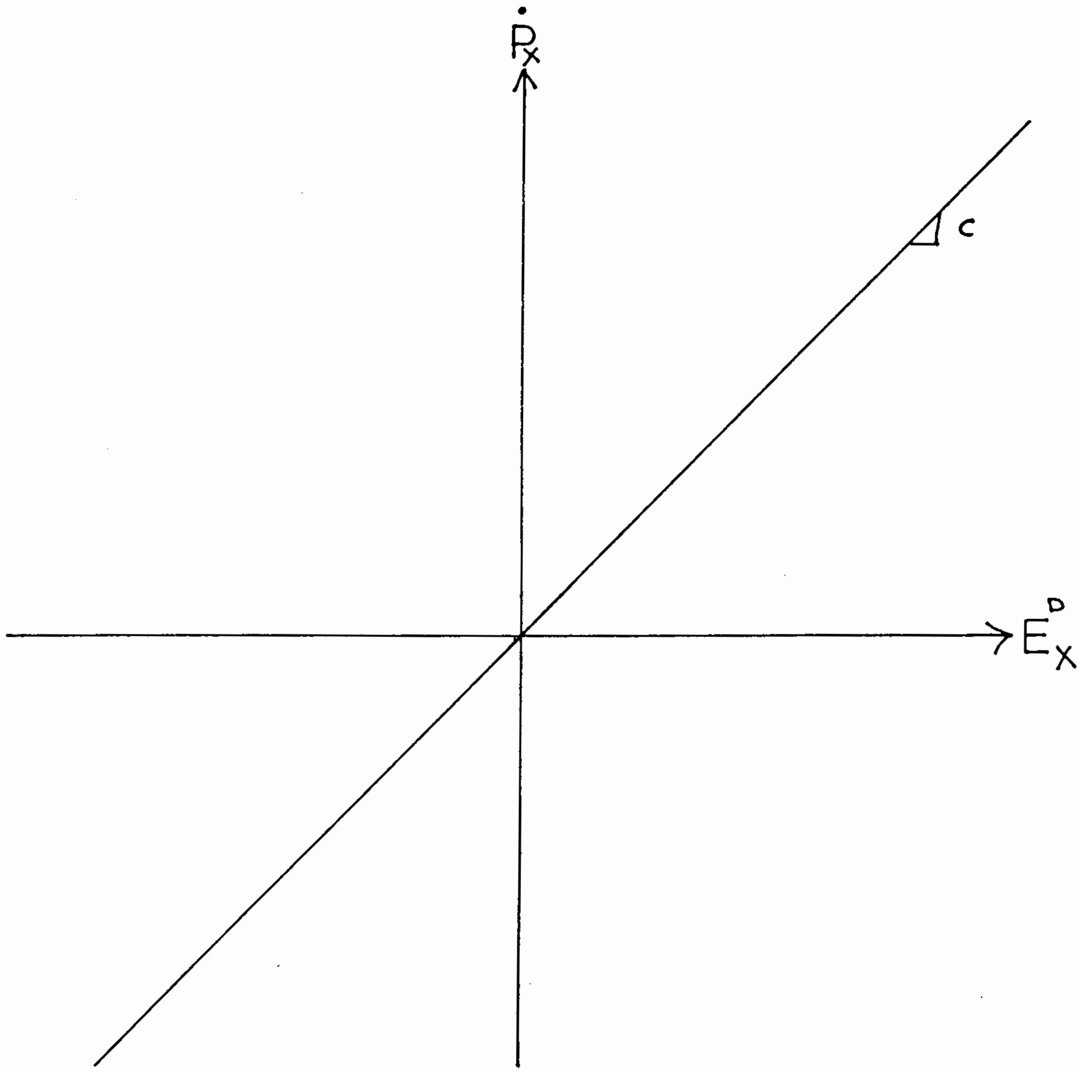
Economists usually model disequilibrium processes in continuous terms. Following Samuelson's lead,[5] it is usual to specify the process by which a competitive market responds to disequilibribrating shocks as a reaction function (usually in linear form) of the type

$$\dot{P}_x = f(E_x^D) \qquad f(0) = 0, \quad f' = c > 0.$$

where $\dot{P}_x = \frac{dPx}{dt}$ and $E_x^D = \frac{Dx-Sx}{Sx}$ are the rate of price change, and the percentage excess demand for the commodity, X, in question. Such a formulation can be illustrated by the familiar textbook diagram in Figure 4.1.

Phillips obviously viewed the Phillips curve as an attempt to estimate the reaction function for "the" U.K. labour market,[6] but, because economic data are available only at discrete intervals of time, he was forced to approximate the instantaneous rates of change specified by the theory by the use of finite difference techniques. It would also appear that Phillips viewed his task as predicting the <u>annual average</u>

Figure 4.1: The Standard Linear Reaction Function



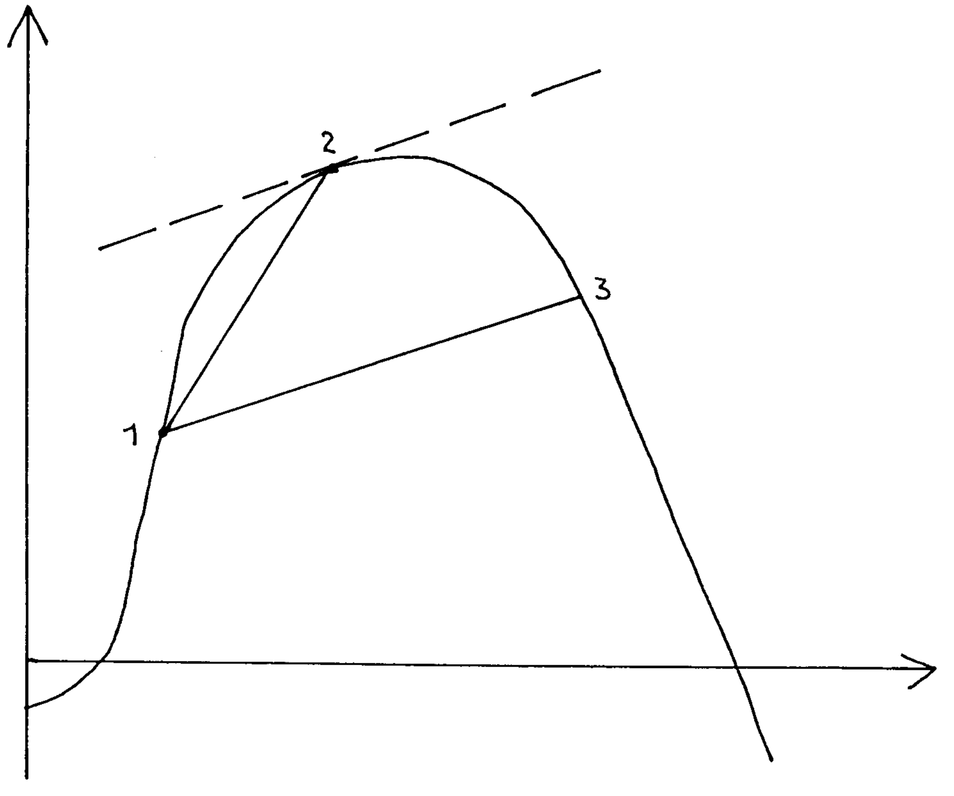
rate of wage or price inflation[7] (most U.K. labour contracts are annual, and the public and policy makers are usually primarily concerned with forecasting over the next year) and hence Phillips regarded these numerical derivatives as approximating averages of the instantaneous rates over the calendar year. Phillips therefore used (half) the first central proportional differences to calculate his rates of change variables from the annual data available to him for the period 1860 to 1920 on the grounds that it was "the best simple approximation to the average absolute rate of change of wage rates during a year....".[8] Lipsey, who followed Phillips in using first central differences for the pre-World War One period, justified this approach as follows:

> "The argument for approximating a continuous derivative by this method rather than by the more intuitively plausible method of taking the difference between this year's wage index and last year's (w_t - w_{t-1}) can best be explained by reference to the diagram. Figure 1 shows a continuous time series (say one for the rate of change of wages). Only a discrete number of regularly-spaced observations are available, say those at 1, 2, and 3, and it is desired to approximate the derivative at 2 (the true value being given by the slope of the broken line tangent to the curve at 2). Taking the rate of change to be equal to the difference between the values of the function at 2 and at 1 is equivalent to estimating the derivative at 2 to be equal to the slope of the line joining 1 and 2. But the slope of this line is typical of the value of the derivative somewhere

between 1 and 2, so that this method gives the derivative somewhere between the two points of time and is thus equivalent to introducing a time lag of approximately six months into the rate of change series. On the other hand, taking half of the first central difference is equivalent to estimating the derivative to be equal to the slope of the line joining 1 and 3. In a regular curve this latter value is likely to be closer to the true value of the derivative at 2 than is the former value."[9]

One year after Phillips' paper appeared, Professor Guy Routh published an article[10] which cast doubts upon the reliability of Phillips' results, essentially on the grounds that Phillips' data before 1947 was of such poor quality as not to be strong enough to support the structure of inference built upon it. Routh makes two main points: (1) the use of first central differences "has a smoothing effect and thus introduces distortion....,"[11] and (2) that Phillips' belief,[12] that the Wood and Bowley wage series used to construct the Phelps Brown and Hopkins series Phillips used represented rates averaged over each year, was unfounded.[13] Routh argued that the second point vitiated the choice of the first central differences method for generating the rate of change series, and sought to show the effect of the smoothing by recalculating the rates series using both first central differences and percentage changes. An inspection of Routh's Tables 2 and 3 does not, however, show any marked differences in the alternative series, although there is some evidence of diminished amplitude in the first central difference series.[14]

Figure 4.2: Lipsey's Figure 1



Interest in the problem of the optimal technique for calculating rates of change then languished until the issue was revived in 1963 by Bowen and Berry.[15] in one of the earliest studies of the U.S. Phillips curve. In the Appendix to their paper they discuss three methods of solving the alignment problem: the Wage-Lag, First Central Difference, and Averaged Unemployment methods. They describe the Wage-Lag method as follows: "This method consists of correlating U_t with $(W_{t+1} - W_t)/W_t$ and implies roughly a six months lag in the effect of unemployment on changes in money wages."[16] They claim that this procedure avoids the problem of smoothing, although the rate of change appears to take the form of a moving average, and point out that its desirability rests upon the appropriateness of the implied time lag.[17]

Bowen and Berry criticise the First Central Difference approach on the grounds that it succeeds in locating all of the variables at the same point of time only by "in effect introducing <u>both</u> a lead and a lag of a type. That is, the first central difference method implicitly introduces the assumption that wage movements in t-1 and t+1, as well as in time in t, are related to the level of unemployment in t."[18] They go on to say "...it is hard to understand how one can expect wages in a <u>previous</u> period (t-1) to be influenced by unemployment in t - causation cannot run backwards in time."[19]

These arguments seem to be confused. In the first place the point about reverse causation could equally well be made about the wage lag method since it also involves W_{t+1}. Secondly, Bowen and Berry seem to have forgotten that the first central difference concept was introduced to provide a measure of an <u>instantaneous</u> rate of change: the time derivative of the variable in question. In this context breaking the formula $\frac{W_{t+1}-X_{t-1}}{2X_t}$ into its constituent components does not make sense, just as breaking the symbol dw/dt into its constituent parts (usually) does not make sense.[20] Further, and, in addition to the general conceptual confusion just discussed, there are at least two technical problems associated with the Bowen and Berry approach. These problems are most easily illustrated by a example.

Let two variables, both of which are continuous functions of time, be related by the following linear equation

$$\frac{dy}{dt} = f(x, \frac{dx}{dt}) \quad (1)$$

$$= a + bx + c\,\frac{dx}{dt} \quad (2)$$

and let us approximate the time derivatives by first central differences, yielding

$$\frac{y_{t+1}-y_{t-1}}{2y_t} = a_1+a_2x_t+a_3\left(\frac{x_{t+1}-x_{t-1}}{2x_t}\right) \quad (3)$$

Bowen and Berry (and Galloway and Koshal) apparently wish to interpret equation (3) as if it were equivalent to the two equations

$$y_t = g(y_{t+1}, y_{t-1}, x_t, x_{t+1}, x_{t-1}) \quad (4)$$

and

$$Y_t = b_1 + b_2y_{t+1} + b_3y_{t-1} + b_4x_t + b_5x_{t+1} + b_6x_{t-1} \quad (5)$$

But although equation (4) may be formally correct (since obviously there does exist a functional relationship between y_t and y_{t-1}, y_{t+1}, x_{t-1}, x_t and x_{t-1}), equation (5) is a mis-specification of the true relationship between the variables. Simple cross-multiplication and re-arrangement of terms yields

$$y_t = \frac{y_{t+1}-y_{t-1}}{2(a_1+a_2x_t) + a_3 \left(\frac{x_{t+1}}{x_t} \right) - a_3 \left(\frac{x_{t-1}}{x_t} \right)} \qquad (6)$$

which is a non-linear (in variables and coefficients) transformation of equation (3). Further, it can be seen that even if there existed a simple valid version of equation (5), that the coefficients of that equation would not be free to take any values, but would be subject to a set of implicit constraints (e.g. the coefficients of the variables y_{t+1} and y_{t-1} must be numerically equal but of opposite sign).[21]

Of course, these comments do not imply that the moving average form of the proportional first central difference transformation is free from problems, but rather that the Bowen and Berry, and Galloway and Koshal approach to these problems is not satisfactory. Indeed section four of this paper is specifically concerned with the implications of this moving average structure.

Bowen and Berry's third method for dealing with the Alignment Problem involves replacing U_t by $(U_{t+1} + U_t)/2$ and approximating $\frac{dW_t}{dt}/W_t$ by $\frac{W_{t+1}-W_t}{W_t}$. They cite three reasons for preferring this method:

> "1) The averaged unemployment method accomplishes the objective of centering all three series on the same point of time...while making it necessary to average elements of only one of the two explanatory variable series (the unemployment series). The first central difference method, on the other

hand, requires averaging in both the rate of change of unemployment (an explanatory variable) series, and the rate of change of wages (the dependent variable) series,"[22]..."2)...the averaged unemployment method requires averaging over only a two year span,"[23] and "...there is some correspondence among the time periods from which the three sets of data come, whereas the First Central Difference method draws its rate of change of wages and rate of change of unemployment figures from a three year period and the related unemployment figures from just one of the three years, thus involving more stringent assumptions concerning lead and lag relationships."[24]

However, Bowen and Berry's statements concerning the moving average error processes generated by the first central proportional differences and the averaged unemployment method are confused. Because it requires observations at three points of time, and because the calculations are overlapped, the first central difference technique is likely to generate a second order serially correlated error term, but by similar reasoning Bowen and Berry's preferred measure will also lead to a first order serially correlated error term.

Having looked at some of the arguments in the early literature concerning the measurement of rates of change we will now turn our attention to the problem of systematically listing and evaluating potential measures of the proportional, or percentage, rate of change of some variable $X = X(t)$.[25]

3. MEASURING RATES OF CHANGE

The approximation of a derivative of a continuous function from a finite discrete, set of values of that function (X_{t+i} $i = \pm 1, \pm 2, \pm \ldots$) is one of the concerns of the branch of mathematics known as Numerical Analysis. The obvious first step in our hunt for an optimal algorithm is therefore to consult texts on Numerical Analysis. Unfortunately the results of such a search are not encouraging. The concensus of numerical analysts seems to be that "numerical differentiation should be avoided wherever possible."[26] Even worse, the quotation continues: "This is particularly true when the $f(x_i)$ values are themselves subject to some error"[27] which is, of course, the usual case in economics. However, if forced to numerically approximate a derivative the numerical analyst seems to prefer to use half the first central difference, i.e. $(X_{t+1} - X_{t-1})/2$.

It is important to remember that we are interested in a measure of the proportional or percentage rate of change of X with respect to t, i.e. $\frac{dX}{dt}/X$, and so we need to obtain approximations for both the numerator and the denominator of the proportional rate of change formula. Phillips and Lipsey and some subsequent researchers chose to express the half central difference $(X_{t+1} - X_{t-1})/2$ approximation to $\frac{dX}{dt}$ as a percentage of the value of X at time $t(X_t)$. We shall call this measure XDOT and define it as

$$\begin{aligned} XDOT_t &= 100\,[((X_{t+1} - X_{t-1})/2)/X_t\,] \\ &= 50((X_{t+1} - X_{t-1})/X_t). \end{aligned}$$

However, $XDOT_t$, is only one possible measure. Other contenders we will examine include the first difference of X_t, ΔX_t, as a percentage of the value of X at time t-1, X_{t-1}, which we will call $PCHX_t$ (this is the "commonsense measure"), defined as

$$PCHX_t \equiv 100\ (\tilde{\Delta}\ X_t/X_{t-1})$$
$$= 100\ ((X_t - X_{t-1})/X_{t-1}$$

This measure was used by Phillips and Lipsey in conjunction with their December based time series.

Since we are interested in <u>proportional</u> rates of change logarithmic differences have obvious appeal, since $\frac{d\log X_t}{dt} \doteq \frac{dX_t}{dt}/X_t$.[28] The measure which is usually used in the literature, which we will call LDX_t, is defined as

$$LDX_t = 100\ (\log X_t - \log X_{t-1})$$

but we will also consider the logarithmic analogue of $XDoT_t$ ($LCHX_t$) defined by

$$LCHX_t = 100\ ((\log X_{t+1} - \log X_{t-1})/2)$$
$$= 50\ (\log X_{t+1} - \log X_{t-1})$$

One of the obvious problems with the $PCHX_t$ is the discrepancy between the centreing of its numerator (at a point half way between t and t-1) and its denominator (at t-1). A simple way to avoid this conflict is to use the arithmetic mean of X_t and X_{t-1} in the denominator of our measure in which case we arrive at the $RCHX_t$ which we define as

$$RCHX_t \equiv 100\ \ (X_t - X_{t-1})/(X_t + X_{t-1})/2$$
$$= 200\ \ (X_t - X_{t-1})/(X_t + X_{t-1})$$

However, these five basic measures -- $XDOT_t$, $PCHX_t$, LDX_t, $LCHX_t$ and $RCHX_t$ -- are by no means exhaustive, and if we take into account the fact that for most of the post-World War One period there exist at least three sets of time series for our variables -- annual average, December

	Δ / L	HFCD			Δ			Δ/2			ΔLOG/2			ΔLOG		
		X	DX	JX	X	DX	JX	X	DX	JX	X	DX	JX	X	DX	JX
t	X	$\dot{X}$		J$\dot{X}$(X)		PCHDX(X)			ACHDX(X)		LCHX		LCHJX		LDDX	
	DX															
	JX	$\dot{X}$(J)		J$\dot{X}$		PCHDX(J)			ACHDX(J)							
t-1	X															
	DX					PCHDX										
	JX															
Σ(t,t-1)	X															
	DX					RCHDX			ACHDX(AD)							
	JX															
Σ(t+1, t-1) /2	X	$\dot{X}$($\dot{X}$)				RCHDX($\dot{X}$)			ACHDX($\dot{X}$)							
	DX															
	JX	$\dot{X}$($\dot{J}$)				RCHDX($\dot{J}$)			ACHDX($\dot{J}$)							

Table 4.1 Alternative Rates of Change Measures

and June observations -- then the number of possible measures increases rapidly. Table 4.1 below is designed to illustrate how measures may be created and how they are interrelated.

The columns of Table 4.1 refer to the numerators of the proposed measures (i.e. to the technique for calculating dx/dt, symbolised by Δ), while the rows of the table refer to the corresponding denominators (i.e. to the term $100(1/X_t)$). The rows and columns are in turn divided into three sub-divisions labelled X, DX and JX which, respectively, refer to the three time series -- the annual averages, X_t; the December observations, DX_t; and the June observations, JX_t. There are five basic column headings which are to be read as follows:

HFCD refers to half the difference between the t+1 and t-1 values, e.g. $HFCDX_t = (X_{t+1} - X_{t-1})/2$

Δ refers to the first difference of the values e.g. $DX_t = DX_t - DX_{t-1}$

$\Delta/2$ refers to half the first difference of the values, e.g. $\Delta JX_t/2 = (JX_t - JX_{t-1})/2$,

HFCLD refers to half the first central logarithmic difference of the values, e.g. $HFCLDX_t = (\log X_{t+1} - \log X_{t-1})/2$

LOG refers to the logarithmic difference of the values, e.g. $LOGX_t = \log X_t - \log X_{t-1}$

and HFCLOGD refers to half the logarithmic first central difference e.g. $HFCLOGDX_t = (\log X_{t+1} - \log X_{t-1})/2$.

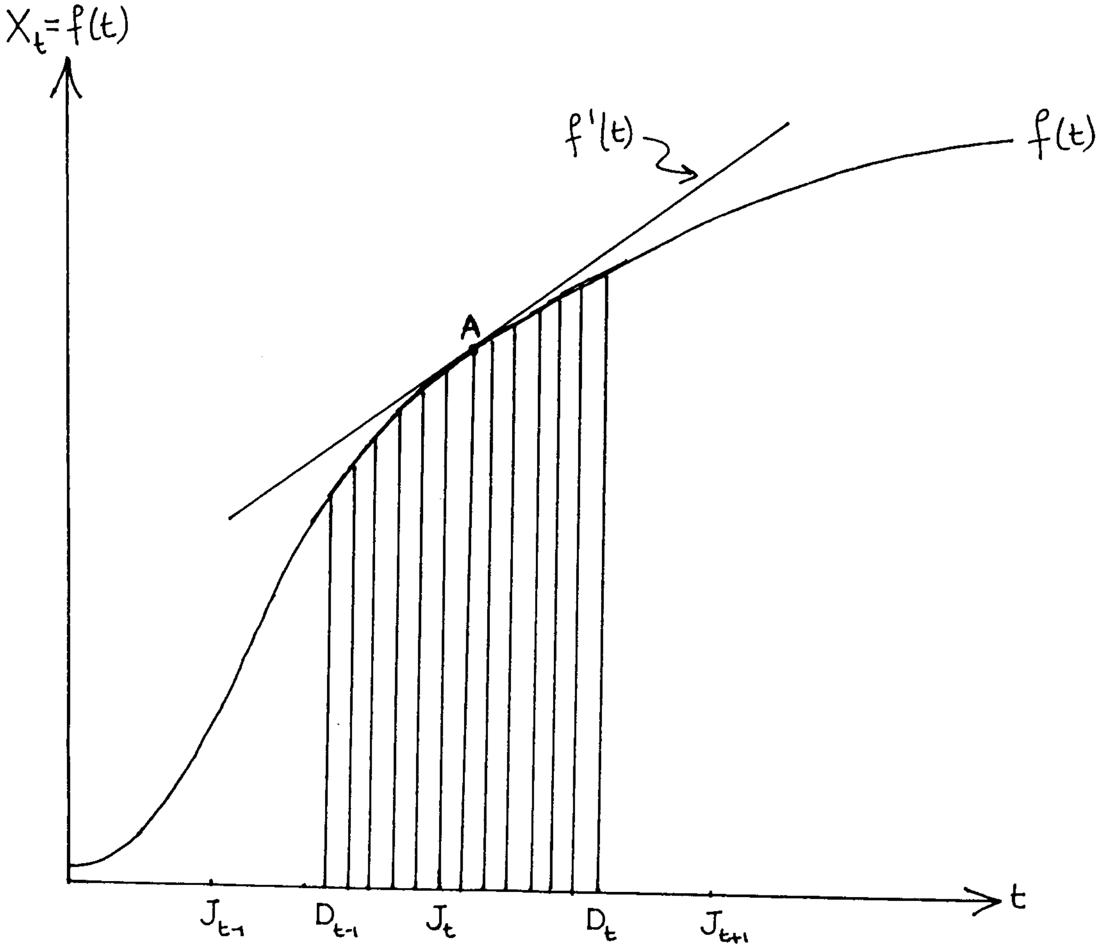
There are four basic row classifications which are generally denoted by L (for level i.e. the measure of the appropriate height of the function X = X(t)). The rows labelled t correspond to the choice of the value of the series at the time t for denominator, e.g. DX_t tells us to multiply the column argument by one hundred and divide by X_t to obtain the proportional rate of change. Similarly t-1 requires us to use X_{t-1} as denominator. The last two main row classifications involve averaging to obtain the denominator value. Further Σ (t, t-1)/2 means, form the arithmetic average of the corresponding values, e.g., Σ(t, t-1)/2 applied to JX_t yields $(JX_t + JX_{t-1})/2$. Similarly Σ (t+1, t-1)/2 takes the average of the t+1 and t-1 values to form the denominator value, e.g., Σ(t+1, t-1)/2 applied to DX_t gives $(DX_{t+1} + DX_{t-1})/2$.

The first nine columns and the twelve rows of Table 1 define 108 possible proportional rate of change measures, and the last six columns add another six measures.[29] We therefore have 114 measures generated by this classification scheme. Twenty of these possibilities have been singled out for special attention, and the corresponding cells of the table have been filled by an appropriate symbol. Of these twenty measures, nineteen have both numerator and denominator centred at the middle of the t time period. The remaining measure, PCHDX, has the numerator centred at mid-t but the denominator at the end of t-1. All of these measures are therefore potential candidates for approximating the rate of change of X when the levels variables in the equation refer either to annual average data or to observations made at the end of June in year t.

Before examining these measures in detail it will be helpful if we consider some general issues which may be classified with the aid of Figure 4.3.

There are 365 days in a non-leap year. The mid-point of the year

Figure 4.3: The Average Rate of Change Between D_t and D_{t-1}

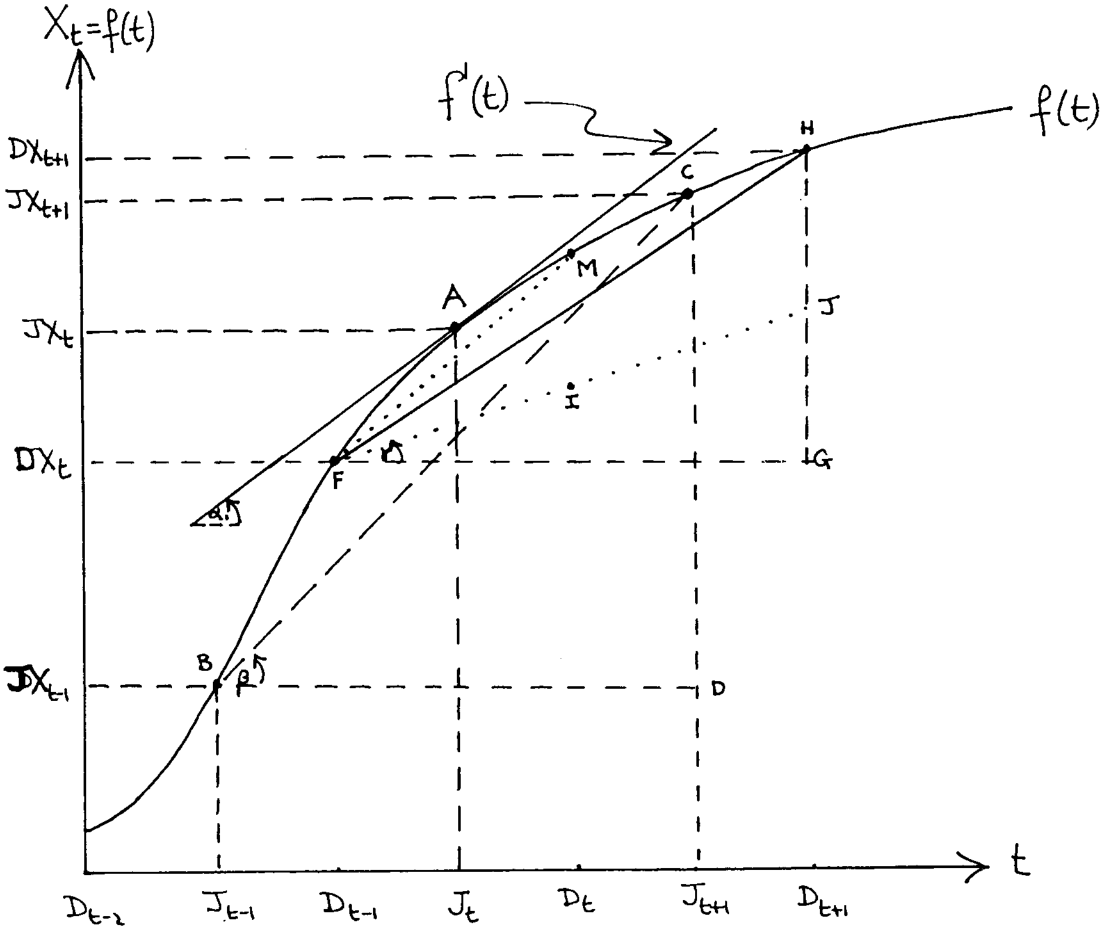


therefore lies between July 1st and July 2nd. We will assume that mid-year coincides with the end of June since most of our data refer to the end rather than the beginning of the month.[30] The first problem which needs to be discussed is whether we are attempting to estimate the instantaneous rate of change of $X_t = f(t)$ at the mid-point of the time interval, i.e. at June 30th, or the average rate of change over the time interval, i.e. the average of the twelve, monthly, rates of change. Although the theory underlying the disequilibrium adjustment process seems to imply a process of continual adjustment it also seems likely that most researchers in this area, and most policy makers concerned with real world inflationary processes, are primarily interested in explaining and forecasting average inflation rates over calendar years or perhaps quarters. Thus, although Lipsey's diagram and the accompanying commentary seem to imply a preoccupation with instantaneous rates of change, we will assume that our proper concern must be with average rates of change over calendar years. In terms of Figure 4.3 we are therefore concerned with the average value of the twelve tangents to the mid-points of the monthly intervals, rather than in attempting to measure the slope of the tangent to f(t) at the end of June (i.e. the slope of the line f'(t) which is tangent to f(t) at A).

If monthly data are available for each of the levels variables, then from a policy point of view, we should concentrate on calculating the average of the instantaneous rates of change at the mid-points of the twelve months, whereas, from a theoretical point of view, we should be concerned with calculating the instantaneous rates of change at the mid-month points but would deal with these directly rather than in annual averaged form. However, if the calendar year behaviour of f(t) is sampled less frequently than twelve times a year, then our primary concern would still be with the average rate of change over the year rather than with the instantaneous rate at some intermediate point, except insofar as we interpret that instantaneous rate as being in some sense "representative" of the rate of change over the whole year.

The second issue we must confront is the "centreing or "alignment" of our rate of change measure. As we have already seen above this topic has been the subject of considerable discussion in the Phillips curve literature. The problem can be illustrated by Figures 4.4 and 4.5. Phillips' pre-1920 data set consisted of a set of unemployment figures which were annual averages of twelve monthly observations and a set of observations on a wage index which he also interpreted to be annual averages. Since an unweighted average is centred at the mid-point of the relevant interval (i.e. it represents the "centre of gravity" of the observations) both Phillips' unemployment and wages series were centred at the end of June or beginning of July. Phillips, therefore, wanted to use a rate of change measure which would also be centred at the mid-point of the interval, so he chose to express half the first central difference of the wage series (i.e. $1/2(W_{t+1} - W_{t-1})$) as a proportion of the value of the wage index at time t (i.e. W_t). In terms of figure 3(b) Phillips approximated the slope of the tangent to f(t) at A (i.e. the slope of f'(t) measured by the angle α) by half the slope of the chord from B to C (i.e. he used the angle associated with the line BE because the period t-1 to t+1 covers two years), and he approximated the value of X_t during the annual interval t by the average value over that

Figure 4.4: Approximations to f'(t)

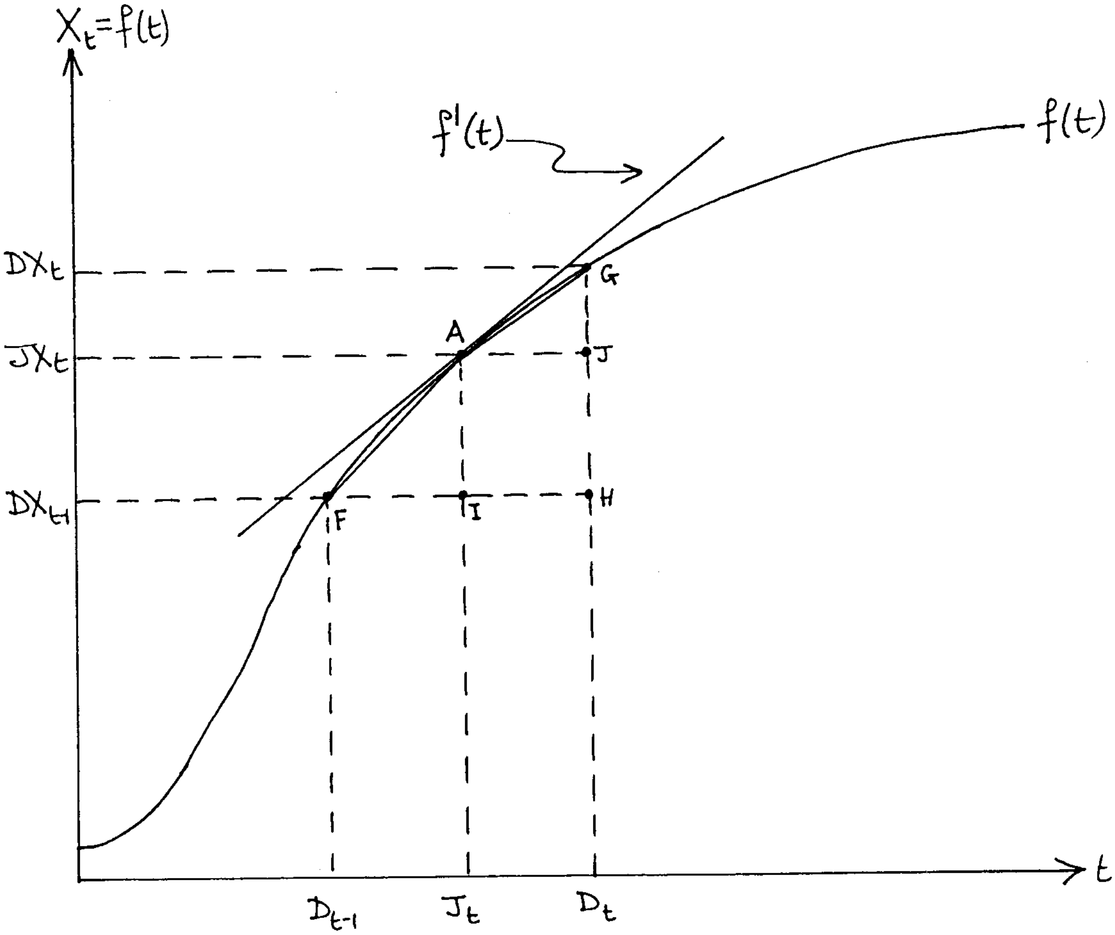


rate of change measure for mid-year centred data) would be aligned at J_t causing the equation to exhibit an unintended 6-month lag between the rate of change of wages and the excess demand proxies. In order to avoid introducing this half period lag Phillips, as we have seen, switched to the percentage change measure for the DW_t series. $PCHDW_t$ uses the line joining F to M in Figure 4.4 to approximate f'(t) at J_t. However, although the numerator of $PCHDW_t$ is correctly centred the denominator is the value of the wage index at the end of December in year t-1 (the height of f(t) at D_{t-1}) and so the $PCHDW_t$ measure provides only a partial solution to the alignment problem.

Two alternative measures which use DW_t but avoid the $PCHDW_t$ problem are the rate of change of DW_t, $RCHDW_t$, and the logarithmic difference of DW_t, $LDDW_t$. The $RCHDW_t$ shares its numerator with $PCHDW_t$ but uses the simple arithmetic average of DW_{t-1} and DW_t so that both parts of the ratio are correctly aligned with U_t and $UDOT_t$. The logarithmic difference is already in proportional form and so, in this case, there is no explicit denominator to cause problems.

Now let us use Figure 4.5 to suggest yet another approach to measuring the average rate of a variable over a calendar year and for which December and June values are available -- as is now the case for the U.K. time series. We wish to approximate the average rate of change over the interval from the end of December in t-1 to the end of December in t. But the slope of f'(t) at A (i.e. at J_t) is itself only an approximation to that average rate of change. Since we have observations at D_{t-1}, J_t and D_t we could use the slopes of the chords FA and AG to approximate the average by providing estimates for the average

Figure 4.5 The $ACHX_t$ Approximation



rate of change of X_t over the first and last halves of the year. This suggests that we could measure the average rate of change by calculating the average rate of change $ACHX_t$, defined as

$$ACHX_t = 100 \frac{[(JX_t - DX_{t-1}) + (DX_t - JX_t)] / 2}{(DX_{t-1} + DX_t)/2}$$

$$= 100 ((DX_t - DX_{t-1})/(DX_t + DX_{t-1}))$$

which can be calculated from the December series. The obvious appeal of the average change measure is that it much more closely approximates the true average rate of change over the interval than do the other measures which are conceptually closer to measures of the instantaneous rate of change at J_t.

We can summarise this discussion by saying that $XDOT_t$ and $LCHX_t$ may be used with annual averages or end of June data to centre the rate of change at mid-year. Similarly $PCHDX_t$, $RCHDX_t$, $LDDX_t$, and $ACHDX_t$ can all be used with end of December series to centre the rate of change at mid-year. Problems arise if the first two measures are applied to December data or if the last four measures are used with annual average or end of June data. Of course, since data now exist on a monthly basis for all of the series after 1935 and June and December series exist after 1920, it is possible to run many combinations of dependent and independent variables in a particular Phillips curve specification. For example, the $DXDOT_t$ transformation could be used for the dependent variable (which would be centred at the end of year t) in conjunction with the DU_t unemployment series and the $PCHJU_t$ rate of change of unemployment series (both of the excess demand proxies being centred at the end of December in year t). However, the logic of this specification is not completely clear since the (instantaneous) rate of change of wages at the <u>end</u> of the usual calendar decision period is being related to the corresponding excess demand at the end of this period. How this formulation captures either the theory or the practise of the wage bargain needs to be spelled out.

Returning to Table 4.1 it should by now be apparent that not all of the 114 possibilities defined by the 9 main columns and 12 rows plus the six logarithmic measures are exactly equivalent. The cells which contain entries (e.g. $\dot{X}$ in row 1, column 1) all refer to measures which have at least the numerator centred at the end of June in year t. We will now examine some of the features of these measures with the help of Table 4.2.

Each row of Table 4.2 refers to a particular measure of the proportional rate of change of some variable X. There are seven columns, the first of which (headed Δ) tells us how the numerator of the expression was constructed, (e.g. $\dot{X}$, $\dot{X}(J)$, $\dot{X}(\dot{X})$, $\dot{X}(\dot{J})$ and LCHX all use all of the information contained in years t-1 and t+1, whereas the remaining measures use only the information available in two months -- J$\dot{X}$(X), J$\dot{X}$ and LCHJX using the June values in years t-1 and t+1, while the last twelve measures use December values for years t-1 and t). The second column (headed L) describes the denominator of the measure (the level factor) where it can be seen that the numerators of X, JX(X), PCHDX(X), and ACHDX(X) use all of the information available in year t, RCHDX(X) and ACHDX(X) use all of the information available during years t-1 and t+1 and $\dot{X}(\dot{X})$ uses the mean of the average values of X during t-1 and t+1. The other measures use the information available in not more

Table 4.2 Characteristics of the Rates of Change Measures

	Δ	L	e	Centre for Δ	Centre for L	Hetero. correction?	t+1 needed?
$\dot{X}$	All X t-1,t+1	All X t	All e's t-1,t,t+1	mid-t	mid-t	No	X_{t+1}
$\dot{X}(J)$	All X t-1,t+1	JX t	All e's, t-1, t+1, JX_t	mid-t	end JX_t	No	X_{t+1}
$\dot{X}(\dot{X})$	All X t-1,t+1	$\frac{X(1)-X(-1)}{2}$	All e's t-1,t+1	mid-t	mid-t	No	X_{t+1}
$\dot{X}(\dot{J})$	All X t-1,t+1	$\frac{JX(1)-JX(-1)}{2}$	All e's t-1,t+1	mid-t	end JX_t	No	X_{t+1}
$\dot{J}X(X)$	JX t-1,t+1	All X t	All e's, t JX_{t-1}, JX_{t+1}	end JX_t	mid-t	No	JX_{t+1}
$J\dot{X}$	JX t-1,t+1	JX t	All e's, JX t-1,t,t+1	end JX_t	end JX_t	No	JX_{t+1}
LCHX	All X t-1,t+1	(mid-t)	All e's t-1,t+1	mid-t	(mid-t)	Yes	X_{t+1}
LCHJX	JX t-1,t+1	(end JX_t)	e's at JX_{t-1}, JX_{t+1}	end JX_t	(end JX_t)	Yes	JX_{t+1}
PCHDX(X)	DX t-1,t	All X t	All e's, t Δ DX_{t-1}	end JX_t	mid-t	No	No
PCHDX(J)	DX t-1,t	JX t	e's for JX, DX_t, DX_{t-1}	end JX_t	end JX_t	No	No
PCHDX	DX t-1,t	DX t-1	e's for DX t-1,t	end JX_t	end DX_{t-1}	No	No

(Continued)

	Δ	L	e	Centre for Δ	Centre for L	Hetero. correction?	t+1 needed?
RCHDX	DX t-1,t	DX t-1,t	e's for DX t-1, t	end JX_t	end JX_t	No	No
RCHDX($\dot{X}$)	DX t-1,t	All X t-1,t+1	All e's for t-1,t+1	end JX_t	mid-t	No	X_{t+1}
RCHDX($\dot{J}$)	DX t-1,t	JX t-1,t+1	e's for DX JX_{t-1}, DX_t, JX_{t-1}	end JX_t	end JX_t	No	JX_{t+1}
LDDX	DX t-1,t	(end JX_t)	e's for DX t-1,t	end JX_t	(end JX_t)	Yes	No
ACHDX(X)	DX t-1,t	All X t	All e's for Xt DX t-1,t	end JX_t	mid-t	No	No
ACHDX(J)	DX t-1,t	JX t	e's for DX t-1,t,JX_t	end JX_t	end JX_t	No	No
ACHDX(AD)	DX t-1,t	DX t-1,t	e's for DX t-1,t	end JX_t	end JX_t	No	No
ACHDX($\dot{X}$)	DX t-1,t	All X t-1,t+1	All e's, t-1, t+1, DX_t	end JX_t	mid-t	No	No
ACHDX($\dot{J}$)	DX t-1,t	JX t-1,t+1	e's, t-1,t+1 DX, JX	end JX_t	end JX_t	No	JX_{t+1}

Table 4.2 (Continued)

than two months (e.g. $\dot{X}(\dot{J})$ takes the mean of the values at X at the end of years t-1 and t+1).

In column three we indicate which years or months contribute to the error term in the equation. $\dot{X}$, for example transmits errors from all 36 months in years t-1, t and t+1, whereas $\dot{X}(J)$ is sensitive to errors in only 25 months since only the June observation in year t is needed for its calculation.

The fourth column tells us where the numerator of the measure is centred which, for these twenty measures is always at the mid-point of year t. The fifth column details the centreing of the denominator which is at the mid-point of the year (except for $PCHDX_t$ which is centred at the end of December in year t-1). (The logarithmic measures are implicitly centred at mid-t.)

Column six indicates whether the rate of change calculation is likely to help reduce possible heteroskedasticity in the level of X_t. This correction is likely only with respect to the logarithmic transformations. Finally, in the last column, we list whether information concerning the behaviour of X during year t is required for the calculation: $\dot{X}$, $\dot{X}(\dot{J})$, $\dot{X}(\dot{X})$, $\dot{X}(J)$, LCHX and RCHDX(X) all require complete information, while $\dot{J}X(X)$, $\dot{J}X$, LCHJX, RCHDX(J) and ACHDX(J) all require information concerning the level of X at the end of June in year t+1, and the remaining measures do not require any information concerning year t+1.

Which measure should be used is not clear. Measures such as $\dot{X}$ have the advantage that they approximate the average rate of change over an interval, the year t, by using all of the information available concerning the behaviour of X_t during that year. On the other hand they require more information to be available -- the level of X during each month in year t+1 -- than is in fact available to decision takers and policy makers at the end of t. Measures such as PCHDX(J) use only data available up to the end of year t, which recommends them to forecasters and policy makers, and they are further parsimonious in that they only require data to be available for X_t at the end of three months, but such measures are conceptually closer to instantaneous rates of change than to average rates of change.

Before we leave this topic to turn our attention to the results of our empirical experiment we should explore one further approach to measuring rates of change, which is to take a moving average of some of the previously defined measures. Four such measures are:

$$M\dot{X} = 1/3\ [D\dot{X}_t + J\dot{X}_t + D\dot{X}_{t-1}]$$

$$= 1/3\left[100\left\{1/2\left(\frac{DX_{t+1}-DX_{t-1}}{DX_t}\right) + 1/2\left(\frac{JX_{t+1}-JX_{t-1}}{JX_t}\right) + 1/2\left(\frac{DX_t-DX_{t-2}}{DX_{t-1}}\right)\right\}\right]$$

$$= 50/3\left[\frac{DX_{t+1}-DX_{t-1}}{JX_t} + \frac{JX_{t+1}-JX_{t-1}}{JX_t} + \frac{DX_t-DX_{t-2}}{DX_{t-1}}\right]$$

$$MLCHX_t = 1/3\ [LCHDX_t + LCHJX_t + LCHDX_{t-1}]$$
$$= 100/3\ [\{LOGDX_t - LOGDX_{t-1}\}/2 \quad \{LOGJX_t - LOGJX_{t-1}\}/2 + \{LOGDX_{t-1} - LOGDX_{t-2}\}/2]$$
$$= 50/3\ [LOGDX_t - LOGDX_{t-1} + LOGJX_t - LOGJX_{t-1} + LOGDX_{t-1} - LOGDX_{t-2}]$$

$$MPRCHX_t = 1/3\ [PCHX_t + PCHDX_t + PCHX_{t-1}]$$
$$= 100/3\ [\{(X_t - X_{t-1})/X_{t-1}\} + \{(DX_t - DX_{t-1})/DX_{t-1}\}$$

$$+ \{(X_{t-1} - X_{t-2})/X_{t-2} \}]$$

$$MPCHJX_t = 1/3 \quad [PCHJX_t + PCHDX_t + PCHJX_{t-1}]$$

$$= 100/3 \ [(JX_t - JX_{t-1})/JX_{t-1} + (DX_t - DX_{t-1})/DX_{t-1}$$

$$+ (JX_{t-1} - JX_{t-2})/JX_{t-2} \ ]$$

Each of these measures attempts to approximate the average of the instantaneous rates of change during year t by averaging measures of the instantaneous rates of change at the beginning of the year (strictly speaking measured at the 31st of December in year t-1), at the mid-point of the year, and on the last day of the year, these measures would therefore be appropriate if the Phillips curve is interpreted in terms of the theoretical reaction function relating the instantaneous rate of change of money wages at time t to the level of excess demand at time t.

In this section we have seen that if monthly observations exist so that annual average, end of June and end of December series are available for the variables then there are many ways to measure the rates of change of the variables. These measures are not equally satisfactory and some of the ways in which they differ were examined. It is obviously important to see whether the implicit assumption made by Phillips, Lipsey and many later writers -- that so long as the rate of change variables were correctly aligned in time with the levels variables the choice of a particular measure would not have a major impact on the empirical results -- is consistent with the evidence.

4. THE EXPERIMENT

We now report the results of an experiment designed to see just how sensitive our parameter estimates are to the choice of technique to measure the rates of change. The form of this experiment is very simple. Standard Phillips curves using three functional forms were estimated for a number of time periods. The three functional forms chosen were

$$\dot{W}_t = a_1 + a_2U_t + a_3U_t^{-1} + a_4 \dot{U}_t + a_5\dot{P}_t + u, \quad (1)$$

$$\dot{W}_t = b_1 + b_2U_t^{-1} + b_3U_t^{-2} + b_4\dot{U}_t + b_5\dot{P}_t + u_2 \quad (2)$$

$$\dot{W}_t - c_1 + c_2U_t^{-1} + c_3U_t^{-4} + c_4\dot{U}_t + c_5\dot{P}_t = u_3 \quad (3)$$

where $\dot{W}_t$ is some measure of the rate of change of an index of money wage rates, U_t^i (i = -4, -2, -1, 1) is the annual rate of unemployment, $\dot{U}_t$ is a measure of the rate of change of unemployment, and $\dot{P}_t$ is the rate of change of an index of consumer prices. W_t is a proxy for the nominal price of labour, the polynomials in U_t^{-1} are used to jointly proxy the excess demand for labour, the $\dot{U}_t$ is a term introduced either to improve the ability of U_t^{-1} to proxy excess demand, or as a proxy for the expected excess demand for labour over the firms' planning horizon, while $\dot{P}_t$ is introduced to pick up acceleration effects, "catch up" effects and the general cost-push impact of changes in the cost-of-living.[31] Equations (2) and (3) are the preferred functional forms from Lipsey's original experiment (the former being the best fitting equation for the pre-World War One sample, and the latter for the post-World War One period) and equation (1) is used because it has a particularly appealing theoretical interpretation.[32]

The wage series used (W for annual averages, DW for end of December values, and JW for end of June values) was the hourly wage index for the United Kingdom, calculated by the Department of Employment.[33] The unemployment series (U, DU and JU) were also collected by the Department of Employment, or its predecessors, and measure U.K rates of unemployment either as percentages of the insured labour force (before 1948), or as percentages of total employees (1948 and after). The break in this series is not crucial to our experiment since we are not primarily concerned wth making inter-temporal comparisons.[34] Finally the price data refer to the official Retail Price Index which is the standard measure of consumer prices in the U.K. We have data for most of these series from 1921 onwards. Lipsey estimated a Phillips curve for the combined periods 1923-1939 and 1948-1957 (deleting the 1919-1922 and 1940-1947 observations from his sample on the grounds that they were war years or distorted by the wars or other exceptional events). We have estimated the three functional forms over the combined 1922-1938 and 1948-1957 periods (dropping 1939 on the grounds that it too was a year severely affected by war activity -- Britain declared war on Germany on the 3rd of September, 1939 -- and adding 1922 to maintain the sample size) which we call the Lipsey period. We have also run the same set of regressions over the whole period from 1922 to 1978 and over the peacetime years 1922 to 1938 combined with 1948 to 1978. Regressions were also run over the sub-periods 1922-1938, 1948-1957, 1948-1966, 1967-1978 and 1948-1978 (which we call the pre-War, post-war Lipsey, pre-1967, post-1966 and post-War periods, respectively). These periods were singled out for analysis either because, as in the case of the post-war Lipsey sample, they allow us to make comparisons with previously published results, or because they correspond to periods (such as the pre-1967 and post-1966 periods) associated with potential structural breaks in data or economic process.

As we have seen above there are more than one hundred candidates to choose from as measures of the rates of change variables in the equations. In order to keep the size of this paper within reasonable bounds[35] we have concentrated on the five basic measures XDOT, LCHX, PCHX, LDX, and the RCHX and have reported below on regression results for only some of the sub-periods. We now turn our attention to analysing the results.

Our ordinary least squares (OLSQ) results are reported in Table 3.[36] The table is divided into five subsections according to the sample period in question. Within each subsection the results are further sub-divided by functional form (UU^{-1}, $U^{-1}U^{-2}$, $U^{-1}U^{-4}$). Each of the sub-sub-divisions contains two sets of results: first the regressions associated with each of the basic rates formulas with all variables correctly aligned at mid-year, and second two regressions designed to illustrate instantaneous rates of change measures both aligned at the end of June.

The "whole period" regressions are shown in Table 4.3.

We see that the results, as was anticipated, fall into two groups, the first proportional central difference (XDOT) and logarithmic change (LCHX) formulations having tighter fits (higher $\bar{R}^2$s) than the rates measures using end-December values (the PCHDX, RCHDX and LDDX measures).[37,38] On the other hand the first two equations, and particularly the second, have much lower Durbin-Watson (DW) statistics than do the next three equations. In fact the DWs for equations (1) and (2) both suggest the presence of first order positive serial correlation at the 5% significance level ($d_L = 1.41$, $d_U = 1.72$ with $N = 55$, $k' = 4$ and using a one tail test), whereas the equations (3) - (5) DWs are all

TABLE 4.3

1922-1978 ORDINARY LEAST SQUARES N=57

$$WDOT = \underset{(2.49)}{2.97} - \underset{(1.40)}{.13}\,U + \underset{(.32)}{.40}U^{-1} + \underset{(1.50)}{.015}\,UDOT + \underset{(11.92)}{.86}\,PDOT \quad (1)$$

R^2= .83 $\bar{R}^2$ = .82 F (4.52) = 63.61

$F_1(2,52)$ = 2.90 $F_2(2,52)$ = 73.21 $F_3(3,52)$ = 2.74

DW = 1.28

$$LCHW = \underset{(2.51)}{2.86} - \underset{(1.36)}{.12}\,U + \underset{(.41)}{.50}U^{-1} + \underset{(2.03)}{.022}\,LCHU + \underset{(12.33)}{.876}\,LCHP \quad (2)$$

R^2 = .84 $\bar{R}^2$ .83 F(4.52) = 68.08

$F_1(2,52)$ - 3.02 $F_2(2,52)$ = 78.03 $F_3(3,52)$ = 3.55

DW = 1.24

$$PCHDW = \underset{(2.00)}{3.40} - \underset{(1.56)}{.20}\,U + \underset{(\,.12)}{.21}\,U^{-1} + \underset{(.76)}{.012}\,PCHDU + \underset{(9.23)}{.88}\,PCHDP \quad (3)$$

R^2 = .74 $\bar{R}^2$ = .72 F(4.52) = 37.94

$F_1(2,52)$ = 2.87 $F_2(3,52)$ = 43.84 $F_3(3,52)$ = 2.11

DW = 1.65

$$RCHDW = \underset{(1.94)}{3.16} - \underset{(1.54)}{.19}\,U + \underset{(.20)}{.34}\,U^{-1} + \underset{(.76)}{.011}\,RCHU + \underset{(8.95)}{.87}\,RCHDP \quad (4)$$

R^2 = .74 $\bar{R}^2$ = .72 F(4.52) = 36.92

$F_1(2,52)$ = 2.99 $F_2(2,52)$ = 41.17 $F_3(3,52)$ = 2.20

DW = 1.60

$$LDDW = \underset{(1.93)}{3.15} - \underset{(1.53)}{.19}\,U + \underset{(.20)}{.35}\,U^{-1} + \underset{(.76)}{.011}\,LDDU = \underset{(8.96)}{.87}\,LDDP \quad (5)$$

R^2 = .74 $\bar{R}^2$ = .72 F(4.52) = 36.88

$F_1(2,52)$ = 2.97 $F_2(2,52)$ = 41.22 $F_3(3,52)$ = 2.18

DW = 1.61

$$\text{JWDOT} = 1.90 - .10\ \text{JU} + 1.04\ \text{JU}^{-1} + .011\ \text{JUDOT} = .95\ \text{JPDOT} \qquad (6)$$

(1.64) (1.10) (.96) (1.19) (13.31)

$R^2 - .86$ $\bar{R}^2 = .85$ $F(4.52) = 79.11$

DW = 1.15

$$\text{LCHJW} = 1.93 - .098\ \text{JU} = 1.04\ \text{JU}^{-1} + .019\ \text{LCHJU} + .94\ \text{LCHLP} \qquad (7)$$

(1.71) (1.11) (1.00) (1.81) (13.43)

$R^2 = .86$ $\bar{R}^2 = .85$ $F(4.52) = 81.34$

$F_1(2,52) = 4.16$ $F_2(2,52) = 92.92$ $F_3(3,52) = 4.06$

DW = 1.16

****

$$\text{WDOT} = 1.12 + 3.62\ U^{-1} - 1.22\ U^{-2} + .016\ \text{UDOT} + .90\ \text{PDOT} \qquad (8)$$

(1.72) (1.58) (.91) (1.52) (14.44)

$R^2 = .83$ $\bar{R}^2 = .81$ $F(4,52) = 62.00$

$F_1(2,52) = 2.29$ $F_2(2,52) = 107.21$ $F_3(3,52) = 2.32$

DW = 1.27

$$\text{LCHW} = 1.18 + 3.24\ U^{-1} - .98\ U^{-2} + .022\ \text{LCHU} + .91\ \text{LCHP} \qquad (9)$$

(1.90) (1.50) (.78) (2.03) (14.98)

$R^2 = .84$ $\bar{R}^2 = .82$ $F(4,52) = 66.20$

$F_1(2,52) = 2.34$ $F_2(2,52) = 114.64$ $F_3(3,52) = 3.06$

DW = 1.25

$$\text{PCHDW} = .45 + 5.38\ U^{-1} - 1.96\ U^{-2} + .012\ \text{PCHDU} + .94\ \text{PCHDP} \qquad (10)$$

(.48) (1.62) (1.01) (.78) (11.08)

$R^2 = .74$ $\bar{R}^2 = .72$ $F(4,52) = 36.60$

$F_1(2,52) - 2.11$ $F_2(2,52) = 63.12$ $F_3(3,52) = 1.60$

DW = 1.70

$$\text{RCHDW} = .38 + 5.26\ U^{-1} - 1.89\ U^{-2} + .012\ \text{RCHU} + .93\ \text{RCHDP} \qquad (11)$$

(.42) (1.66) (1.02) (.78) (10.84)

$R^2 = .73$ $\bar{R}^2 = .71$ $F(4,52) = 35.70$

$F_1(2,52) = 2.28$ $F_2(2,52) - 60.28$ $F_3(3,52) = 1.72$

DW = 1.66

$$LDDW = .37 + 5.26\ U^{-1} - 1.88\ U^{-2} + .012\ LDDU + .93\ LDDP \qquad (12)$$
(.41) (1.66) (1.01) (.78) (10.84)

$R^2 - .73\ \bar{R}^2 = .71\ F(4,52) = 35.68$

$F_1(2,52) = 2.27\ F_2(2,52) = 60.39\ F_3(3,52) = 1.71$

DW = 1.66

$$JWDOT = .45 + 3.48\ JU^{-1} - .93\ JU^{-2} + .010\ JUDOT + .98\ JPDOT \qquad (13)$$
(.71) (1.68) (.82) (1.12) (16.05)

$R^2 = .86\ \bar{R}^2 = .85\ F(4,52) = 78.16$

$F_1(2,52) = 3.66\ F_2(2,52) = 130.50\ F_3(3,52) = 3.08$

DW = 1.17

$$LCHJW = .52 + 3.40\ JU^{-1} - .89\ JU^{-2} + .0L8\ LCHJU + .97\ LCHJP \qquad (14)$$
(.84() (1.70) (.81) (1.77) (16.22)

$R^2 = .86\ \bar{R}^2 = .85\ F(2,52) = 80.30$

$F_1(2,52) = 3.83\ F_2(2,52) = 134.26\ F_3(3,52) = 3.83$

DW = 1.18

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$$WDOT = 1.22 + 2.68\ U^{-1} - .21\ U^{-4} + .017\ UDOT + .91\ PDOT \qquad (15)$$
(2.07) (1.94) (.92) (1.58) (14.84)

$R^2 = .83\ \bar{R}^2 = .81\ F(2,52) = 62.02$

$F_1(2,52) = 2.29\ F_2(2,52) = 113.76\ F_3(3,52) = 2.32$

DW = 1.27

$$LCHW = 1.26 + 2.49\ U^{-1} - .17\ U^{-4} + .023\ LCHU + .91\ LCHP \qquad (16)$$
(2.24) (1.90) (.80) (2.08) (15.40)

$R^2 = .84\ \bar{R}^2 = .82\ F(4,52) = 66.24$

$F_1(2,52) = 2.36\ F_2(2,52) = 121.60\ F_3(3,52) = 3.07$

DW = 1.25

$$PCHDW = .67 + 3.66\ U^{-1} - .30\ U^{-4} + .013\ PCHDU + .95\ PCHDP \qquad (17)$$
(.77) (1.81) (.88) (.83) (11.36)

$R^2 = .74$ $\bar{R}^2 = .72$ $F(4,52) = 36.37$

$F_1(2,52) = 1.98$ $F_2(2,52) = 66.58$ $(F_3(3,52) = 1.51$

$DW = 1.71$

$$\underset{}{RCHDW} = \underset{(.71)}{.58} + \underset{(1.88)}{3.62}\ U^{-1} - \underset{(.90)}{.29}\ U^{-4} + \underset{(84)}{.012}\ RCHU + \underset{(11.14)}{.94}\ RCHDP \qquad (18)$$

$R^2 = .73$ $\bar{R}^2 = .71$ $F(4,52) = 35.50$

$F_1(2,52) = 2.16$ $F_2(2,52) = 63.91$ $F_3(3,52) = 1.64$

$DW = 1.68$

$$LDDW = \underset{(.70)}{.58} + \underset{(1.88)}{3.62}\ U^{-1} - \underset{(.90)}{.29}\ U^{-4} + \underset{(.84)}{.012}\ LDDU + \underset{(11.14)}{.94}\ LDDP \qquad (19)$$

$R^2 = .72$ $\bar{R}^2 = .71$ $F(4,52) = 35.48$

$F_1(2,52) = 2.15$ $F_2(2,52) = 63.92$ $F_3(3,52) = 1.63$

$DW = 1.68$

$$JWDOT = \underset{(.98)}{.56} + \underset{(2.16)}{2.60}\ JU^{-1} - \underset{(.73)}{.13}\ JU^{-4} + \underset{(1.09)}{.0098}\ JUDOT + \underset{(16.58)}{.99}\ JPDOT \qquad (20)$$

$R^2 = .86$ $\bar{R}^2 = .85$ $F(2,52) = 77.93$

$F_1(2,52) = 3.58$ $F_2(2,52) = 138.95$ $F_3(3,52) = 3.03$

$DW = 1.18$

$$LCHJM = \underset{(1.11)}{.62} + \underset{(2.21)}{2.58}\ JU^{-1} - \underset{(.74)}{.13}\ JU^{-4} + \underset{(1.76)}{.018}\ LCHJU + \underset{(16.75)}{.98}\ LCHJP \qquad (21)$$

$R^2 = .86$ $\bar{R}^2 = .85$ $F(4,52) = 80.13$

$F_1(2,52) = 3.78$ $F_2(2,52) = 143.03$ $F_3(3,52) = 3.79$

$DW = 1.19$

in the indeterminate range.[39] Now, as is well known,[40] positive serial correlation leads to inflated t and $\bar{R}^2$ values and so the apparent superiority of the fit in the first two equations may be spurious (and all of the t and $\bar{R}^2$ and F statistics are at least under the suspicion of being biased upwards).

Looking at individual coefficients we see that the five estimates of the coefficient on the expected inflation term are all very close to 0.87 but that there is greater variation amongst the estimates of the coefficients of the excess demand proxies, particularly between those for U and U^{-1}. A similar pattern emerges for the other two functional specifications (equations (11) - (15) and (21) - (25)).

The overall conclusion suggested by these estimates is that all five measures give broadly similar sets of results with the largest difference occurring between measures involving first central differences (either in natural numbers or natural logarithms) and those involving first differences. (The logarithmic difference and the rate of change measures are essentially identical.) Further the XDOT and LCHX formulations seem to induce first-order serial correlation to a greater extent than the first difference transformations.

Turning our attention to the differences between average rate of change measures and those which more clearly approximate instantaneous rates of change (equations (1) - (2) versus (6) - (7) etc.), we see that the latter equations give slightly better fits but also have lower DW statistics. Again there are differences between the coefficient estimates which are quite considerable irrespective of which specification we look at. However, in this case, the differences are to be expected since there are no a priori grounds for expecting an average and an instantaneous rate of change to be equal, even when all variables are rates of change are centred at the same point in time (the middle of year t).

Overall we may assess these results as indicating that although we must reject the argument that "since all of the (correctly aligned) rates of change measures are mathematically equivalent it is irrelevant which measure one uses," in practice the differences between the estimated equations are not sufficiently large to cause serious concern.

Before turning to the next sample let us evaluate the 1922-1978 regressions in terms of what they seem to indicate about the U.K. Phillips curve, using standard econometric criteria (overall fit, signs and significance of individual coefficients, and Durbin-Watson tests of first-order serial correlation).[41] From this point of view the most striking feature of these results is the remarkable similarity of the estimated equations for the three different functional forms. All of the signs of the coefficients are acceptable but only the expected inflation variable has a coefficient estimate which is consistently statistically significant at better than the 5% level. The excess demand proxies seldom have individual significance, although the F_1 statistic is close to significance at the 2-1/2% level for the U, U^{-1} formulation and at about a 7-1/2% level for the Lipsey pre- and post-World War One specifications. We have argued elsewhere (Sleeman, 1981) that there are problems with the standard Lipsey specifications. The first-order correlations for the U terms are presented in Table 4.4.

TABLE 4.4 First-Order Correlational Coefficients

	Annual Average	December	June
	1922-1978		
UU^{-1}	-0.67	-0.66	-0.66
$U^{-1}U^{-2}$	0.92	0.92	0.93
$U^{-1}U^{-4}$	0.76	0.76	0.78
	1922-38/1948-78		
UU^{-1}	-0.84	-0.84	-0.82
$U^{-1}U^{-2}$	0.97	0.96	0.97
$U^{-1}U^{-4}$	0.83	0.78	0.85
	1948-1978		
UU^{-1}	-0.89	-0.89	-0.87
$U^{-1}U^{-2}$	0.98	0.97	0.98
$U^{-1}U^{-4}$	0.88	0.83	0.90
	1948-1966		
UU^{-1}	-0.98	-0.96	-0.98
$U^{-1}U^{-2}$	0.99	0.99	0.995
$U^{-1}U^{-4}$	0.95	0.91	0.96
	1967-1979		
UU^{-1}	-0.98	-0.97	-0.97
$U^{-1}U^{-2}$	0.99	0.99	0.99
$U^{-1}U^{-4}$	0.96	0.94	0.96
	1922-1938		
UU^{-1}	-0.98	-0.97	-0.95
$U^{-1}U^{-2}$	0.99	0.99	0.98
$U^{-1}U^{-4}$	0.96	0.94	0.90

Taken at face falue these results do not suggest that excess demand terms have a major direct part to play in wage determination independent of any effects via their impacts on inflation expectations. It is also obvious, and hardly surprising, that over this fifty year period the inflationary expectations terms dominate the regression, indicating that the highly trended nominal variables in the economy tend to move together over time and that these movements dominate the impact of short run cyclical deviations from trend. We also note that none of the estimated inflation expectations coefficients is significantly different from unity.[42] Overall then our results are not inconsistent with the augmented Phillips curve approach although the unsatisfactory Durbin-Watson statistics indicate that the problem of serially correlated errors should be addressed before any firm conclusions are drawn.

Table 4.5 reports results for the peacetime years 1922-1938 and 1948-78.[43] These equations show a pattern which is basically similar to that of the whole period results, 1922-1978: the two first-central difference rate of change measures exhibit marginally better fits, but also have Durbin Watson statistics which lie within, or very close to, the indeterminate range at the 5% significance level ($DW^{L}_{4,45} = 1.34$, $DW^{U}_{4,45} = 1.72$; $DW^{L}_{4,50} = 1.38$, $DW^{U}_{4,50} = 1.72$ for a one-tail test), whereas the first difference rate of change measures equations all have DW values which are consistent with the null hypothesis of zero autocorrelation.[44] In general the signs of the coefficients are satisfactory, although the two negative coefficients on the U terms in equations (1) and (2) may be associated with a positively sloped, and difficult to interpret, Phillips curve for low levels of unemployment.

TABLE 4.5

1922-1938/ ORDINARY LEAST SQUARES
1948-1978 N=48

$$WDOT = 2.91 - .13\ U - 2.13\ U^{-1} + .014\ UDOT + 1.03\ PDOT \quad (1)$$
(1.39) (.95) (.68) (.65) (12.56)

$R^2 = .87$ $\bar{R}^2 = .86$ $F(4,45) = 76.70$

$F_1(2,45) = .47$ $F_2(1,45) = .14$ ** $F_3(3,45) = .44$

DW = 1.46

$$LCHW = 2.95 - .13\ U - 2.21\ U^{-1} + .0024\ LCHU + 1.03\ LCHP \quad (2)$$
(1.51) (.98) (.75) (.13) (13.38)

$R^2 = .88$ $\bar{R}^2 = .87$ $F(4,45) = 84.93$

$F_1(2,45) = .49$ $F_2(1,45) = .14$ ** $F_3(3,45) = .33$

DW = 1.43

$$PCHDW = -2.65 + .25\ U + 1.60\ U^{-1} - .034\ PCHDU + 1.67\ PCHDP \quad (3)$$
(.55) (.80) (.22) (.65) (11.27)

$R^2 = .79$ $\bar{R}^2 = .77$ $F(4,45) = 42.12$

$F_1(2,45) = .69$ $F_2\ (1,45) = 20.37$ ** $F_3(3,45) = .57$

DW = 1.65

$$RCHDW = 5.74 - .32\ U - 5.51\ U^{-1} + .012\ RCHU + 1.01\ RCHDP \quad (4)$$
(1.74)(1.46) (.98) (.28) (37.26)

$R^2 = .97$ $\bar{R}^2 = .97$ $F(4,45) = 379.83$

$F_1(2,45) = 1.17$ $F_2(1,45) = .21$ ** $F_3(3,45) = .83$

DW = 1.87

$$LDDW = 9.02 - .54\ U - 8.62\ U^{-1} + .021\ LDDU + .82\ LDDP \quad (5)$$
(2.38)(2.11) (1.33) (.42) (42.90)

$R^2 = .97$ $\bar{R}^2 = .97$ $F(4,45) = 379.83$

$F_1(2,45) = 1.17$ $F_2(1,45) = .21$ ** $F_3(3,45) = .83$

DW = 1.87

$$LDDW = 9.02 - .54\ U - 8.62\ U^{-1} + .021\ LDDU + .82\ LDDP \quad (5)$$
(2.38)(2.11) (1.33) (.42) (42.90)

$R^2 = .98$ $\bar{R}^2 = .98$ $F(4,45) = 505.65$

$F_1(2,45) = 2.54$ $F_2(1,45) = 94.57$ ** $F_3(3,45) = 1.83$

DW = 1.87

$$LDDW = 9.02 - .54\ U - 8.62\ U^{-1} + .021\ LDDU + .82\ LDDP \quad (5)$$
(2.38) (2.11) (1.33) (.42) (42.90)

$R^2 = .98$ $\bar{R}^2 = .98$ $F(4,45) = 505.65$

$F_1(2,45) = 2.54$ $F_2(1,45) = 94.57$ ** $F_3(3,45) = 1.83$

DW = 1.87

$$JWDOT = 2.96 + .56\ JU + 1.24\ JU^{-1} + .12\ JUDOT + .50\ JPDOT \quad (6)$$
(.57) (.16) (.18) (2.38) (2.18)

$R^2 = .28$ $\bar{R}^2 = .21$ $F(3,45) = 4.27$

$F_1(2,45) = .02$ $F_2(1,45) = 4.89$ ** $F_3(3,45) = 1.97$

DW = 1.29

$$LCHJW = 5.56 - .0092\ JU + 2.28\ JU + .49\ LCHJU - .22\ LCHJP \quad (7)$$
(.56) (.013) (.18) (6.57) (.52)

$R^2 = .50$ $\bar{R}^2 = .46$ $F(4,45) = 11.27$

$F_1(2,45) = .05$ $F_2(1,45) = 8.16$ ** $F_3(3,45) = 14.54$

DW = 1.17

****

$$WDOT = .068 + 9.76\ U^{-1} - 12.13\ U^{-2} + .015\ UDOT + 1.03\ PDOT \quad (8)$$
(.070) (1.37) (1.36) (.69) (14.18)

$R^2 = .87$ $\bar{R}^2 - .86$ $F(4,45) = 78.49$

$F_1(2,45) = .94$ $F_2(1,45) = .22$ ** $F_3(3,45) = .76$

DW = 1.50

$$LCHW = .23 + 9.14\ U^{-1} - 11.55\ U^{-2} - .0024\ LCHU + 1.03\ LCHP \quad (9)$$
(.25) (1.37) (1.38) (.12) (15.21)

$R^2 = .88$ $\bar{R}^2 = .88$ $F(4,45) = 86.91$

$F_1(2,45) = .96$ $F_2(1,45) = .24$ ** $F_3(3,45) = .65$

DW = 1.48

$$PCHDW = \underset{(.30)}{.66} - \underset{(.019)}{.32}\ U^{-1} - \underset{(.19)}{4.01}\ U^{02} - \underset{(.61)}{.032}\ PCHDU + \underset{(11.52)}{1.60}\ PCHDP \qquad (10)$$

$R^2 = .79$ $\bar{R}^2 = .77$ $F(4,45) = 41.41$

$F_1(2,45) = .38$ $F_2(1,45) = 18.54$ ** $F_3(3,45) = .37$

DW = 1.64

$$RCHDW = \underset{(.48)}{-.86} + \underset{(1.81)}{21.59}\ U^{-1} - \underset{(1.76)}{27.13}\ U^{-2} + \underset{(.35)}{.015}\ RCHU + \underset{(35.67)}{1.01}\ RCHDP \qquad (11)$$

$R^2 = .97$ $\bar{R}^2 = .97$ $F(4,45) = 387.72$

$F_1(2,45) = 1.65$ $F_2(1,45) = .16$ ** $F_3(3,45) = 1.15$

DW = 1.91

$$LDDW = -1.48 + 31.74\ U^{-1} - 38.75\ U^{02} + .027\ LDDU + .81\ LDDP \qquad (12)$$

$R^2 = .98$ $\bar{R}^2 = .98$ $F(4,45) = 507.78$

$F_1(2,45) = 2.64$ $F_2(1,45) = 98.64$ ** $F_3(3,45) = 1.90$

DW = 1.92

$$JWDOT = \underset{(.68)}{1.66} + \underset{(1.16)}{18.62}\ JU^{-1} - \underset{(1.17)}{20.25}\ JU^{02} + \underset{(2.61)}{.13}\ JUDOT + \underset{(1.91)}{.37}\ JPDOT \qquad (13)$$

$R^2 = .30$ $\bar{R}^2 = .23$ $F(4,45) = 4.73$

$F_1(2,45) = .68$ $F_2(1,45) = 10.30$ ** $F_3(3,45) = 2.47$

DW = 1.32

$$LCHJW = \underset{(.46)}{2.15} + \underset{(1.03)}{31.44}\ JU^{-1} - \underset{(.98)}{32.24}\ JU^{-2} + \underset{(6.71)}{.49}\ LCHJU - \underset{(1.02)}{.37}\ LCHJP \qquad (14)$$

$R^2 = .51$ $\bar{R}^2 = .47$ $F(4,45) = 11.75$

$F_1(2,45) = .54$ $F_2(1,45) = 14.01$ ** $F_3(3,45) = 15.18$

DW = 1.18
****

$$WDOT = .65 + 2.90\ U^{-1} - 6.61\ U^{-4} + .015\ UDOT + 1.06\ PDOT \qquad (15)$$
(.85) (.91) (.94) (.70) (15.22)

$R^2 = .87$ $\bar{R}^2 = .86$ $F(4,45) = 76.68$

$F_1(2,45) = .47$ $F_2(1,45) = .68$ ** $F_3(3,45) = .44$

DW = 1.50

$$LCHW = .80 + 2.48\ U^{-1} - 5.96\ U^{-4} - .0017\ LCHU + 1.06\ LCHP \qquad (16)$$
(1.11) (.83) (.91) (.088) (16.32)

$R^2 = .88$ $\bar{R}^2 = .87$ $F(4,45) = 84.64$

$F(2,45) = .42$ $F(1,45) = .77$ ** $F(3,45) = .28$

DW = 1.47

$$PCHDW = .70 - 1.53\ U^{-1} - 4.97\ U^{-4} - .032\ PCHDU + 1.60\ PCHDP \qquad (17)$$
(.38) (.21) (.30) (.60) (12.14)

$R^2 = .79$ $R^2 = .77$ $F(4,45) = 41.48$

$F_1(2,45) = .41$ $F_2(1,45) = 20.59$ ** $F_3(3,45) = .38$

DW = 1.64

$$RCHDW = .37 + 7.25\ U^{-1} - 16.34\ U^{-4} + .018\ RCHU + 1.01\ RCHDP \qquad (19)$$
(.25) (1.30) (1.27) (.42) (37.07)

$R^2 = .97$ $\bar{R}^2 = .97$ $F(4,45) = 375.41$

$F_1(2,45) = .90$ $F_2(1,45) = .14$ ** $F_3(3,45) = .65$

DW = 1.91

$$LDDW = .36 + 10.87\ U^{-1} = 22.36\ U^{-4} + .032\ LDDU + .81\ LDDP \qquad (19)$$
(.20) (1.66) (1.48) (.63) (42.02)

$R^2 = .98$ $\bar{R}^2 = .98$ $F(4,45) = 481.87$

$F_1(2,45) = 1.39$ $F_2(1,45) = 95.46$ ** $F_3(3,45) = 1.05$

DW = 1.90

$$JWDOT = 2.61 + 7.18\ JU^{-1} - 11.18\ JU^{-4} + .13\ JUDOT + .41\ JPDOT \qquad (20)$$
(1.30) (.94) (1.03) (2.61) (2.22)

$R^2 = .29$ $\bar{R}^2 = .23$ $F(4,45) = 4.63$

$F_1(2,45) = .54$ $F_2(1,45) = 10.03$ ** $F_3(3,45) = 2.36$

DW = 1.30

$$LCHJW = \underset{(.89)}{3.42} + \underset{(1.02)}{14.63}\ JU^{-1} - \underset{(.99)}{10.10}\ JU^{-4} + \underset{(6.74)}{.50}\ LCHJU - \underset{(.92)}{.32}\ LCHJP \qquad (21)$$

$R^2 = .51$ $\bar{R}^2 = .47$ $F(4,45) = 11.76)$

$F_1(2,45) = .55$ $F_2(1,45) = 14.45$ ** $F_3\ (3,45) = 15.19$

DW = 1.17

****

Once again the low t-values (and questionable signs) of the excess demand proxies are probably the consequence of mis-specification. Another feature shared by this set of data and the whole period regressions is the absence of negative constant terms. All of the intercept terms are positive although most of them are not statistically significant at much better than the 5% level.

A comparison of Tables 4.4 and 4.6 shows that the two sets of results are broadly similar with some evidence of an improvement in fit when the effects of the Second World War are removed. There are, however, quite large changes in coefficient estimates between the two samples most notably in those coefficients associated with the excess demand proxies.

Table 4.6 contains the results for the full post-Second World War period: 1948-1978. This set of results shows a similar pattern to those examined above. Although the overall fit of the equations is satisfactory (with about 75% of the variation of the dependent variable being explained by variation in the independent variables), the lack of individual and joint significance of the excess demand terms gives cause for alarm.

On the whole the results in Table 4.3, 4.5 and 4.6 (where the samples contained thirty or more observations) suggest that, although we would have to reject the extreme (and somewhat implausible) view that there is no difference between the various rates measures -- so long as they are correctly centred -- the observed differences in the well determined coefficients are negligible and that the large variations in the estimates of the excess demand proxies reflect specification

TABLE 4.6

1948-1978	ORDINARY LEAST SQUARES	N = 31

$$WDOT = \underset{(2.19)}{10.12} - \underset{(1.54)}{1.27}\ U - \underset{(1.81)}{10.41}\ U^{-1} + \underset{(1.42)}{.038}\ UDOT + \underset{(6.78)}{.96}\ PDOT \quad (1)$$

$R^2 = .80$ $\bar{R}^2 = .76$ $F(4,26) = 25.17$

$F_1(2,26) = 1.64$ $F_2(2,26) = 30.05$ $F_3(3,26) = 1.80$

DW = 1.56

$$LCHW = \underset{(2.20)}{9.76} - \underset{(1.54)}{1.23} - \underset{(1.81)}{10.01}\ U^{-1} + \underset{(1.22)}{.034}\ LCHU + \underset{(6.99)}{.96}\ LCHP \quad (2)$$

$R^2 = .80$ $\bar{R}^2 = .79$ $F(4,26) = 26.62$

$F_1(2, 26) = 1.49$ $F_2(2, 26) = 10.17$ $F_3(2, 26) = 0.76$

DW = 1.54

$$PCHDW = \underset{(1.74)}{10.54} - \underset{(1.21)}{1.30}\ U - \underset{(1.45)}{10.99}\ U^{-1} + \underset{(.37)}{.014}\ PCHDU + \underset{(6.56)}{.98}\ PCHDP \quad (3)$$

$R^2 = .75$ $\bar{R}^2 = .71$ $F(4,26) = 19.57$

$F_1(2,26) = 1.06$ $F_2(2,26) = 26.71$ $F_3(3,26) = .76$

DW = 1.92

$$RCHDW = \underset{(1.76)}{9.36} - \underset{(1.17)}{1.11}\ U - \underset{(1.43)}{9.51}U^{-1} + \underset{(.42)}{.014}\ RCHU + \underset{(6.49)}{.95}\ RCHDP \quad (4)$$

$R^2 = .75$ $\bar{R}^2 = .71$ $F(4,26) = 19.44$

$F_1(2,26) = 1.03$ $F_2(2,26) = 26.28$ $F_3(3,26) = .76$

DW = 1.91

$$LDDW = \underset{(1.76)}{9.40} - \underset{(1.17)}{1.12}\ U - \underset{(1.43)}{9.57}\ U^{-1} + \underset{(.42)}{.014}\ LDDU + \underset{(6.50)}{.95}\ LDDP \quad (5)$$

$R^2 = .75$ $\bar{R}^2 = .71$ $F(4,26) - 19.45$

$F_1(2,26) = 1.03$ $F_2(2,26) = 26.32$ $F_3(3,26) = .76$

DW = 1.91

$$JWDOT = 7.62 - 1.10\ JU - 6.66\ JU^{-1} - .021\ JUDOT + 1.07\ JPDOT \qquad (6)$$

(2.47) (1.90) (1.96) (1.09) (10.30)

$R^2 = .87$ $\bar{R}^2 = .85$ $F(4.26) = 42.38$

$F_1(2,26) = 2.06$ $F_2(2,26) = 57.84$ $F_3(3,26) = 1.86$

$DW = 1.38$

$$LCHJW = 7.50 - 1.05\ JU - 6.63\ JU^{-1} - .024\ LCHJU + 1.07\ LCHJP \qquad (7)$$

(2.50) (1.84) (2.00) (1.20) (10.40)

$R^2 = .87$ $\bar{R}^2 = .85$ $F(4,26) = 42.98$

$F_1(2,26) = 2.06$ $F_2(2,26) = 57.42$ $F_3(3,26) = 1.84$

$DW = 1.34$

****

$$WDOT = 1.09 + 7.87\ U^{-1} - 10.70\ U^{-2} + .040\ UDOT + .93\ PDOT \qquad (9)$$

(.24) (.48) (.67) (1.45) (6.01)

$R^2 = .78$ $\bar{R}^2 = .75$ $F(4,26) = 23.03$

$F_1(2,26) = .65$ $F_2(2,26) = 23.42$ $F_3(3,26) = 1.09$

$DW = 1.50$

$$LCHW = 1.43 + 6.18\ U^{-1} - 8.92\ U^{-2} + .036\ LCHU + .93\ LCHP \qquad (9)$$

(.32) (.38) (.58) (1.29) (6.10)

$R^2 = .79$ $\bar{R}^2 = .76$ $F(4,26) = 24.24$

$F_1(2,26) = .59$ $F_2(2,26) = 23.60$ $F_3(3,26) = .94$

$DW = 1.47$

$$PCHDW = 1.50 + 6.61\ U^{-1} - 9.73\ U^{-2} + .016\ PCHDU + .96\ PCHDP \qquad (10)$$

(.27) (.32) (.48) (.44) (5.91)

$R^2 = .74$ $\bar{R}^2 = .70$ $F(4,26) = 18.39$

$F_1(2,26) = .42$ $F_2(2,26) = 21.46$ $F_3(3,26) = .34$

$DW = 1.87$

$$RCHDW = 1.96 + 4.31\ U^{-1} - 7.14\ U^{-2} + .016\ RCHU + .93\ RCHDP \qquad (11)$$

(.39) (.23) (.40) (.49) (5.80)

$R^2 = .74$ $\bar{R}^2 = .70$ $F(4,26) = 18.29$

$F_1(2,26) = .41$ $F_2(2,26)$ $F_3(3,26) = .34$

DW = 1.86

$$LDDW = \underset{(.38)}{1.97} + \underset{(.24)}{4.45}\ U^{-1} - \underset{(.40)}{7.29}\ U^{02} + \underset{(.49)}{.016}\ LDDU + \underset{(5.80)}{.93}\ LDDP \qquad (12)$$

$R^2 = .74$ $\bar{R}^2 = .70$ $F(4,26) = 18.30$

$F_1(2,26) = .41$ $F_2(2,26) = 20.75$ $F_3(3,26) = .34$

DW = 1.86

$$JWDOT = \underset{(.10)}{.32} + \underset{(.66)}{6.83}\ JU^{-1} - \underset{(.81)}{7.17}\ JU^{-2} - \underset{(.94)}{.019}\ JUDOT + \underset{(9.31)}{1.05}\ JPDOT \qquad (13)$$

$R^2 = .85$ $\bar{R}^2 = .83$ $F(4.26) = 37.52$

$F_1(2,26) = .56$ $F_2(2,26) = 45.87$ $F_3(3,26) = .81$

DW = 1.32

$$LCHJW = \underset{(.24)}{.75} + \underset{(.54)}{5.50}\ JU^{-1} - \underset{(.71)}{6.19}\ JU^{-2} - \underset{(1.02)}{.021}\ LCHJU + \underset{(9.30)}{1.04}\ LCHJP \qquad (14)$$

$R^2= .85$ $\bar{R}^2 = 83$ $F(4,26) = 38.13$

$F_1(2,26) = .59$ $F_2(2,26) = 44.85$ $F_3(3,26) = .81$

DW = 1.28

****

$$WDOT = \underset{(.98)}{3.52} - \underset{(.29)}{2.29}\ U^{-1} - \underset{(.11)}{1.11}\ U^{-4} + \underset{(1.44)}{.040}\ UDOT + \underset{(5.67)}{.89}\ PDOT \qquad (15)$$

$R^2 = .78$ $\bar{R}^2 = .74$ $F(4,26) = 22..53$

$F_1(2,26) = .42$ $F_2(2,26) = 20.80$ $F_3(3,26) = .93$

DW = 1.47

$$LCHW = \underset{(1.07)}{3.45} - \underset{(.40)}{2.99}\ U^{-1} + \underset{(.007)}{.071}\ U^{-4} + \underset{(1.30)}{.037}\ LCHU + \underset{(5.76)}{.89}\ LCHP \qquad (16)$$

$R^2 = .78$ $\bar{R}^2 = 00.00$ $F(4,26) = 23.85$

$F_1(2,26) = .62$, $F_2(2, 26) = 21.28$ $F_3(2,26) = 0.93$

DW = 1.44

$$PCHDW = 3.68 - 2.73\ U^{-1} - .66\ U^{-4} + .017\ PCHDU + .93\ PCHDP \quad (17)$$
(.88) (.28) (.049) (.45) (5.67)

$R^2 = .74$ $R^2 = .70$ $F(4,26) = 18.18$

$F_1(2,26) = .31$ $F_2(2,26) = 19.57$ $F_3(3,26) = .26$

DW = 1.86

$$RCHDW = 3.83 - 3.19\ U^{-1} + .48\ U^{-4} + .017\ RCHU + .89\ RCHDP \quad (18)$$
(1.02` (.38) (.041) (.51) (5.55)

$R^2 = .74$ $\bar{R}^2 = .70$ $F(4,26) = 18.14$

$F_1(2,26) = .33$ $F_2(2,26) = 18.86$ $F_3(3,26) = .29$

DW = 1.84

$$LDDW = 3.80 - 3.14\ U^{-1} + .40\ U^{-4} + .017\ LDDU + .90\ LDDP \quad (19)$$
(1.01) (.37) (.034) (.50) (5.56)

$R^2 = .74$ $\bar{R}^2 = .70$ $F(4.26) - 18.15$

$F_1(2,26) = .33$ $F_2(2,26) = 18.91$ $F_3(3,26) = .29$

DW = 1.84

$$JWDOT = 1.92 + .050\ JU^{-1} - 1.49\ JU^{-4} - .019\ JUDOT + 1.03\ JPDOT \quad (20)$$
(.75) (.0096) (.31) (.96) (8.96)

$R^2 = .85$ $\bar{R}^2 = .83$ $F(4,26) = 36.59$

$F_1(2,26) = .27$ $F_2(2,26) = 41.85$ $F_3\ (3,26) = .61$

DW = 1.29

$$LCHJW = 2.27 - .65\ JU^{-1} - 1.01\ JU^{-4} - .022\ LCHJU + 1.02\ LCHJP \quad (21)$$
(.89) (.13) (.21) (1.03) (8.94)

$R^2 = .85$ $\bar{R}^2 = .83$ $F(4,26) = 37.36$

$F_1(2,26) = .35$ $F_2(2,26) = 40.91$ $F_3(3,26) = .64$

DW = 1.25

****

problems rather than differences arising from the use of different rates of change formulae. The next three tables, 4.7 to 4.9 all deal with smaller samples where, in fact, we have less than fifteen degrees of freedom.

Turning to Table 4.7, which reports results for the post-war period up to the "structural break," (which is often assumed to have manifested itself in the U.K. about 1966) we notice a reversal of our previous pattern of fit/autocorrelation for the first central proportional difference relative to the first difference measures. In this table the XDOT and LCHX formulations have much worse fits than the PCHX, RCHX and LDX equations, but now it is the first two equations which have satisfactory Durbin-Watson statistics whereas equations (3) - (5) have DW-statistics which are in the indeterminate range for negative serial correlation. What is even more interesting from our point of view is the large differences in the coefficient estimates of the rate of change of unemployment and inflation variables. In equations (1) and (2) the acceleration coefficient is not significantly different from zero (with an actual estimated value of 0.28), while the rate of change of excess demand has a coefficient which is significant at a 5% level (with an estimated value of 0.056). In equations (3) - (5) the acceleration coefficient has an estimated value of 0.43 which is significant at the 1% level, while the rate of change of unemployment coefficient is only one third as large as the previous estimate (although it is not sigificantly different from zero even at the 10% level).[45]

As usual the excess demand variables are uniformly poorly determined although most of them now have t-values greater than one and

TABLE 4.7

1948-1966 ORDINARY LEAST SQUARES N=19

$$WDOT = \underset{(.48)}{-12.61} + \underset{(.62)}{4.54}\ U + \underset{(.64)}{14.77}\ U^{-1} + \underset{(1.88)}{.056}\ UDOT + \underset{(.69)}{.28}\ PDOT \qquad (1)$$

$R^2 = .30$ $\bar{R}^2 = .10$ $F(4,14) = 1.50$

$F_1(2,14) = .20$ $F_2(2,14) = 2.16$ $F_3(3,14) = 1.44$

DW = 2.09

$$LCHW = \underset{(.74)}{-17.84} + \underset{(.89)}{5.96}\ U + \underset{(.91)}{19.33}\ U^{-1} + \underset{(1.90)}{.056}\ LCHU + \underset{(.76)}{.28}\ LCHP \qquad (2)$$

$R^2 = .33$ $\bar{R}^2 = .13$ $F(4,14) = 1.70$

$F_1(2,14) = .41$ $F_2(2,14) = 2.29$ $F_3(3,14) = 1.58$

DW = 2.04

$$PCHDW = \underset{(1.21)}{-16.43} + \underset{(1.24)}{4.66}\ U + \underset{(1.65)}{19.77}\ U^{-1} + \underset{(1.13)}{.018}\ PCHDU + \underset{(2.97)}{.43}\ PCHDP \qquad (3)$$

$R^2 = .70$ $\bar{R}^2 = .62$ $F(4,14) = 8.29$

$F_1(2,14) = 2.37$ $F_2(2,14) = 5.98$ $F_3(3,14) = 2.11$

DW = 2.46

$$RCHDW = \underset{(1.19)}{-15.39} + \underset{(1.22)}{4.39}\ U + \underset{(1.62)}{18.63}\ U^{-1} + \underset{(1.13)}{.017}\ RCHU + \underset{(2.92)}{.43}\ RCHDP \qquad (4)$$

$R^2 = .70$ $\bar{R}^2 = .61$ $F(4,14) = 8.03$

$F_1(2,14) = 2.29$ $F_2(2,14) = 5.78$ $F_3(3,14) = 2.05$

DW = 2.46

$$LDDW = \underset{(1.19)}{-15.412} + \underset{(1.22)}{4.40}\ U + \underset{(1.62)}{18.65}\ U^{-1} + \underset{(1.13)}{.07}\ LDDU + \underset{(2.92)}{.43}\ LDDP \qquad (5)$$

$R^2 = .70$ $\bar{R}^2 = .61$ $F(4,14) = 8.04$

$F_1(2,14) = 2.29$ $F_2(2,14) = 5.79$ $F_3(3,14) = 2.06$

DW = 2.46

$$JWDOT = -22.89 + 7.56\ JU + 21.58\ JU^{-1} - .027\ JUDOT + .41\ JPDOT \quad (6)$$
$$(2.89)\quad(3.08)\quad(3.48)\quad(3.20)\quad(4.32)$$

$R^2 = .80$ $\bar{R}^2 = .74$ $F(4,14) = 13.98$

$F_1(2,14) = 7.59$ $F_2(2,14) = 12.28$ $F_3(3,14) = 6.44$

$DW = 1.06$

$$LCHJW = -23.41 + 7.79\ JU + 21.84\ JU^{-1} - .028\ LCHJU + .40\ LCHJP \quad (7)$$
$$(2.93)\quad(3.14)\quad(3.50)\quad(3.05)\quad(4.23)$$

$R^2 = .80$ $\bar{R}^2 = .74$ $F(4,14) = 13.96$

$F_1(2,14) = 7.46$ $F_2(2,14) = 11.85$ $F_3(3,14) = 6.32$

$DW = 1.01$

****

$$WDOT = 14.46 - 36.70\ U^{-1} + 31.40\ U^{-2} + .055\ UDOT + .26\ PDOT \quad (8)$$
$$(1.12)\quad(.84)\quad(.86)\quad(1.89)\quad(.67)$$

$F_1(2,14) = .59$ ($F_2(2,14) = 2.17$ $F_3(3,14) = 1.59$

$R^2 = .32$ $\bar{R}^2 = .12$ $F(4,14) = 1.62$

$DW = 2.09$

$$LCHW = 15.85 - 41.87\ U^{-1} + 35.88\ U^{-2} + .056\ LCHU + .27\ LCHP \quad (9)$$
$$(1.32)\quad(1.04)\quad(1.07)\quad(1.90)\quad(.75)$$

$R^2 = .34$ $\bar{R}^2 = .15$ $F(4,14) = 1.82$

$F_1(2,14) = .59$ $F_2(2,14) = 2.29$ $F_3(3,14) = 1.73$

$DW = 2.04$

$$PCHDW = 8.03 - 21.66\ U^{-1} + 22.70\ U^{-2} + .018\ PCHDU + .43\ PCHDP \quad (10)$$
$$(1.18)\quad(.94)\quad(1.19)\quad(1.15)\quad(2.95)$$

$R^2 = .70$ $\bar{R}^2 = .62$ $F(4,14) = 8.20$

$F_1(2,14) = 2.30$ $F_2(2,14) = 5.95$ $F_3(3,14) = 2.06$

$DW = 2.42$

$$RCHDW = 7.68 - 20.45\ U^{-1} + 21.41\ U^{-2} + .017\ RCHU + .43\ RCHDP \quad (11)$$
$$(1.18)\quad(.93)\quad(1.17)\quad(1.15)\quad(2.89)$$

$R^2 = .69$ $\bar{R}^2 = .61$ $F(4,14) = 7.94$

$F_1(2,14) = 2.22$ $F_2(2,14) = 5.75$ $F_3(3,14) = 2.00$

DW = 2.42

$$LDDW = \underset{(1.18)}{7.69} - \underset{(.93)}{20.47}\ U^{-1} + \underset{(1.17)}{21.43}\ U^{-2} + \underset{(1.14)}{.017}\ LDDU + \underset{(2.90)}{.43}\ LDDP \quad (12)$$

$R^2 = .69$ $\bar{R}^2 = .61$ $F(4,14) = 7.95$

$F_1(2,14) = 2.22$ $F_2(2,14) = 5.76$ $F_3(3,14) = 2.00$

DW = 2.42

$$JWDOT = \underset{(3.31)}{12.89} - \underset{(2.77)}{32.91}\ JU^{-1} + \underset{(3.01)}{26.79}\ JU^{-2} - \underset{(3.10)}{.026}\ JUDOT + \underset{(4.30)}{.41}\ JPDOT \quad (13)$$

$R^2 = .80$ $\bar{R}^2 = .74$ $F(4,14) = 13.66$

$F_1(2,14) = 7.32$ $F_2(2,14) = 11.86$ $F_3(3,14) = 6.24$

DW = .88

$$LCHJW = \underset{(3.32)}{13.24} - \underset{(2.76)}{33.62}\ JU^{-1} + \underset{(2.88)}{27.10}\ JU^{-2} - \underset{(4.17)}{.027}\ LCHJU + .40\ LCHJP \quad (14)$$

$R^2 = .79$ $\bar{R}^2 = .73$ $F(4,14) = 13.31$

$F_1(2,14) = 6.92$ $F_2(2,14) = 11.12$ $F_3(3,14) = 5.91$

DW = .85

****

$$WDOT = \underset{(1.39)}{9.74} - \underset{(.86)}{13.23}\ U^{-1} + \underset{(.97)}{15.15}\ U^{-4} + \underset{(1.92)}{.056}\ UDOT + \underset{(.67)}{.26}\ PDOT \quad (15)$$

$R^2 = .33$ $\bar{R}^2 = .13$ $F(4,14) = 1.69$

$F_1(2,14) = .48$ $F_2(2,14) = 2.33$ $F_3(3,14) = 1.67$

DW = 2.10

$$LCHW = \underset{(1.55)}{10.11} - \underset{(.99)}{14.35}\ U^{-1} + \underset{(1.14)}{16.45}\ U^{-4} + \underset{(1.92)}{.056}\ LCHU + \underset{(.75)}{.27}\ LCHP \quad (16)$$

$R^2 = .35$ $\bar{R}^2 = .16$ $F(4,14) = 1.88$

$F_1(1,14M) = .67$ $F_2(2,14) = 2.34$ $F_3(3,14) = 1.80$

DW = 2.05

$$PCHDW = \underset{(1.07)}{3.98} - \underset{(.40)}{3.28}\ U^{-1} + \underset{(1.13)}{9.37}\ U^{-4} + \underset{(1.18)}{.018}\ PCHDU + \underset{(2.95)}{.43}\ PCHDP \quad (17)$$

$R^2 = .70$ $\bar{R}^2 = .61$ $F(4,14) = 8.10$

$F_1(2,14) = 2.22$ $F_2(2,14) = 6.01$ $F_3(3,14) = 2.00$

$DW = 2.40$

$$RCHDW = \underset{(1.08)}{3.86} - \underset{(.39)}{3.12}\ U^{-1} + \underset{(1.11)}{8.84}\ U^{-4} + \underset{(1.17)}{.018}\ RCHU + \underset{(2.89)}{.43}\ RCHDP \quad (18)$$

$R^2 = .69$ $\bar{R}^2 = .60$ $F(4,14) = 7.84$

$F_1(2,14) = 2.14$ $F_2(2,14) = 5.81$ $F_3(3,14) = 1.95$

$DW = 2.40$

$$LDDW = \underset{(1.08)}{3.86} - \underset{(.39)}{3.12}\ U^{-1} + \underset{(1.11)}{8.85}\ U^{-4} + \underset{(1.17)}{.018}\ LDDU + \underset{(2.89)}{.43}\ LDDP \quad (19)$$

$R^2 = .69$ $\bar{R}^2 = .60$ $F(4,14) = 7.85$

$F_1(2,14) = 2.14$ $F_2(2,14) = 5.82$ $F_3(3,14) = 1.95$

$DW = 2.40$

$$JWDOT = \underset{(3.33)}{7.03} - \underset{(2.10)}{8.84}\ JU^{-1} + \underset{(2.88)}{8.98}\ JU^{-4} - \underset{(2.95)}{.025}\ JUDOT + \underset{(4.20)}{.41}\ JPDOT \quad (20)$$

$R^2 = .79$ $\bar{R}^2 = .73$ $F(4,14) = 13.05$

$F_1(2,14) = 6.81$ $F_2(2,14) = 11.11$ $F_3(3,14) = 5.86$

$DW = .82$

$$LCHJW = \underset{(3.34)}{7.26} - \underset{(2.12)}{9.16}\ JU^{-1} + \underset{(2.82)}{9.00}\ JU^{-4} - \underset{(2.72)}{.026}\ LCHJU + \underset{(4.07)}{.40}\ LCHJP \quad (21)$$

$R^2 = .78$ $\bar{R}^2 = .72$ $F(4,14) = 12.60$

$F_1(2,14) - 6.33$ $F_2(2,14) = 10.32$ $F_3(3,14) = 5.46$

$DW = .81$

****

so, following an R^2 maximisation strategy, they would normally not be dropped from the equations. Also there is almost no difference in the results as we move from one specification to another which is, again, consistent with our previous results. Further, a comparison between the average rates of change and the instantaneous rates of change equations ((1) - (2) versus (6) - (7) etc.) indicates the familiar pattern of better overall fit and individually significant coefficients for all variables combined with extremely low Durbin-Watson statistics for the average rates of change specifications.

Table 4.8 contains the results for the post-1966 period. There are only 12 observations in the sample and so we would again expect quite large differences between our parameter estimates. Equations (1) and (2), (8) and (9), and (15) and (16) all exhibit reasonable fits somewhat marred by Durbin-Watson statistics in the indeterminate range. The coefficients on the U variables are significant at the 2-1/2% level or better, but the U^{-1} U^2 and U^{-1} U^{-4} specifications lead to numerical estimates which are bizarre. (The simple correlations between U^{-1} and U^{-2} and U^{-1} and U^{-4} are .99 and .96 respectively.) The first difference equations ((3) - (5) etc.) have less impressive fits but also Durbin-Watson statistics which are almost exactly equal to the 5%, one-tail, upper bound of 2.177. An examination of the estimated coefficients for the fifteen average rates of change equations shows that they vary more widely than for the larger samples (as is to be expected).

The instantaneous rates of change equations have better Durbin-Watson's than the average rates of change equations but are otherwise quite similar. Once again the conventional criteria do not provide any

TABLE 4.8

1967-1978 ORDINARY LEAST SQUARES N-12

$$WDOT = 45.58 - 5.51\,U - 73.41\,U^{-1} - .056\,UDOT + .99\,PDOT \quad (1)$$
$$\quad (2.41)\ (2.56)\quad (2.14)\quad (1.18)\quad (6.04)$$

$R^2 = .90$ $\bar{R}^2 = .85$ $F(4,7) = 16.81$

$F_1(2,7) = 4.53$ $F_2(2,7) = 18.94$ $F_3(2,7) = 3.14$

DW = 1.69

$$LCHW = 46.72 - 5.61\,U - 75.64\,U^{-1} - .055\,LCHU + .98\,LCHP \quad (2)$$
$$\quad (2.66)\ (2.82)\quad (2.37)\quad (1.27)\quad (6.28)$$

$R^2 = .92$ $\bar{R}^2 = .87$ $F(4,7) = 19.54$

$F_1(2,7) = 5.39$ $F_2(2,7) = 20.41$ $F_3(3,7) = 3.79$

DW = 1.67

$$PCHDW = 45.79 - 5.42\,U - 70.56\,U^{-1} - .016\,PCHDU + .88\,PCHDP \quad (3)$$
$$\quad (.85)\ (.89)\quad (.72)\quad (.11)\quad (2.22)$$

$R^2 = .66$ $\bar{R}^2 = .46$ $F(4,7) = 3.34$

$F_1(2,7) = .67$ $F_2(2,7) = 3.31$ $F_3(3,7) = .44$

DW = 2.18

$$RCHDW = 43.01 - 5.02\,U - 66.54\,U^{-1} - .013\,RCHU + .84\,RCHDP \quad (4)$$
$$\quad (.93)\ (.96)\quad (.79)\quad (.11)\quad (2.17)$$

$R^2 = .65$ $\bar{R}^2 = .45$ $F(4,7) = 3.28$

$F_1(2,7) = .72$ $F_2(2,7) = 3.10$ $F_3(3,7) = .48$

DW = 2.16

$$LDDW = 43.00 - 5.02\,U - 66.49\,U^{-1} - .013\,LDDU + .84\,LDDP \quad (5)$$
$$\quad (.92)\ (.96)\quad (.78)\quad (.11)\quad (2.17)$$

$R^2 = .65$ $\bar{R}^2 = .45$ $F(4,7) = 3.28$

$F_1(2,7) = .72$ $F_2(2,7) = 3.11$ $F_3(3,7) = .48$

DW = 2.17

$$JWDOT = 37.92 - \underset{(2.11)}{4.89}\ JU - \underset{(2.18)}{55.90}\ JU^{-1} - \underset{(1.84)}{.035}\ JUDOT + \underset{(.78)}{1.05}\ JPDOT \quad (6.20) \tag{6}$$

$R^2 = .88$ $\bar{R}^2 = .80$ $F(4,7) = 12.35$

$F_1(2,7) = 3.08$ $F_2(2,7) = 20.65$ $F_3(3,7) = 2.08$

$DW = 1.80$

$$LCHJW = 40.23 - \underset{(2.43)}{5.12}\ JU - \underset{(2.50)}{59.95}\ JU^{-1} - \underset{(2.15)}{.040}\ LCHJU + \underset{(1.01)}{1.03}\ LCHJ \quad (6.67) \tag{7}$$

$R^2 = .89$ $\bar{R}^2 = .83$ $F(4,7) = 14.53$

$F_1(2,7) = 3.80$ $F_2(2,7) = 22.89$ $F_3(3,7) = 2.64$

$DW = 1.77$

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$$WDOT = \underset{(3.06)}{-23.39} + \underset{(3.21)}{201.17}\ U^{-1} - \underset{(3.04)}{343.11}\ U^{-2} - \underset{(1.13)}{.049}\ UDOT + \underset{(6.20)}{.95}\ PDOT \tag{8}$$

$R^2 = .92$ $\bar{R}^2 = .88$ $F(4,7) = 20.50$

$F_1(2,7) = 6.13$ $F_2(2,7) = 20.20$ $F_3(3,7) = 4.22$

$DW = 1.69$

$$LCHW = \underset{(3.22)}{-22.93} + \underset{(3.39)}{199.08}\ U^{-1} - \underset{(3.20)}{340.76}\ U^{-2} - \underset{(1.14)}{.046}\ LCHU + \underset{(6.33)}{.94}\ LCHP \tag{9}$$

$R^2 = .93$ $\bar{R}^2 = .89$ $F(4,7) = 22.82$

$F_1(2,7) = 6.76$ $F_2(2,7) = 21.15$ $F_3(3,7) = 4.74$

$DW = 1.70$

$$PCHDW = \underset{(1.09)}{-24.23} + \underset{(1.17)}{217.57}\ U^{-1} - \underset{(1.09)}{370.08}\ U^{-2} - \underset{(.047)}{.065}\ PCHDU + \underset{(2.12)}{.84}\ PCHDP \tag{10}$$

$R^2 = .67$ $\bar{R}^2 = .48$ $F(4,7) = 3.60$

$F_1(2,7) = .88$ $F_2(2,7) = 3.21$ $F_3(3,7) = .59$

$DW = 2.19$

$$RCHDW = \underset{(1.12)}{-21.22} + \underset{(1.22)}{195.69}\ U^{-1} - \underset{(1.15)}{334.64}\ U^{-2} - \underset{(.036)}{.042}\ RCHU + \underset{(2.07)}{.79}\ RCHDP \tag{11}$$

$R^2 = .67$ $\bar{R}^2 = .48$ $F(4,7) = 3.53$

$F_1(2,7) = .93$ $F_2(2,7) = 2.98$ $F_3(3,7) = .62$

DW = 2.18

$$LDDW = -21.32 + 196.22\ U^{-1} - 335.39\ U^{-2} - .0043\ LDDU + .80\ LDDP \quad (12)$$
$$\quad (1.12) \quad (1.22) \quad (1.15) \quad (.036) \quad (2.07)$$

$R^2 - .67$ $R^2 = .48$ $F(4,7) = 3.54$

$F_1(2,7) = .93$ $F_2(2,7) = 3.00$ $F_3(3,7) = .62$

DW = 2.18

$$JWDOT = -19.32 + 150.77\ JU^{-1} - 233.07\ JU^{-2} - .028\ JUDOT + 1.05\ JPDOT \quad (13)$$
$$\quad (2.20) \quad (2.40) \quad (2.28) \quad (.65) \quad (6.30)$$

$R^2 = .88$ $\bar{R}^2 = .81$ $F(4,7) = 12.88$

$F_1(2,7) = 3.32$ $F_2(2,7) = 21.68$ $F_3(3,7) = 2.24$

DW = 1.86

$$LCHJW = -19.50 + 154.82\ JU^{-1} - 241.38\ JU^{-2} - .033\ LCHJU + 1.04\ LCHJP \quad (14)$$
$$\quad (2.43) \quad (2.68) \quad (2.57) \quad (.86) \quad (6.76)$$

$R^2 = .90$ $\bar{R}^2 = .84$ $F(4,7) = 14.96$

$F_1(2,7) = 3.99$ $F_2(2,7) = 23.84$ $F_3(3,7) = 2.77$

DW = 1.83

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$$WDOT = -12.20 + 82.61\ U^{-1} - 735.33\ U^{-4} - .042\ UDOT + .91\ PDOT \quad (15)$$
$$\quad (2.86) \quad (3.63) \quad (3.24) \quad (1.02) \quad (6.06)$$

$R^2 = .93$ $\bar{R}^2 = .88$ $F(4,7) = 22.22$

$F_1(2,7) = 6.88$ $F_2(2,7) = 19.49$ $F_3(3,7) = 4.73$

DW = 1.72

$$LCHW = -11.70 + 80.49\ U^{-1} - 721.88\ U^{-4} - .037\ LCHU + .91\ LCHP \quad (16)$$
$$\quad (2.88) \quad (3.71) \quad (3.31) \quad (.98) \quad (6.09)$$

$R^2 = .93$ $\bar{R}^2 = .89$ $F(4,7) = 23.81$

$F_1(2,7) = 7.17$ $F_2(2,7) = 19.93$ $F_3(3,7) = 5.02$

DW = 1.75

$$PCHDW = -13.03 + 94.36\ U^{01} - 839.75\ U^{-4} + .0018\ PCHDU + .80\ PCHDP \quad (17)$$
$$(1.07) \quad (1.39) \quad (1.22) \quad (.013) \quad (2.04)$$

$R^2 = .68$ $\bar{R}^2 = .50$ $F(4,7) = 3.79$

$F_1(2,7) = 1.04$ $F_2 2,7) = 3.13$ $F_3(3,7) = .69$

DW = 2.18

$$RCHDW = -10.94 + 83.50\ U^{-1} - 751.71\ U^{-4} + .0032\ RCHU + .76\ RCHDP \quad (18)$$
$$(1.04) \quad (1.43) \quad (1.27) \quad (.028) \quad (1.98)$$

$R^2 = .68$ $\bar{R}^2 = .50$ $F(4,7) = 3.71$

$F_1(2,7) = 1.08$ $F_2(2,7) = 2.89$ $F_3(3,7) = .72$

DW = 2.18

$$LDDW = -11.02 + 83.83\ U^{-1} - 753.92\ U^{-4} + .0032\ LDDU + .76\ LDDP \quad (19)$$
$$(1.04) \quad (1.43) \quad (1.26) \quad (.027) \quad (1.98)$$

$R^2 = .68$ $\bar{R}^2 = .50$ $F(4,7) = 3.72$

$F_1(2,7) = 1.08$ $F_2(2,7) = 2.90$ $F_3(3,7) = .73$

DW = 2.18

$$JWDOT = -10.83 + 63.52\ JU^{-1} - 411.83\ JU^{-4} - .023\ JUDOT + 1.04\ JPDOT \quad (20)$$
$$(1.94) \quad (2.50) \quad (2.25) \quad (.52) \quad (6.23)$$

$R^2 = .88$ $\bar{R}^2 = ,71$ $F(4,7) = 12.70$

$F_1(2,7) = 3.24$ $F_2(2,7) = 21.48$ $F_3(3,7) = 2.19$

DW = 1.92

$$LCHJW = -10.73 + 75.56\ JU^{-1} - 426.09\ JU^{-4} - .028\ LCHJU + 2.03\ LCHJP \quad (21)$$
$$(2.10) \quad (2.74) \quad (2.52) \quad (.73) \quad (6.68)$$

$R^2 = .89$ $\bar{R}^2 = .83$ $F(4,7) = 14.64$

$F_1(2,7) = 3.85$ $F_2(2,7) = 23.50$ $F_3(3,7) = 2.68$

DW = 1.89

****

clear evidence that any of the functional forms outperform the others.

Table 4.9 contains results for the inter-war period, 1922-1938. This period, as is well known, has proved difficult to model in the past -- and not simply in the context of the Phillips curve. The pattern of results essentially duplicates those of Table 4.8: the XDOT and LCHX formulations have better fits, both types of difference yield Durbin-Watson statistics in the indeterminate range (D_L = .78, D_U = 1.90 at the 5% level for two-tail tests), with the central differences showing patterns consistent with positive serial correlation and the first difference measures consistent with negative serial correlation.

The most striking feature of this set of results is the astonishing set of coefficients estimated for the U^{-4} term of the Lipsey post-World War One specification, which suggest mis-specification. As we expected the size of the estimated coefficients on the two variables with well determined values shows systematic variation with the rate of change measure adopted. The coefficients on the inflation term, for example, lie between 0.77 and 1.10, while those on the rate of change of U vary between 0.04 and 0.13. The Durbin-Watson statistics of the XDOT and LCHX equations are in the indeterminate region for positive serial correlation, whereas those for the three other major measures are in the interminate range for negative serial correlation.

Before taking up this autocorrelation problem in greater detail in section 5, we will attempt to summarize the results of our experiment. Our basic conclusion is that there is sufficient evidence that, at least for small samples, parameter estimates will show considerable variation depending upon the specific choice of how to calculate the rates of

TABLE 4.9

1922-1938 ORDINARY LEAST SQUARES (N= 17)

$$WDOT = \underset{(.21)}{1.67} - \underset{(.033)}{.0087}\ U - \underset{(.14)}{7.80}\ U^{-1} + \underset{(2.60)}{.040}\ UDOT + \underset{(14.04)}{.78}\ PDOT \qquad (1)$$

R^2 = .94 $\bar{R}^2$ = .93 F(4,12) = 51.60

$F_1(2,12)$ = .12 $F_2(2,12)$ = 98.76 $F_3(3,12)$ = 2.37

DW = 1.81

$$LCHW = \underset{(.31)}{2.32} - \underset{(.66)}{.034}\ U - \underset{(.20)}{11.75}\ U^{-1} + \underset{(6.77)}{.040}\ LCHU + \underset{(17.39)}{.77}\ LCHP \qquad (2)$$

R^2 = .94 $\bar{R}^2$ = .92 F(4.12) = 46.66

$F_1(2,12)$ = .08 $F_2(2,12)$ = 89.14 $F_3(3,12)$ = 2.38

DW = 1.82

$$PCHDW = -\underset{(.44)}{12.34} + \underset{(.50)}{.46}\ U + \underset{(.45)}{88.07}\ U^{-1} + \underset{(2.19)}{.12}\ PCHDU + \underset{(4.83)}{1.03}\ PCHDP \qquad (3)$$

R^2 = .69 $\bar{R}^2$ = .58 F(4,12) = 6.61

$F_1(2,12)$ = .14 $F_2(2,12)$ = 12.21 $F_3(3,12)$ = 1.90

DW = 2.38

$$RCHDW = -\underset{(.49)}{14.71} + \underset{(.55)}{.55}\ U + \underset{(.48)}{103.93}\ U^{-1} + \underset{(2.20)}{.12}\ RCHU + \underset{(4.80)}{1.09}\ RCHDP \qquad (4)$$

R^2 = .69 $\bar{R}^2$ = .58 F(4,12) = 6.56

$F_1(2,12)$ = .17 $F_2(2,12)$ = 12.12 $F_3(3,12)$ = 1.96

DW = 2.41

$$LDDW = -\underset{(.49)}{14.12} + \underset{(.55)}{.55}\ U - \underset{(.49)}{104.62}\ U^{-1} + \underset{(2.20)}{.13}\ LDDU + \underset{(4.80)}{1.09}\ LDDP \qquad (5)$$

R^2 = .69 $\bar{R}^2$ = .58 F(4.12) = 6.56

$F_1(2,12)$ = .18 $F_2(2,12)$ = 12.11 $F_3(3,12)$= 1.97

DW = 2.41

$$JWDOT = .74 + .058\ JU - 10.13\ JU^{-1} + .079\ JUDOT + 1.04\ JPDOT \quad (6)$$
(.11) (.24) (.25) (4.63) (12.28)

$R^2 = .94$ $\bar{R}^2 = .92$ $F(4,12) = 46.70$

$F_1(2,12) = 1.01$ $F_2(2,12) = 90.03$ $F_3(3,12) = 7.85$

$DW = 2.28$

$$LCHJW = .070 + .072\ JU - 4.23\ JU^{-1} + .071\ LCHJU + 1.03\ LCHJP \quad (7)$$
(.010) (.28) (.096) (3.98) (10.65)

$R^2 = .92$ $\bar{R}^2 = .89$ $F(4,12) = 34.95$

$F_1(2,12) = .58$ $F_2(2,12) = 67.25$ $F_3(3,12) = 5.80$

$DW = 2.34$

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$$WDOT = .39 + 23.65\ U^{-1} - 202.18\ U^{-2} + .040\ UDOT + .78\ PDOT \quad (8)$$
(.095) (.20) (.26) (2.65) (14.09)

$R^2 = .94$ $\bar{R}^2 = .93$ $F(4,12) = 51.89$

$F_1(2,12) = .15$ $F_2(2,12) = 99.54$ $F_3(3,12) = 2.40$

$DW = 1.82$

$$LCHW = -.13 + 36.95\ U^{-1} - 283.50\ U^{-2} + .040\ LCHU + .77\ LCHP \quad (9)$$
(.033) (.32) (.37) (2.69) (13.42)

$R^2 = .94$ $\bar{R}^2 = .92$ $F(4,12) = 47.14$

$F_1(2,12) = .14$ $F_2(2,12) = 90.16$ $F_3(3,12) = 2.44$

$DW = 1.83$

$$PCHDW = 10.02 - 256.17\ U^{-1} + 1687.\ U^{-2}\ \ .12\ PCHDU + 1.04\ PCHDP \quad (10)$$
(.70) (.63) (.61) (2.19) (4.87)

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.71$

$F_1(2,12) = .21$ $F_2(2,12) = 12.47$ $F_3(3,12) = 1.96$

$DW = 2.40$

$$RCHDW = 11.77 - 302.35\ U^{-1} + 1986.\ U^{-2}\ \ .13\ RCHU + 1.09\ RCHDP \quad (11)$$
(.76) (.69) (.67) (2.20) (4.85)

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.67$

$F_1(2,12) = .25$ $F_2(2,12) = 12.40$ $F_3(3,12) = 2.03$

DW = 2.42

$$LDDW = \underset{(.76)}{11.83} - \underset{(.69)}{304.24}\ U^{-1} + 1998.\ U^{-2} + \underset{(.67)}{.13}\ LDDU + \underset{(2.20)}{1.10}\ LDDP \quad (4.85) \qquad (12)$$

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.67$

$F_1(2,12) = .25$ $F_2(2,12) = 12.39$ $F_3(3,12) = 2.04$

DW = 2.42

$$JWDOT = 2.37 - 21.36\ JU^{-1} + 10.37\ JU^{-2} + .080\ JUDOT + 1.04\ JPDOT \qquad (13)$$
$$(.70) \quad (.26) \quad (.023) \quad (4.67) \quad (12.22)$$

$R^2 = .94$ $\bar{R}^2 = .92$ $F(4,12) = 46.46$

$F_2(2,12) = .97$ $F_2(2,12) = 89.59$ $F_2(3,12) = 7.79$

DW = 2.28

$$LCHJW = 2.25 - 22.68\ JU^{-1} + 39.67\ JU^{-2} + .072\ LCHJU + 1.02\ LCHJP \qquad (14)$$
$$(.61) \quad (.26) \quad (.081) \quad (4.02) \quad (10.60)$$

$R^2 = .92$ $R^2 = .89$ $F(4,12) = 34.72$

$F_1(2,12) = .54$ $F_2(2.12) = 66.82$ $F_3(3,12) = 5.74$

DW = 2.34

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$$WDOT = .57 + 10.48\ U^{-1} - 9440.\ U^{-4} + .041\ UDOT + .78\ PDOT \qquad (15)$$
$$(.25) \quad (.25) \quad (.40) \quad (2.70) \quad (14.51)$$

$R^2 = .95$ $\bar{R}^2 = .93$ $F(4,12) = 52.34$

$F_1(2,12) = .20$ $F_2(2,12) = 100.43$ $F_3(3,12) = 2.45$

DW = 1.83

$$LCHW = .24 + 16.18\ U^{-1} - 11908.\ U^{-4} + .041\ LCHU + .77\ LCHP \qquad (16)$$
$$(.11) \quad (.39) \quad (.52) \quad (2.74) \quad (13.49)$$

$R^2 = .94$ $\bar{R}^2 = .92$ $F(4,12) = 47.72$

$F_1(2,12) = .21$ $F_2(2.12) = 91.16$ $F_3(3,12) = 2.52$

DW = 1.85

$$PCHDW = 6.58 - 108.49\ U^{-1} + 56997.\ U^{-4}\quad .12\ PCHDU + 1.04\ PCHDP \qquad (17)$$
$$\quad (.81)\quad (.72)\qquad (.70)\quad (2.21)\qquad (4.92)$$

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.80$

$F_1(2,12) = .26$ $F_2(2,12) = 12.72$ $F_3(3,12) = 2.02$

DW = 2.41

$$RCHDW = 7.68 - 127.74\ U^{-1} + 66586.\ U^{-4} + .13\ RCHU + 1.10\ RCHDP \qquad (18)$$
$$\quad (.88)\quad (.79)\qquad (.75)\quad (2.23)\qquad (4.90)$$

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.77$

$F_1(2,12) = .31$ $F_2(2,12) = 12.68$ $F_3(3,12) = 2.09$

DW = 2.44

$$LDDW = 7.72 - 128.50\ U^{-1} + 66967.\ U^{-4} + .13\ LDDU + 1.10\ LDDP \qquad (19)$$
$$\quad (.88)\quad (.79)\qquad (.76)\quad (2.23)\qquad (4.90)$$

$R^2 = .69$ $\bar{R}^2 = .59$ $F(4,12) = 6.76$

$F_1(2,12) = .31$ $F_2(2,12) = 12.68$ $F_3(3,12) = 2.10$

DW = 2.44

$$JWDOT = 2.13 - 16.84\ JU^{-1} - 825.53\ JU^{-4} + .080\ JUDOT + 1.04\ JPDOT \qquad (20)$$
$$\quad (1.04)\quad (.54)\qquad (.096)\quad (4.70)\qquad (12.22)$$

$R^2 = .94$ $\bar{R}^2 = .92$ $F(4,12) = 7.80$

DW = 2.30

$$LCHJW = 1.93 - 15.12\ JU^{-1} - 182.48\ JU^{-4} + .072\ LCHJU + 1.02\ LCHJP \qquad (21)$$
$$\quad (.86)\quad (.44)\qquad (.020)\quad (4.04)\qquad (10.59)$$

$R^2 = .92$ $\bar{R}^2 = .89$ $F(4,12) = 34.71$

$F_1(2,12) = .54$ $F_2(2,12) = 66.76$ $F_3(3,12) = 5.74$

DW = 2.35

****

change. It also seems to be clear that the basic measures fall into two sets: XDOT and LCHX which rely on first central proportional differences, and PCHX, RCHX and LDX which rely upon first differences. These sets of measures lead not only to different coefficient estimates, but also to different indications of serial correlation.

In general the proportional difference measures are associated with Durbin-Watson statistics which suggest the possibility of positive autocorrelation, while the first difference DWs are usually larger.

Insofar as these estimates can be taken seriously they suggest that the augmented Phillips curve is not inconsistent with our data. What is obvious is that the estimated Phillips curves show such large changes in the estimated parameters that it is very unlikely that the equations are stable and that much further work would need to be undertaken before "the" U.K. Phillips curve --if it exists -- could be unearthed. We will now turn our attention to the problem of serial correlation in the estimated errors and its possible connection with the choice of a rate of change measure.

5. AUTOCORRELATION

As Santomero and Seator point out in their well known survey article on the Phillips Curve (1978, p. 513): "Serial correlation seems almost inevitable in time-series work, but the problem is exacerbated in much of the Phillips curve literature by the use of moving averages and first central differencing to obtain annual rates of change of wages." Phillips was well aware of these problems (and of the limitations of the Durbin-Watson statistic as a tool for detecting them),[46] although, because of the unusual estimation procedure he adopted, his own work was largely immune from these problems. Lipsey also seems to have been aware of the need to check for autocorrelation in the residuals, although how he did so is not clear.[47]

Subsequent research in this field has tended either to ignore the problems of autocorrelation altogether, or to focus on the technique for determining the rates of change variables as the possible culprit.[48] Routh, for example, argues that the use of first central differences "has a smoothing effect" (1959, p. 305), a point which is echoed by Purdy and Zis (1974, p. 17). Similarly Gilbert (1976, p. 55) (referring to Wallis (1971, p. 307) and Houthakker and Taylor (1970)) suggests that the first central difference technique will introduce spurious autocorrela-tion into the equation residuals. In none of these cases is the mechanism involved clearly set out, but presumably the argument these authors have in mind is that a shock to the wage level series at time t is transmitted by the process of first central differencing, not simply to the rate of wage change series at time t but also to that series at the adjoining time periods (t-1, t+1) since X_t incorporates observations on $\dot{X}$ at times t-1, t and t+1. Shocks are therefore passed by this process to three regression residuals.

In an important series of studies[49] Rowley and Wilton have criticised the use of overlapping differences in quarterly studies of the Phillips curve. This very popular approach, which seems to stem from the pioneering study by Dicks-Mireaux and Dow (1959), leads to a four quarter moving average error term. Rowley and Wilton point out that neither ordinary least squares nor the standard first-order Cochrane-Orcutt transformation are appropriate in this context,[50] They also show that when the relevant generalized least squares (GLS) estimator is used the empirical results change radically. However, as noted by Santomero and Seator (1978, p. 513), studies using annual first central differences are usually immune from this problem. This is because the Rowley and Wilton critique is concerned with the aggregation process which is a necessary adjunct of the overlapping annual wage change (OAWC) formulation of the Phillips curve model, rather than with the use of first central differences as such. On the other hand Bowen and Berry (1963, p. 171) and Archibald et al. (1974, n. 22, p. 127) both suggest that the use of first central differencing will lead to a (second-order?) moving average error term (on the assumption that the population disturbances are free from serial correlation). Neither of these papers specifies the mechanism by which this moving average error is induced, but it seems likely that they had in mind an heuristic argument of the type outlined in the previous paragraph.

Any measurement error in the underlying levels series, X_t, will be transmitted to the regression equation at times t-1, t, and t+1 since we use each X_t three times: in the generation of $\dot{X}_{t-1}$, $\dot{X}_t$, and $\dot{X}_{t+1}$. Further, since all rates of changes in our equations are generated by the same transformation, measurement errors in any combination of our three basic series (wages, prices and unemployment) will cause three residuals to be contaminated. This argument seems to be quite general, and it should therefore follow that any rate of change measure using more than one level observation (and where degrees of freedom are, apparently, conserved by overlapping) is subject to this objection. Hence all of the standard (and non-standard) formulas considered in section 2 are potential sources of induced serial correlation. Measures using first proportional differences will have only one residual (that at t-1) spuriously affected, whereas measures based upon first central proportional differences induce spurious effects on the residuals at times t+1 and t-1.

We saw above that there was evidence of first order serial correlation amongst the residuals of our equations. Thus it is possible that this autocorrelation may arise from the process of generating the rates of change variables. To investigate this issue we proceed as follows. First, we will use the PDQ option of the ESP software system to investigate the properties of the autocorrelation and partial autocorrelation functions of the residuals from some OLS equations. Second, we will use the SHAZAM package to re-estimate these equations using the procedure (originally devised by Pagan (1974)) for estimating equations with moving average error terms. Before proceeding we will discuss, very briefly, the features of the Box-Jenkins[51] time series analysis methodology which are relevant for our experiement.

A time series is a sequence of observations which are ordered in time. In time series analysis we are concerned to model series in which there is interdependence between observations. The Box-Jenkins approach seeks to describe the behaviour of the series using very parsimonious stochastic processes. The particular stochastic process used in the modelling exercise is "identified" by analysing sample statistics derived from the series of interest. These statistics are the sample autocorrelations and partial autocorrelations between observations k intervals apart. The procedure advocated by Box and Jenkins involves a visual inspection of the graphs of the autocorrelation and partial autocorrelation coefficients against the lag length k. Before useful information can be drawn from these plots, or numbers, we must ensure that the series is a satisfactory approximation to a "stationary" series.[52] If the original series happens to be non-stationary then weak stationarity can normally be produced by differencing the original series "d" times (experience seems to suggest that second differencing is sufficient to make most economic time series stationary). As Granger and Newbold (1977, p. 75) say:

> If differencing is found to be necessary, the sample autocorrelations and partial autocorrelations of the differenced series are far more likely than those of the original series to yield useful information about the underlying stochastic process. This is because any useful information contained in the latter is swamped by the behaviour induced by nonstationarity, rendering further interpretation virtually impossible.

After suitable differencing[53] the sample autocorrelations and partial autocorrelations of the differenced series are examined to see if they exhibit the characteristics of one of the standard ARIMA (integrated autoregressive moving average) stochastic processes. In our case we are expecting to observe first or second order moving average processes.[54] These moving average processes lead to very characteristic shapes for the theoretical autocorrelation and partial autocorrelation function. The autocorrelation at lags in excess of one or two (for the

MA(1) and MA(2) processes respectively) should be zero while the partial autocorrela-tions taper off as the lag length increases ($p_{kk} \rightarrow 0$ as $k \rightarrow \infty$).[55,56]

Unfortunately there may be major discrepancies between the theoretical functions and the actual realizations of the series, especially for small samples.[57] (Granger and Newbold (1977, p. 76) recommend that the series being modelled should have at least 45 to 50 observations). We have therefore reported our calculations only for the period 1923 to 1978--the largest sample available to us incorporating annual, June and December observations.[58]

Table 4.10 reports the results of running regressions for the 1923-1978 period using the XDOT, LCHX, PCHDX and LDDX rates of change measures in an equation of the (general) form:

$$\dot{W} = a + bU^{-1} + c\dot{U} + d\dot{P}.$$ [59]

The first eight rows of the table give the coefficient estimates and their absolute t-values. The next two rows report the usual R^2 and F statistics. The t statistic in row 11 tests the null hypothesis that the coefficient on the price inflation term is unity. The DW(1) row reports the standard Durbin-Watson test (with its exact two-tail probability--calculated by the Pan Jie-Jian technique--in parentheses). The DW(2) statistic tests for second-order serial correlation on the assumption that there is no first-order autocorrelation amongst the residuals.

Referring to column 1 (which contains the XDOT results) we see that we obtain a reasonably good fit ($\bar{R}^2 = 0.78$) and generally satisfactory coefficient estimates (although the UDOT term fails to achieve

TABLE 4.10

1923-1978 OLS REGRESSION RESULTS: U-INVERSE FUNCTIONAL FORM

	WDOT	LCHW	PCHDW	LDDW
C	1.42	1.41	1.49	1.40
	(2.53)	(2.65)	(2.01)	(2.06)
UINV (etc.)	1.71	1.71	2.57	2.72
	(1.93)	(2.03)	(1.93)	(2.18)
UDOT (etc.)	0.015	0.023	0.016	0.016
	(1.41)	(2.02)	(1.08)	(1.28)
PDOT (etc.)	0.93	0.93	0.88	0.85
	(13.87)	(14.52)	(11.18)	(11.33)
$\bar{R}^2$	0.78	0.80	0.71	0.71
F(3,52)	66.01	72.54	44.94	45.18
T(52)	1.06	1.09	1.57	1.97
DW(1)	1.33	1.23	1.74	1.77
	(00.0)	(00.0)	(11.4)	(13.4)
DW(2)	-	-	1.67	1.77
	-	-	(8.75)	(19.9)

statistical significance at the 5% level). However, the DW(1) statistic has a very low value which has a probability of occurrence of approximately zero given that the null hypothesis is true. The expectation that the XDOT rate of change measure would be associated with serial correlation appears to be borne out by our results. A similar conclusion holds for the LCHX formulation which yields very similar results.

If the argument which says that any rate of change measure which involves more than one time period in its calculation (and, of course, all such measures must use at least two pieces of data) will induce serial correlation in regression equation residuals is true, then we would expect that the PCHDW and LDDW formulations would also exhibit significantly low DWs. As can be seen from the last two columns of Table 4.10, this is not the case. Again the overall results for these equations appear acceptable, with the exception of the estimated PCHDU and LDDU coefficients. However, as the result in the last four rows show, there is no evidence of serial correlation of orders one or two according to the Durbin-Watson test.

The sample autocorrelation and partial autocorrelation functions for the 1923-1978 equations are presented in Table 4.11. As would be expected none of the residual series showed any need for differencing. We therefore applied the PDQ procedure from the ESP package to the original, undifferenced, residual series. The first column in the table (headed S.E.) contains estimates of the relevant standard deviation for each row (using Bartlett's approximation[60]). We see that both the WDOT and the LCHW residuals have sample autocorrelation functions which die away rapidly (only the first coefficient is more than twice its

TABLE 4.11 OLS 1923-1978 RESIDUALS

AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS FOR VARIOUS DIFFERENCES

FIRST CENTRAL DIFFERENCES (WDOT)													
S.E./LAG					SAMPLE AUTOCORRELATIONS N=56								
0.13	01-12	0.32	-.16	-.02	-.05	-.10	-.16	-.13	-.09	-.08	-.09	-.06	-.20
0.16	13-24	0.16	-.09	0.08	0.17	-.01	-.14	-.06	0.01	-.09	-.22	-.19	0.07
S.E./LAG					SAMPLE PARTIAL AUTOCORRELATIONS N=56								
0.13	01-12	0.32	-.30	0.18	-.20	-.03	-.23	0.02	-.18	-.01	-.19	0.02	0.16
LOGARITHMIC CENTRAL DIFFERENCES (LCHW)													
S.E./LAG					SAMPLE AUTOCORRELATIONS N=56								
0.13	01-12	0.34	-.14	-.03	-.09	-.12	-.13	-.12	-.10	-.08	-.10	-.08	0.20
0.16	13-24	0.18	-.10	0.05	0.14	-.03	-.11	-.03	0.01	-.09	-.22	-.20	0.06
S.E./LAG					SAMPLE PARTIAL AUTOCORRELATIONS N=56								
0.13	01-12	0.34	-.29	0.17	-.24	0.06	-.22	0.03	-.19	0.01	-.22	0.02	0.16
PERCENTAGE CHANGES (PCHDW)													
S.E./LAG					SAMPLE AUTOCORRELATIONS N=56								
0.13	01-12	0.06	0.05	0.00	0.15	-.10	-.01	-.15	-.06	-.07	-.04	0.05	-.04
0.14	13-24	-.02	0.05	0.05	0.03	-.09	-.02	-.07	-.12	-.15	-.03	-.06	-.02
S.E./LAG					SAMPLE PARTIAL AUTOCORRELATIONS N=56								
0.13	01-12	0.06	0.05	-.00	0.15	-.12	-.01	-.15	-.07	-.02	-.04	0.11	-.07
LOGARITHMIC CHANGES (LDDW)													
S.E./LAG					SAMPLE AUTOCORRELATIONS N=56								
0.13	01-12	0.04	0.00	-.00	0.14	-.03	0.02	-.14	-.05	-.07	-.02	0.06	-.06
0.14	13-24	-.02	0.03	0.04	0.05	-.08	-.03	-.07	-.11	-.14	-.03	-.07	-.03
S.E./LAG					SAMPLE PARTIAL AUTOCORRELATIONS N=56								
0.13	01-12	0.04	0.00	-.00	0.14	-.04	0.03	-.15	-.06	-.06	-.03	0.11	-.06

estimated standard error) and "spikes" at lags one (positive) and two (negative) of the sample partial autocorrelation function. These results suggest an autoregressive error process of order two (AR(2)) rather than a second-order moving-average (MA(2)) process (which would normally yield "spikes" in the autocorrelation function at lags 1 and 2 and a partial autocorrelation function which tapers off rapidly). Both the PCHDW and the LDDW suggest a white noise error structure which is consistent with our Durbin-Watson diagnostics.

In Table 4.12 we report the result of an experiment in which we used the SHAZAM software package to re-estimate the WDOT and LCHW equations. The results in the columns headed CORC were obtained using a Cochrane-Orcutt type[61] iterative procedure assuming an AR(1) error process. The MA(2) estimates in columns 3 and 4 were derived using the least squares procedure developed by Pagan (1974).[62] All of the estimates incorporate the first observation (or the first two observations in the second order cases) using the usual transformation.[63] RHO1 is the coefficient of the first autocorrelation term in the AR(1) specification, and THETA1/THETA2 are the corresponding moving average coefficients (in each case absolute asymptotic t-ratios are reported in parentheses).

Turning to the results themselves we see that in all four equations the U^{-1} term's coefficient is not significantly different from zero (in the case of the MA(2) LCHW specification the negative U^{-1} coefficient, if it were statistically significant would indicate a positively sloped Phillips curve). All four Phillips curves are therefore horizontal lines intersecting the vertical axis at about 2.5 percentage points. We

TABLE 4.12

1923-1978 CORC AND MA(2) REGRESSION RESULTS:

U-INVERSE FUNCTIONAL FORM

	CORC		MA 2	
	WDOT	LCHW	WDOT	LCHW
C	2.14	2.16	2.47	2.86
	(2.70)	(2.82)	(4.25)	(5.10)
UINV (etc.)	0.72	0.68	0.49	-0.15
	(0.62)	(0.61)	(0.53)	(0.16)
UDOT (etc.)	0.016	0.025	0.008	0.021
	(1.25)	(1.90)	(0.59)	(1.45)
PDOT (etc.)	0.86	0.86	0.84	0.81
	(9.36)	(9.60)	(10.8)	(10.5)
$\bar{R}^2$	0.81	0.82	0.85	0.87
T(52)	1.52	1.57	2.07	2.45
RHO(1)/THETA(1)	0.40	0.43	0.80	0.89
	(3.30)	(3.56)	(5.52)	(5.95)
RHO(1)/THETA(2)			-0.20	-0.11
			(1.46)	(0.79)
DW(1)	1.77	1.75	2.05	2.00

note that the price inflation terms are all significantly different from zero, although they are also significantly below unity. We see that the RHO1 coefficient is significantly different from zero as is the THETA1 coefficient, although the THETA2 coefficient is not significantly different from zero.

These results, plus the patterns exhibited by sample autocorrelation and partial autocorrelation functions in Table 4.13, suggest that although the first central difference rates of change measures do introduce serial correlation into the regression residuals, that they lead to autoregressive rather than moving average processes. These autoregressive processes are probably of order two.[64]

6. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

In the conclusion to their review article on Bodkin's book "The Wage-Price-Productivity Perplex" Rees and Hamilton (1967) comment that "they have been astounded by how many different Phillips curves can be constructed on reasonable assumptions from the same body of data." They go on to say that "The nature of the relationship between wage changes and unemployment is highly sensitive to the exact choice of the other variables that enter the regression and to the forms of all of the variables." This paper has concentrated on the question of the effect of one particular choice of form--the choice of the rate of change transform--on the estimated Phillips curve.

We began by noting that recognition of the so-called alignment problem had led to two basic approaches to measuring the rates of change of continuous measures, in the Phillips curve literature. With annual

TABLE 4.13 1923-1978 CORC AND MA(2) RESIDUALS

CORC RESIDUALS

AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS FOR VARIOUS DIFFERENCES

FIRST CENTRAL DIFFERENCES (XDOT)

S.E./LAG		SAMPLE AUTOCORRELATIONS N=56											
0.13	01-12	0.10	-.26	0.12	0.03	0.00	-.08	-.09	-.06	-.02	-.04	-.11	-.18
0.15	13-24	0.13	-.22	0.02	0.14	-.05	-.14	0.00	0.07	-.02	-.15	-.17	-.08

S.E./LAG		SAMPLE PARTIAL AUTOCORRELATIONS N=56											
0.13	01-12	0.10	-.27	0.20	-.10	0.12	-.18	0.00	-.16	0.04	-.12	-.05	0.20

LOGARITHMIC CENTRAL DIFFERENCES (LCHX)

S.E./LAG		SAMPLE AUTOCORRELATIONS N=56											
0.13	01-12	0.10	-.26	0.11	-.04	-.02	-.04	-.04	-.05	-.02	-.06	-.15	0.21
0.15	13-24	0.18	-.23	-.02	0.13	-.07	-.09	0.05	0.07	-.03	-.17	-.18	0.09

S.E./LAG		SAMPLE PARTIAL AUTOCORRELATIONS N=56											
0.13	01-12	0.10	-.28	0.19	-.18	0.12	-.18	0.07	-.17	0.09	-.21	-.04	0.19

MA(2) RESIDUALS

AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS FOR VARIOUS DIFFERENCES

FIRST CENTRAL DIFFERENCES (XDOT)

S.E./LAG		SAMPLE AUTOCORRELATIONS N=56											
0.13	01-12	0.01	0.11	0.05	0.04	-.02	-.09	-.10	-.06	-.04	-.05	-.07	0.08
0.15	13-24	0.15	-.16	0.10	0.12	-.05	-.12	-.04	-.03	-.06	-.14	-.10	0.05

S.E./LAG		SAMPLE PARTIAL AUTOCORRELATIONS N=56											
0.13	01-12	0.01	0.11	0.05	0.03	-.03	-.10	-.10	-.04	-.01	-.03	-.06	0.08

LOGARITHMIC CENTRAL DIFFERENCES (LCHX)

S.E./LAG		SAMPLE AUTOCORRELATIONS N=56											
0.13	01-12	-.01	0.13	0.13	-.00	0.02	-.08	-.05	-.07	-.05	-.03	-.09	0.10
0.14	13-24	0.16	-.20	0.05	0.03	-.05	-.07	0.03	-.02	-.04	-.13	-.12	0.04

S.E./LAG		SAMPLE PARTIAL AUTOCORRELATIONS N=56											
0.13	01-12	-.01	0.13	0.13	-.02	-.01	-.09	-.05	-.06	-.02	-.00	-.07	0.11

series, putatively centred at mid-year, the procedure, following Phillips' original lead, is to calculate first central proportional differences, whereas with series which are generated for the end of December the first (proportional) difference is usually preferred--again following Phillips' practise. We then raised the questions of whether these two measures are identical and whether a consistent application of the measures generated identical parameter estimates. We answered these questions in section four above where we reported the results of an experiment in which a large number of regressions were run using variants of both measures. Our conclusion was that there was sufficient evidence to suggest that the estimates were not invariant to the choice of rates of change measure, and that these differences might be significant in small samples. Certainly this appears to be a problem which needs to be addressed by researchers planning to estimate Phillips curves.

In the third section of this paper we examined a number of alternative rates transforms and saw that the standard techniques commonly used in the literature are far from exhaustive. Indeed we are inclined to agree with Alt's statement that "A fertile imagination can produce infinite possible calculations (of rates of change measures)."[65] This fact necessarily entails a problem of the correct choice of measure. The literature on the alignment problem,[66] which was examined in section two, concentrates upon the issue of the correct temporal alignment of the variables, but other issues are also important and have sometimes been discussed. For example, Black and Kelejian (1972, p. 58) have raised the issue of the loss of degrees of freedom which is likely to be a concern in economics where we often have very small samples at our disposal.[67]

Another problem which has attracted attention is the degree of "smoothing" engendered by the rates transformation and the associated difficulty of induced serial correlation.[68] The major preoccupation of this literature has been with the problems of using the OAWC model with quarterly data, and there now seems to be a trend towards the use of simple differences with quarterly data.[69] However, our concern in this paper has been with annual series and so we reported, in section five above, the results of our own experiments from which we concluded that there is evidence that the first central difference transformations introduce AR(1) or AR(2) error processes into the ordinary least squares results, and that an estimation technique which takes account of this problem should therefore be adopted.[70]

Two other issues which are worth considering in the context of evaluating alternative rates of change measures are whether the measure aids in reducing heteroskedasticity and the ease with which a measure can be understood. Under the former heading we note that both the basic wage and price level series are highly trended after 1934 and so we may expect that the variances of those series will also tend to increase over time. In the time series literature a logarithmic transformation (of an original, strictly positive, series) is often deemed appropriate. The LCHX and LDDX transformations are therefore appealing in this respect.

The issue of ease of comprehension leads to considerations of considerable significance. As we have already noted, one of the most appealing properties of the PCHDX measure is that it corresponds to the rate of change measure which is usually reported by governments and by the media. The XDOT technique is certainly not what most people have in mind when discussing such items as the current rate of inflation. This point should not be dismissed lightly, especially in a field where expectation about future levls and rates of change of the variables entering the equations are so crucial. Further, the comprehensibility criterion leads us naturally to the question of what it is we are, and/or should be, attempting to explain when estimating wage or price inflation equations.

Although this is a major issue, surprisingly little seems to have been written about it in the last twenty-five years during which much ink has been used up reporting the results of experiments designed to measure wage and price inflation processes. Unfortunately the present paper is already unduly long and so we cannot do much more than raise the issue. What seems clear after only a moment's reflection is that it is very unlikely that we are interested in tracking the actual, observed, behaviour of our wage and price series--either in levels or in terms of changes. As Hudson (1982, p. 104) points out "...we regard a time series as consisting of permanent and temporary elements, and in some way it is this permanent element that we are trying to isolate." Hudson's remarks (which obviously conjure up associations with Friedman's permanent income concepts) were made in the context of a discussion of the use of Kalman filtering in models of price expectations formation. The only article with which we are familiar which is specifically directed at the problem of isolating the permanent or underlying inflation rate is John Scadding's interesting paper (Scadding (1979)), in which he applies the theory of optimal prediction to U.S. data in an attempt to calculate the underlying inflation rate. This is an area which deserves further research.[71]

Finally let us provide a tentative answer to the question we set out to illuminate, i.e., do the different rates of change measures lead to different answers in the sense of different Phillips curves when estimating over a common sample period but with data taken from different points in the year? Our answer is that our experiments suggest that the Phillips curves will be different, and that the differences will be larger the smaller the sample size. The answer to the question of how important these differences are, we leave to future theoretical and empirical research.

FOOTNOTES

[1]Lipsey (1960) and Phillips (1958).

[2]See Routh (1959, paragraph 4.2) and Phillips (1958, n. 1, p. 290).

[3]Phillips used the coefficient from his 1861-1913 data to predict the (percentage) rate of change of money wages from 1948 to 1957 (see Table 1, p. 298 of Phillips (1958)). Lipsey (1960, p. 28) performed similar calculations using his estimated equation.

[4]Dogas and Hines (1975, p. 205) discuss some results where different rates of change measures apparently lead to significantly different parameter estimates (although there are additional data differences which might account for the discrepancies).

[5]Samuelson (1947, especially p. 263).

[6]Phillips (1958, p. 283) and Lipsey (1960) (especially section 1 of Part II which was written in conjunction with Professor G. C. Archibald).

[7]Phillips (1958, n. 1, p. 290).

[8]Ibid.

[9]Lipsey (160, n. 2, p. 2). This is essentially an application of the so-called Mean Value Theorem. Note that Lipsey seems to be discussing an instantaneous rather than an average rate of change in this passage.

[10]Routh (1959).

[11]Loc. cit., p. 305.

[12]See footnote 2 above.

[13]See Lipsey (1960, n. 2, p. 3).

[14]See Routh (1959, paragraph 4.5).

[15]Bowen and Berry (1963). They seem to have coined the term "the alignment problem."

[16]Loc. cit., p. 171.

[17]Hines (1964, n. 2, p. 243) also observes that this "implicit" six months lag may sometimes be desireable. Phillips, for example, uses a seven month lag on his unemployment variable for the 1948-1957 period.

[18]Similar arguments have been advanced by Gallaway and Koshal. See Gallaway (1971, pp. 78-79).

[19]See Gallaway (1971, n. 10, p. 80) who interprets the U_{t+1} as a measure of expected unemployment. Mackay and Hart (1974) have estimated Phillips curves with U_{t+1} acting as a proxy for hoarded labour.

[20]With due acknowledgement to the concept of total differentials.

[21]Gallaway (1971, pp. 77-80) argues that equations involving rates of change of unemployment on the left hand side of the estimating equation should be specified as

$$\dot{W}/W = a + bU_{t-1} + cU_t + dU_{t+1} + e \quad ,$$

where U_{t+1} is a proxy for the expected level of excess demand, in order to avoid the non-linearity in variables and a priori weighting of these variables.

[22]Bowen and Berry (1963, n. 6, p. 166 and p. 167) argue for the use of absolute first differences (rather than proportional first differences) to measure the rate of change of unemployment on the grounds that "the incremental changes can be so large relative to the base that sizeable fluctuations in the percentage rate of change of

unemployment can be produced by comparatively modest absolute changes in the level of unemployment" and that "changes in unemployment serve as a handy index of future labour conditions" and "we might expect to find a more consistent relationship between the rate of wage increase and absolute changes in the unemployment percentage than between the rate of wage increase and percentage changes in the unemployment percentage" on the grounds that "absolute changes are presumably less influenced by the amount of structural unemployment contained in the total level of unemployment than are percentage changes in the unemployment variable" (loc. cit., n. 15, p. 169).

[23]Loc. cit., p. 172.

[24]Loc. cit., p. 172.

[25]Further discussion of the alignment problem can be found in Hines (1964, Appendix (i)), Purdy and Zis (1974), and Dogas and Hines (1975).

[26]Carnahan ((1969), p. 128). These authors point out that the inherent difficulty of numerical differentiation arises from the fact that "differentiation tends to magnify small discrepancies or errors in the approximating function...." (ibid.).

[27]A number of conversations with numerical analysts elicited the advice to "fit" a function of time to the level series and then differentiate the function with respect to time. Given the behaviour of the series typically used in Phillips curve analysis this did not seem to be an acceptable strategy. In particular the high degree of smoothing would almost certainly exacerbate the problems of serial correlation discussed below.

[28]See Nelson (1973, p. 58), and Stewart and Wallis (1981).

[29]Table 1 really consists of two parts: the first nine columns and twelve rows, and the last six columns. In general it does not make sense, of course, to divide the logarithmic change estimates by X or its logarithm or logarithmic difference. (But see Klein (1967)).

[30]We make no allowance for unequal numbers of working days in the two "half" years.

[31]See Sleeman (1981) and Santomero and Seater (1978) and Phillips (1958) for further discussion of the specification of the Phillips curve equation. Lipsey (1960) suggested a "dispersion" interpretation of the U term which has been investigated by Archibald (1974) and by Smyth (1979).

[32]See Sleeman (1981, n. 21, p. 20).

[33]Data sources are listed in the Appendix below.

[34]Routh (1959) and Lipsey (1960) both suggest increasing (by 12-1/2% and 20% respectively) the post-war unemployment rates to bring them into line with the inter-war series.

[35]In this kind of experiment one rapidly runs up against problems caused by the embarrassingly large number of regressions which could possibly be run (see, for example, Archibald (1974), pp. 134-5). With eight sample periods, three functional forms and 120 rates of change measures we could run 2,880 regressions which--allowing three lines to the printed page--would mean that we would need about 260 pages, the size of a respectable modern novel, just to print the results.

[36]These results were obtained using the SHAZAM (White, 1978) and ESP (Cooper, (1976)) software programs and were run on the IBM 4341 computer of the Computer Center at Western Washington University. We

would like to express our appreciation for the cooperation of the Center's staff and, in particular for the assistance provided by Ms. Evelyn Albrecht and Mr. Bent Faber.

[37]The figures in parentheses beneath each coefficient are absolute values of t-statistics. The first F-statistic refers to the standard test of the joint significance of the estimated coefficients of the set of independent variables. The F_1, F_2, F_3 statistics test, respectively, the joint significance of the coefficients of the two unemployment variables, the joint significance of the rates of change of unemployment and inflation, and the joint significance of the unemployment and rate of change of unemployment coefficients.

[38]The claim that the first two equations have better fit than the next three equations is, of course, predicated on the claim that all of the rates of change measures are identical (except perhaps for small measurement) since R^2s are comparable only if the left hand side variables are the same.

[39]The Durbin-Watson significance points were obtained from the augmented tables in Savin and White (1977).

[40]See Granger and Newbold (1977, pp. 202-214), Johnston (1972, section 8-2), and Pindyck and Rubinfeld (1981, p. 153). Of course we are assuming that the serial correlation is caused by the population disturbance term exhibiting first-order autocorrelation rather than the Durbin-Watson statistic being significant because of a mis-specification of the Phillips curve equation.

[41]In the last five years or so there has been increasing dissatisfaction (particularly amongst British and Australian

econometricians and applied economists) with these conventional criteria (see Hendry, 1980), but our concern in this paper is less with establishing a definitive Phillips curve for the U.K. and more with examining a question which is not only of general importance, but which could well have been investigated within five years of the original publication of the Phillips curve with then existent techniques. Our argument is that at least part of the explanation for the slow growth of empirical knowledge in this field (despite an enormous expenditure of time and effort) is that issues such as the choice of a measure to calculate rates of change tend to be brushed aside in favour of publishing yet another set of estimates where the relationship to previous results is seldom clear and whose validity may depend crucially upon the chosen rate of change transform.

[42]Our inflationary expectations proxy is consistent with the view that economic agents are rational in the sense that they do not suffer from money illusion and their inflation predictions track the actual outcomes (which we have used as our proxy) exactly.

[43]The choice of the cut-off years 1922, 1938 and 1948, deserves some comment: We start in 1922 because this is the first year for which we have data available for all variables in each of the temporal forms (June, December, annual averages). Lipsey (1960) has argued for the exclusion of the 1922 observation on the grounds that it represents an outlier generated by the sharp contraction which succeeded the post-World War One re-stocking boom. On the other hand Lipsey includes the 1939 observation which includes a fourth quarter during which the U.K. was already at war with Germany. Phillips and Lipsey chose 1948 as

their first post-World War Two year because they felt that 1946 and 1947 were years which were still dominated by wartime conditions. The sensitivity of the parameter estimates to the particular sample chosen is a topic which deserves closer investigation.

[44]Savin and White (1978) and Richardson and White (1979) have investigated the behavior of the Durbin-Watson statistic when there is a break in the sample and conclude that it is still valid, although its power may be lower than a test which takes the missing observations into account (particularly if there are large numbers of missing observations, and for large values of ρ).

[45]The size of the acceleration coefficient estimated in equations (3)-(5) is consistent with the estimates made by Lipsey and Dow and Dicks-Mireaux for the early post-war period.

[46]See his comments on the Dicks-Mireaux and Dow paper, Phillips (1959, p. 176).

[47]In the last section of his paper he states that "There is no evidence of significant auto-correlation of the residuals for lags of one to three periods at the 5 percent probability level" (1960, n. 2, p. 26). Lipsey is referring to his equation fitted to the combined period 1923-39 plus 1948-57. As will be obvious from our discussion above his results disagree with ours.

[48]Gersovitz, in a very interesting paper (1980, p. 439) which investigates the famous Phillips curve "loops," suggests that autocorrelation is an inevitable consequence of fitting a curve to cyclically related data. He points out that "the residuals from a least

squares line through an ellipse are highly autocorrelated" and suggests that a difference equation formulation should be used rather than applying the standard Generalised Least Squares transformation.

[49]Rowley and Wilton (1973, 1973a, 1974, 1974a, 1977).

[50]Phillips (1959) also made this point.

[51]See Box and Jenkins (1976), Granger and Newbold (1977), Harvey (1981), Judge (1982), Nelson (1973), and Pindyck & Rubinfeld (1981).

[52]Roughly speaking a time series is stationary if its properties are invariant to a shift in time, e.g., the properties of the first one hundred observations should be the same as those of any other one hundred observations which are generated subsequently. In practice "covariance" or "weak" stationarity is all that is usually assumed (or required) this beings the property that the mean, variance and autocovariance are constant through time. For technical discussions of these issues see Box and Jenkins (1976, section 2.1.2), Harvey (1981, pp. 22-23), and Nelson (1973, section 2.1).

[53]"Failure of the sample autocorrelations to die out quickly at high lags is an indication that further differencing is required" (Granger and Newbold (1977, p. 76)).

[54]If X_t is a qth order moving average process then we may write

$$X_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_k a_{t-k} \quad (1)$$

where the θs are parameters and the a_t series is a sequence of identically and independently distributed random disturbances with mean zero and constant variance σ^2 (the so-called white noise process).

A second order moving average process (MA(2)) would therefore take the form

$$X_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} \quad (2)$$

[55]See Nelson (73, ch. 5) and Granger and Newbold (1977, p. 75).

[56]The pth order autoregressive process AR(p) is $X_t = \phi_1 X_{t-1} + \ldots + \phi_p X_{t-p} + a_t$ where the ϕs are parameters and a_t is a white noise random disturbance. An AR(p) process has a theoretical autocorrelation function which dies away steadily (either exponentially or with damped sinusoidal motion) and a theoretical partial autocorrelation function which has "spikes" at lags 2 through p and zero values thereafter. See any of the time series references in note 53 above.

[57]See Nelson (1973, pp. 71-2) and Granger and Newbold (1977, pp. 75-77).

[58]We also conducted this experiment on the longest post-World War Two sample (1948-1978) but were unable to estimate a well behaved (negatively sloped, convex to the origin) Phillips curve, even with the U^{-1} functional form. Hence we do not report these results here.

[59]The U^{-1} functional form was used because of the problems of mis-specification suggested by our previous regression experiments. On the whole this functional specification leads to satisfactory (see the previous footnote) estimated Phillips curves.

[60]Nelson (1977, pp. 71 and 78).

[61]The Cochrane-Orcutt procedure has recently been subjected to criticism on the grounds that it may lead to multiple admissible minima. See Dufour, et al. (1980), LaFrance and Belanger (1981), Oxley and Roberts (1982), and Taylor (1981).

[62]See Kirby (1981) and McDonald (1975) for applications of Pagan's technique to the Australian Phillips curve.

[63]See Poirier (1978), Sleeman (1983), and Holmes (1981?). I am

indebted to Dr. Dennis Maki for the last reference.

[64]No results are reported for the AR(2) specification in Table 4.12-4.13 because the AR(C) process exhibits explosive behaviour. An attempt to circumvent this problem by re-estimating after dropping the first two sample observations was unsuccessful.

[65]Alt (1979, p. 66. Parenthesis added).

[66]Bowen and Berry (1963, p. 171) observe that they "...doubt that there is any perfect solution to this problem...." A view with which it is hard to quarrel.

[67]The first central difference approach was an extra observation relative to the first difference approach. However, numerical analysts have derived formulas to calculate the end point values although they have never been utilised in Phillips curve studies to our knowledge. (See Carnahan (1969, p. 129)).

[68]Wallis (1971, p. 308), for example, criticised the well known Lipsey and Parkin incomes policy study on the grounds that their differencing procedure "introduces noise into the system rather than contributing to its explanatory power, and that henceforth price behaviour equations should seek to explain the <u>level</u> of prices" (Emphasis in the original). This advice seems to have been ignored by subsequent researchers.

[69]See McDonald (1975) and Kirby (1981).

[70]The paper by Henry (1974), referring to an earlier study by Hendry and Trivedi, notes that "taking some account of autocorrelation, even if the form is misspecified, is superior policy to ignoring it completely."

[71] Another area which might be explored is that of formulating continuous time models so that they may be directly estimated rather than approximated by a discrete time analogue. See Wymer (1976).

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Data Appendix

1. U: Percentage unemployment.

Usually in annual average form. The data from 1850 to 1914 came from trade union returns. From 1915 the data were collected by the British government in connection with the various unemployment insurance schemes.

1850: Wood, G. H., "Real Wages and the Standard of Comfort Since 1850," *Journal of the Royal Statistical Society*, LXXII, 1909.

1851-1914: Beveridge, W. H. *Full Employment in a Free Society*, London 1944.

1919 Estimate based on Feinstein, C. H., *National Income, Expenditures and Output of the United Kingdom, 1855-1965*, Cambridge, Cambridge University Press, 1972.

1920-1939: BLSHA, T160

1940-1947: BLSHA, T161

1948: BLSHA, T161 and T165

1949-1968: BLSHA T165

1969-1979: *Department of Employment Gazette*, various issues.

2. W: Hourly Wage Rates, Annual Averages.

1850-1859: Col. 11 in Wood, op. cit.

1860-1914: Table D, p. 276, in Phelps Brown and Hopkins.

1915-1919: Table D, p. 281, Phelps Brown and Hopkins.

1920-1979: BLSHA and DEG.

3. P: Cost of Living Index, Annual Averages.

1850-1859: Bowley, A. L. *Wages and Incomes in th U.K. Since 1860*, p. 122, Table XVII.

1860-1914: Phelps Brown and Hopkins, Table D, p. 276.

1915-1980: BLSHA and DEG various issues.