SOME ASPECTS OF INFLATION AND THE VARIABILITY OF RELATIVE PRICES

by

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Some Aspects of Inflation and the Variability of Relative Prices

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ABSTRACT

The independence of the nominal price level and relative prices is a basic postulate of neoclassical economics. Much empirical evidence from recent U.S. experience contradicts this assertion by showing a positive correlation between the variability of the inflation rate and the dispersion of relative price inflation.

In this thesis, a more appropriate weighted measure of the dispersion of relative price inflation is developed. It is argued that the choice of measure is important because the unweighted measure is found to overstate the variability of relative price dispersion. Secondly, alternative theories which attempt to explain relative price variability are examined, and it is noted that there are no *a priori* theoretical reasons for preferring any particular theory. One common theme in the literature suggests that unanticipated inflation, be it demand or supply shock, "causes" heightened relative price variability. Nowhere in the literature has unanticipated inflation been disaggregated into demand shock and supply shock components. I present a technique which allows these components to be disaggregated, and permits tests for causality in order to examine whether demand shocks or supply shocks are dominant influences on relative price variability. The inquiry is extended by examining Canadian price data.

QUOTATION

It is only theory that makes men completely incautious.

Bertrand Russell

"Ideas That Have Harmed Mankind"
Unpopular Essays (1950).

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DEDICATION

To my parents Joy and Ron, and to Jane.

NOTE ON ANNOTATION

In each Chapter equations are numbered consecutively. Figures and Tables are numbered according to Chapter and in the order in which they appear. For example, Figure 3.1 is the first Figure in Chapter 3. In reported regression results, coefficient t statistics and F ratios significant at the 5% level are denoted with a single asterisk, whilst those significant at the 1% level are marked with a double asterisk. Finally, Appendices are located at the end of each relevant chapter, and are numbered alphabetically.

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I. INTRODUCTION

Relative prices, which are determined by the interaction of the utility functions of individuals and the technology that determines the cost function for producers, are the result of the solution to the constrained optimisation problems that confront these actors. The result is said to be Pareto optimal if no individual can be made better off without another being made worse off. In a world of perfect information, and in the absence of transactions costs (which would preclude the necessity of holding money to maintain liquidity) the price system guides the allocation of resources to their most efficient use.

The actual post war experience of many industrialised nations is characterised by substantial swings in the rate of inflation, output and employment. One interpretation (ignoring the desire for liquidity) might be that this evidence challenges the efficacy of the price system in disseminating useful relative price information. Furthermore, recent experience seems to defy the conventional view of a temporary trade off between inflation and unemployment. Friedman (1976), suggests that when inflation is highly variable, it is difficult for agents to distinguish between changes in the price level and changes in relative prices. Consequently, through a variety of mechanisms, the signaling efficiency of the price mechanism is decreased, resulting in a misallocation of resources consistent with the empirical phenomonon of a Phillips Curve which appears to be positively sloped for recent data.

Several theories purport to explain how the allocative role of the price system may have become less efficient. In Chapter two we examine the available explanations of the association of various inflation characteristics with relative price variability. Evidence presented by Logue and Willet (1976) for the U.S. economy is suggestive of a decrease in the signaling efficiency of relative prices when inflation is high. They demonstrate that relative price variability, inflation variability, and inflation rates all seem to be correlated. Blejer and Lederman (1980) evaluate the effect of relative price variability on economic activity in the U.S. economy, and find that increased relative price variability is correlated with a decrease in the level of output and employment.

The question arises as to whether the costs associated with diminished efficiency of the price system in terms of output and employment losses can be avoided. Despite recent evidence in the seventies which seems to indicate that supply shocks appear to have been an important source of inflation, regardless of whether they are accompanied by accomodative monetary policies, many explanations suggest that higher inflation will "cause" higher relative price variability. [1] The question of causality is an important issue, because an increase in relative price variability caused by supply shocks should not necessarily be

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[1] See for example, Fischer (1981).

interpreted as undesirable, even if associated with a reduction in output and employment.[2] Because increased variability may be a symptom of the dispersion of useful relative price information throughout the economy, heightened relative price variability is undesirable only if it is a symptom of increased "noise", which makes it difficult for agents to extract useful relative price information. Supply shocks are often regarded as non-monetary phenomena, although this distinction is not clear cut, because shocks that occur as a result of exchange rate movements may be regarded as the consequence of monetary forces. The interpretation of demand shocks is also complicated by ambiguity over whether real or monetary forces are at play.

The policy implications surrounding this issue are crucial. If action to reduce relative price variability is taken by attempting to reduce the inflation that is associated with it, this policy may either be useful or counter-productive, depending upon the source of the relative price disturbance. If the disturbance is the result of a shift in relative demands or supplies, resources will be re-allocated to higher valued uses, and reduction of this variability is undesirable. If the disturbance is due to a change in nominal aggregate demand, but its composition remains the same, any re-allocation of resources

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[2] It is useful to make the distinction between pure relative disturbances, which entail re-allocations in supply and/or demand but which leave real output unchanged, and a relative shock (for example oil price hikes in the seventies) which not only increased the price of oil, but also reduced aggregate supply and real output.

will be either to lower valued uses causing a decline in output. It may also result in labour and other supply decisions that occur as a result of misperceptions which do not maximise net social welfare.

Some of the questions that arise from the preceeding discussion are the motivation for this thesis. A brief indication of the contents of each Chapter is now given. We begin Chapter two with a review of the empirical regularities that have been shown to exist between relative price variability and various characteristics of inflation. Next, the theoretical contributions which attempt to explain these phenomena are explored. In Chapter three the measurement of the variability of relative prices is examined. An interesting, although not altogether surprising, result is that a measure which disregards the expenditure weights of sub-components of the consumer price index overstates the variability of relative prices, compared to a measure that does incorporate these weights. Chapter four reviews conventional explanations of the relationship between unanticipated inflation and short run deviations from trend income, and explores the ways in which unanticipated inflation is measured. In Chapter five an attempt to identify demand and supply components of unanticipated inflation is presented, and residuals derived from ARIMA models of inflation and income are tested. In Chapter six, tests for temporal precedence and regressions are conducted on disaggregated unanticipated inflation data to investigate the relationship between relative price variability and demand/supply shock inflation.

An indirect benefit of this research results from testing the generality of established empirical results derived from U.S. data. The Canadian economy is a typical small open economy. Exogenous shocks, when exchange rates are fixed or are imperfectly flexible, may have significant impacts on the structure of relative prices and their variability. For the US, this phenomonon may be less important because it is a large relatively closed economy. Therefore empirical regularities that exist in the U.S. data may not hold for Canadian data.

II. EMPIRICAL REGULARITIES AND THEORETICAL EXPLANATIONS OF RELATIVE PRICE VARIABILITY

2.1 Introduction and Background

We begin this discussion with a recapitulation of received neoclassical doctrine concerning the long run neutrality of money, where the "Classical Dichotomy" traditionally separated monetary and value theory. A one time change in the quantity of money was deemed not to alter the equilibrium of the system in terms of relative prices, including the real interest rate. [1] Traditionally it was also argued that fully anticipated inflation would be neutral in its effects. That assertion has been modified by the recognition of the cash balance effect, and by impacts due to institutional features such as the tax structure. [2] Further sources of non neutrality include the effect of government and other debt, when the rate of inflation changes. [3]

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[1] An excellent summary, including the Archibald-Lipsey Lange-Patinkin debate, can be found in Johnson (1967).

[2] For citations to this literature see Barro (1972).

[3] An increase in the rate of inflation will raise nominal interest rates, assuming no offsetting declines in the real rate, causing the price of assets such as bonds to fall, which may reduce net wealth. Neutrality is preserved only under the following conditions. If future tax payments required to service the interest payments on government bonds are taken into

The most wideley cited example of non-neutrality is the cash balance effect, which suggests that the quantity of cash balances held by economic agents will be influenced by the rate of expected inflation plus the real interest rate. [4] Agents take account of the fact that in an inflationary environment, a premium over the real interest rate is required in order to maintain the real purchasing power of wealth held in nominal terms.

Increased inflation causes the cost of holding non interest bearing money balances to increase, resulting in a downward re-adjustment in desired real balances. There are four well known effects that result from this re-adjustment. The first is the overshooting phenomenon, where the inflation rate temporarily overshoots its long run equilibrium rate as a consequence of agents' attempts to lower real balances. Second, when equilibrium is re-established, there exists a per period "tax" on real balance holders. Third, there is a "boot leather" cost, which occurs as a result of increased banking transactions

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[3](cont'd) account, the public may recognise that the lower present value of the coupon payments would translate into lower real taxes. Although the fall in the price of bonds is equal to the reduction in the present value of coupon interest payments, if both interest and taxes are properly and equally discounted, net income receipts remain unaltered since the reduced present value of coupon is matched by the reduced present value of taxes, leaving net wealth unaffected.

[4] Mundell (1977), also points out that an increase in anticipated inflation may be responsible for substitutions away from cash and liquid assets into physical assets or claims on physical assets, which may cause a decline in the real interest rate.

required to replenish real balances which depreciate at a faster rate. Finally, there is a deadweight welfare loss associated with a loss of consumer surplus.

In the past two decades, however, the most pervasive and ongoing debate has been the controversy regarding the Phillips Curve. [5] The issue is over the magnitude and duration of short run systematic real effects which may be produced when an unanticipated monetary event occurs. [6]

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[5] The Expectations-Augmented Phillips Curve was suggested by Friedman (1968) and in a slightly different form by Phelps (1967). Both versions suggested a "natural" rate of unemployment which could be thought of as that level of unemployment associated with expectations equilibrium, where on average no agents plans are frustrated because their subjective expectations conform to the objective opportunity set. Therefore unemployment associated with the natural rate is a result of optimal decisions made while the economy is in general equilibrium. This does not imply that the natural rate is secularly fixed. Since it is determined by real phenomena, any change in these forces could result in changes in the natural rate. Regarding persistence, the size and duration of systematic effects depend, among other factors, on the velocity of adjustment of expected inflation to new information, and on the elasticity of the short run aggregate supply function, which in turn depends on labour market conditions including labour market contracting practices.

[6] In Friedman (1968), workers accept lower real wages because they are temporarily fooled by increases in the price level. Since by assumption, employers cannot be as easily fooled, this well known asymmetry is explained through employee needs for price information on a comprehensive set of consumption items, in order to ascertain knowledge of the price level. In contrast, employers need to know only the price of their output and inputs in order to make decisions (Friedman 1975)). Lucas and Rapping focus on labour supply decisions, suggesting that labour supply depends on the expected real wage. When a change in the real wage is perceived to be temporary, an increase in the real wage will induce agents to work more because the cost of leisure is high. In contrast, permanent increases in the real wage will have negligable effects on labour supply, because opportunities for intertemporal speculation depend on temporary fluctuations in the real wage. This induces suppliers to take leisure when they think it costs the least.

Milton Friedman (1976) points out in his Nobel lecture that professional views on the Phillips Curve have gone through three distinct historical stages. These range from a stable tradeoff, to a temporary or no tradeoff as embodied in the expectations augmented version, to an apparent positively sloped relation. Commenting on the evidence that recent curves fitted on data for a number of countries are positively sloped, Friedman suggests that the level of inflation and its variability are positively correlated, submitting that the relationship implied by the curve is a statistical abberation which is hiding the actual causal relationship between inflation variability and unemployment. [7] Consequently, recent literature is directed towards investigation of the stochastic nature of inflation variability and related characteristics such as the dispersion of relative prices. [8]

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[7] Other explanations for a positively sloped Phillips Curve have been offered by Barro (1976) and Mullineaux (1981). Barro suggests influences may occur through wealth effects on labour supply, while Mullineaux adds that imperfections in indexing may play a role.

[8] It would be easy to become embroiled with the problem of defining inflation. Which price level is to be measured? Operationally the GNP deflator, the consumer price index, or the wholesale price index are well known but imperfect measures. Conceptual definitions include sustained and significant increases in the general price level. There is perhaps no satisfactory operational definition that would please every taste. Brown and Santoni (1981) examine the price data widely cited in empirical studies, and find that the index most frequently used is the CPI. They cite a number of studies that use the CPI: Burger (1976), Elliot (1977), Fama (1976), Hess and Bicksler (1975), and Yohe and Karnosky (1969). The GNP deflator has been used less frequently, for example Feldstein and Eckstein (1970). Fama (1975), provides a somewhat cavalier yet typical justification for using the CPI. He suggests that the use of any index to measure the level of prices of consumption

Jaffee and Kleinman (1977), in accord with Friedman's suggestion that ascribes real effects to a higher rate of inflation if it is accompanied by increased inflation variability, suggest that in order for neutrality to be preserved (ignoring the cash balance and government debt effects) inflation is implicitly or explicitly assumed to have the following characteristics: i) it is perfectly forseen; the expected rate which influences individuals' optimising decisions is equal to the realised rate; ii) institutions adapt to accommodate inflation. For example they may adopt price indexed contracts; iii) the effects of inflation are uniform over all commodity groups. Inflation does not cause changes in relative prices.

It is our intention to examine point iii) in detail. Section 2.2 examines the empirical evidence while Section 2.3 considers the theoretical aspects involved. Much of the discussion in 2.3 is anchored in the contribution of Lucas (1973), because this is one of the clearest statements that inflation variability does not affect relative prices which can be utilised in an empirically tractable form. [9]

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[8] (cont'd) goods can be questioned, but on page 247 he states that there is "no need to speculate about the effect of shortcomings of the data on the tests. If the results of the test seem meaningful, the data are probably adequate."

[9] We would be remiss in not mentioning the contribution of Cuikerman (1983) and references therein, which are elaborations and significant extensions of the Lucas model which take explicit account of correlations between relative price variability and inflation variability.

2.2 The US and other Empirical Evidence

In this section we shall see that there is empirical evidence which suggests that (i) relative price change variability and the rate of inflation are positively related in a cross section of countries (Glejser (1965), Wolozin (1959). (ii) relative price change variability and the variability of inflation are positively related over time in the U.S. (Vining and Eltowerski (1976)), (iii) relative price change variability is positively related to unanticipated inflation (Parks (1978), Ashley (1981), Blejer and Lederman (1980)), and (iv), the level and variability of inflation are positively related both cross sectionally and over time (Okun (1971), Gordon (1971), Logue and Willet (1976), Jaffee and Kleinman (1977), Foster (1978), Mullineaux (1980), and Blejer (1979)).

2.2(i) Correlation with the Inflation Rate

To measure the change in the relative price of a commodity group, Glejser uses a measure that computes the standard deviation of relative price (levels) weighted by expenditure share. He compares the average value for the years 1953-1959 of a given price index with an average of the whole consumer price index. Among seven main commodity groups, he computes the standard deviation of each relative price change for fifteen OECD countries. He finds that the rate of inflation is the most important explanation of relative price change. A contrary view can be found in Wolozin, who using an unweighted measure of dispersion, finds that for the period 1947-1957 inflation does not appear to affect the efficiency of relative price adjustment in US price data.

2.2(ii) Correlation with Inflation Variability

In an inquiry into the variability of inflation, Vining and Eltowerski examine price data covering the period 1947-1974, and find that for both wholesale and consumer price indices in the U.S., the variance of relative price change is related to general inflation variability. The variance of relative price change is calculated by taking every sub-index of the main series and calculating a variance for each point in time. Their concept of general price change instability is less clear. They refer to a chart which shows the inflation rate over the interval, suggesting that a decrease in instability can be represented by a gradual horizontal straightening in the line connecting successive inflation rates. Although this is a classic article, it can be criticised on two points. First, the measure of relative price variability is a variance which uses the same weights for all expenditure items. Second, this study fails to give a clear measure of inflation variability.

2.2(iii) Correlation with Unanticipated Inflation

Ashley, using Granger causality tests, concludes that fluctuations in the inflation rate help cause fluctuations in relative prices, but not vice-versa (unless the entire effect occurs within the period of his monthly data). He uses an unweighted measure of the variance of relative price change and calculates the general inflation rate as an unweighted arithmetic average of the sub-indices. Despite these methodological weaknesses of measurement, he claims that his results validate the earlier contribution of Parks, who using a weighted measure of relative price change dispersion, demonstrates that this variance is correlated with the squared rate of change of consumer prices for both the Netherlands and the U.S. Furthermore, using a multisectoral supply and demand framework, Parks shows that unanticipated inflation is more closely related to relative price variability than the rate of inflation. [10]

Blejer and Lederman use a cumulative weighted measure of relative price dispersion, concluding that output and employment are negatively related to relative price dispersion and positively related to unanticipated inflation. They find that anticipated inflation has an insignificant coefficient in all but one of their regressions. They suggest that a cumulative measure is consistent with a build up of lagged effects on

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[10] Parks assumes the direction of causality is from inflation to relative price change dispersion in his regressions. Ashley claims that his Granger causality test validates this method.

output that occur as a result of increased relative price dispersion.

2.2(iv) Links Between Inflation and Inflation Variability

The most substantial body of evidence of a correlation between the level and the variability of inflation comes from comparisons of different countries and time periods. Okun's study compares 17 OECD countries during the period 1951-68. He uses the standard deviation of the annual increases in the GNP deflator as a measure of variability, finding that countries with a high average inflation rate also have a high standard deviation. Okun's findings are not uncontested, however. Gordon demonstrates that the correlation is lower if the comparison is made only for the sixties.

An international comparison is made by Logue and Willet over the period 1949-70 for a total of 41 countries. Breaking their sample into groups, they demonstrate a nonlinear relationship between inflation and inflation variability, finding that the relationship is stronger for countries that have relatively high rates of inflation. Foster confirms many of these findings, using average absolute changes rather than variances as measures of inflation. Mullineaux conducts tests on Livingston survey data, investigating the proposition (suggested by Friedman) that the natural rate may be positively associated with the variability of the inflation rate. Using a moving standard deviation of the expected inflation rate, he finds that unemployment is positively associated with inflation variability in the short run.

The proposition that U.S. unemployment is positively related to inflation uncertainty is also tested by Mullineaux. He uses two measures of uncertainty; the standard deviation of the bi-annual inflation forecasts collected by Livingston and a moving standard deviation calculated from time series data. Unemployment deviations from trend are significantly correlated with each measure of inflation uncertainty. It is interesting to note the peripheral finding that the level of inflation and the measures of uncertainty tend to move together.

2.2(v) Summary

There has been an extensive research effort towards establishing empirical generalisations from the inflation data. Indeed, one complaint might be that there is so much information that it is difficult to isolate any dominant relationship. We note however that there are few, if any, contradictory findings. It is therefore not surprising to find that there has been an equally extensive theoretical effort to rationalise the evidence.

2.3 Theories of Relative Price Dispersion

In this section we examine some of the most convincing explanations of the correlation between inflation and relative price variability. In sections 2.3(i) through 2.3(iii), some of the more obvious causes of relative price variability are noted. Section 2.3(i) briefly considers the distorting effects of risk and uncertainty, where it is suggested that there may exist a positive relationship between inflation unpredictability and relative price variability. Section 2.3(ii) examines effects induced by government policy. It is apparent that unanticipated or anticipated inflation may influence relative price variability. Section 2.3(iii) explores the effects of price inflexibility when there is excess demand in some but not all markets. Inflation and relative price variability are found to be associated.

Section 2.3(iv) presents models where a relationship between relative price variability and inflation variability is implied (Lucas (1973), Barro (1976), Cuikerman (1982), Parks (1978), Cuikerman and Wachtel (1982), Amihud and Mendelson (1982)). In Section 2.3(v) contracting practices and supply shocks are explored (Taylor (1981)). This model suggests a relationship between relative price variability and the variability of inflation. In Section 2.3(vi) models in which costs of price adjustment have been submitted are also noted (Sheshinski and Weiss (1977), Mussa (1977)). These models suggest that relative price variability is related to the level of anticipated inflation.

2.3(i) Risk and Uncertainty

In this dissertation risk aversion is ignored because of space and tractability constraints. We assume that agents' utility functions are invariant to the variance of expected values. Uncertainty may clearly affect relative prices, and although we consider this no further, the potentially distorting effects of uncertainty are briefly discussed.

Highly variable inflation rates, if they are unpredictable, may be be responsible for substitutions that occur as a result of agents' attempts to optimise, subject to transactions costs, their exposure to risk and hence assets (such as bonds) denominated in nominal terms. [11] It is known that the price of an asset will reflect its present value, discounted appropriately in terms of its yield of future services. Uncertainty about future inflation rates means that the discount factor to be applied is uncertain. [12] In the absence of insurance markets for the future real value of nominal assets, risk averse agents will tend to avoid holding nominal assets at current expected values. Even if some agents are "plungers", it

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[11] See for example, Jaffee and Kleinman (1977).

[12] The expressions risk and uncertainty are used interchangably here, to mean a known subjective probability distribution of possible states of nature. We note the distinction made by F. Knight, where he defines risk as corresponding to a known probability distribution, and uncertainty as corresponding to an undefined probability distribution.

is improbable that effects will be offsetting, and therefore some re-alignment of relative prices will occur. If risk averse effects dominate, the prices of nominal assets will fall relative to physical assets until agents are willing to hold them. Changes in the unpredictability of inflation may cause increased relative price variability because of distortions induced by risk.

2.3(ii) Government Macroeconomic Policy

A change in government expenditure can be thought of as being responsible for changes in the composition of final output and thus relative prices, because the mechanism through which the composition of aggregate output is changed is through changes in relative prices.

2.3(iii) Asymmetric Price Responses

This approach draws on Lipsey's (1960) nonlinear aggregation hypothesis. Assuming relative price variability as exogenous, it uses asymmetric responses of prices to relative disturbances to derive a positive association between relative price variability and the rate of inflation. If prices are inflexible downwards in some but not all markets, in the absence of relative disturbances the price level remains the same as last period. A re-allocation of demand from the fixed price markets to the flexible price markets causes price rises. In markets where excess demands exist, prices rise and in markets where there is excess supply nominal prices remain the same. Hence a relative disturbance may induce a higher price level or inflation rate and an increase in its dispersion. [13]

2.3(iv) Rational Expectations with Misperceptions

We now take a somewhat extended view of the explanation which has its roots in the contribution of Lucas (1973). We shall see that heightened variability of relative prices occurs when confusion exists between nominal and relative price signals, since greater volatility in relative prices is the only way in which price signals can be transmitted (and in which markets clear). This signal extraction problem is the basis of Lucas's contribution, and is also alluded to in Friedman's (1976) Nobel Lecture on the apparent demise of the Phillips Curve.

The Lucas model postulates that a lack of full information prevents individuals from dichotomising unanticipated price movements into relative and nominal components. The independence of relative prices from the general price level is a basic neoclassical postulate which Lucas elegantly restates, allowing for random fluctuations of relative prices. [14] The expression

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[13] This description of the goods market is the equivalent of the labour market model of Tobin (1972).

[14] Patinkin (1965) is often cited as an important statement of the classical dichotomy. Lucas's innovation lies in the fact that unlike Patinkin, where relative prices are rigidly invariant to the price level, he allows random fluctuations in relative prices (as exemplified by Z(t) in equation (1)) which makes his restatement amenable to statistical testing.

takes the form [15]

(1) $$Pt(Z) = Pt + Z(t)$$

where Pt(Z) is the logarithm of the price of the Z'th good at time t, Pt is the logarithm of the general price level at time t distributed random normal, and independent of Pt(Z), and Z(t) is a random normal stochastic error term. The first and second moments of the distributions Z and Pt are known and are written as:

(2) $$\begin{aligned} Z(t) &\text{ is distributed } (0, \tau^2) \\ Pt &\text{ is distributed } (Pt, \sigma^2) \end{aligned}$$

Information It(Z) relevant for estimating the unobserved Pt consists of observed price Pt(Z) and the history summarised in the expectation of (Pt), written as E{Pt}. Thus the individual faces a signal extraction problem of decomposing the change in his selling price into general price level changes and relative

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[15] This is equation (4) in Lucas. Note that unlike Lucas, Z is indexed by the time subscript in order to provide annotation for the derivation of the expression for the variance in one period changes in Pt below.

price changes.[16] Suppliers use (1) and the variance information to calculate the distribution of Pt. This distribution is normal and has an expected value[17]

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[16] It is essential to this analysis that the individual has imperfect information. If a producer knew all other prices in the economy, he would calculate a price index and determine the average price level in the economy. Producers are presumed not to have this information, an assumption that has been criticised on the grounds that price data are published regularly with minimal lags. Lucas has responded by suggesting that accurate economy wide information is costly, and that profit opportunities depend on being able to react quickly to changes in the economy. We add that the relevant planning time horizon can be arbitrarily lengthened so that information regarding prices is not available for the current period. Indeed, a popular variant of the Phillips Curve postulates an environment where agents form future price expectations this period. Cuikerman (1982), has given a rigorous foundation to the argument that the duration of effects may be lasting, by replacing the aggregate/relative confusion with a permanent/transitory confusion, which is not dispelled by the publication of statistics about the general price level. Finally, movements in the general price level are explained by movements in money. Lucas argues that a loose short term link between past money growth and prices supports his theory, because agents cannot just check appropriate money statistics in order to calculate the general price level.

[17] It is optimal to utilise all available information on the distribution of Pt(Z) and Pt in the calculation of this expectation. Given an observation on Pt(Z) and Pt, and the variance information, the expectation can be calculated by utilising a weighted linear combination of Pt(Z) and Pt. The extraction of the relevant information is accomplished by subtracting the proportion of total variance attributable to relative price inflation from unity. Consistency requires that the proportion is replaced and it appears as the weight on Pt.

(3) $E\{Pt | It(Z)\} = (1 - \theta)Pt(Z) + \theta . \bar{P}t$

$$\text{where } \theta = \frac{\tau^2}{\tau^2 + \sigma^2}$$

By combining this information with a behavioral equation for supply, Lucas derives a supply function for the Z'th market of the form [18]

(4) $Yt(Z) = Yn,t + \theta\gamma(Pt(Z) - \bar{P}t) + \lambda Yc,t-1.$

Where Yn,t denotes trend income, γ is a supply parameter, Yc,t-1 denotes lagged deviation from trend income. Aggregation over Z markets yields the aggregate supply function. The main conclusions can be stated as follows: greater average price variability causes agents to attribute a larger fraction of observed price movement to nominal causes. Since agents react only to relative prices, this results in reduced responsiveness

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[18] This is equation (6) in Lucas. It is derived by combining his equations (1), (3), and (5).

of output. Greater variation in aggregate demand will be reflected in an increase in σ. When σ rises θ becomes smaller, causing a worsening of the short run Phillips Curve trade off. Greater variation in relative prices will be reflected in an increase in τ. When τ rises, θ approaches unity, which suggests that the supply function is governed by the limiting value γ. Lucas claims that his empirical evidence suggests that countries with high average price variability suffer the most unfavourable tradeoff, which is consistent with the predictions from the signal extraction problem. Unfortunately, his results depend on a few extreme cases where the variability of the inflation rate is high.

This theory does have an interesting policy implication. An economy with a stable inflation history will be characterised by large responses to unanticipated inflation created by policy makers. If this policy is pursued, the inflation rate will become more volatile, making it difficult to continue to engage in similar policies because agents will learn of the changed stochastic properties of the inflation rate. They will learn to distrust price changes as signals of relative price change and therefore respond less to price signals.

As written in equation (2), it is assumed that the variance of relative prices is constant and therefore independent of the variability of the general price level. Empirical investigation of this assumption is performed on the rates of change of relative prices. To make Lucas's statement applicable to rates of price change, the following simple transformation of equation (1) into log first differences is made. [19]

$$(5)\qquad Pt+1(Z) - Pt(Z) = Pt+1 - Pt + Z(t+1) - Z(t)$$

Rearranging (5) and squaring both sides yields:

$$(6)\qquad \{(Pt+1(Z) - Pt(Z)) -(Pt+1 - Pt)\}^2 = \{Z(t+1) - Z(t)\}^2$$

The expected value of the left hand term is the expected variance of one period changes in Pt(Z).

$$(7)\qquad Var(Pt+1(Z) - Pt(Z))= E\{Z(t+1) - Z(t)\}^2 = 2\tau^2$$

It can be observed that the variance of relative price inflation is twice that of the levels, but it retains invariance with respect to the variability of aggregate inflation.

Having detailed the essentials of the Lucas framework, it is possible to examine the paradoxical correlation between

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[19] This demonstration draws upon the upon the contribution of Vining and Eltowerski (1976). The point being made is that in the Lucas model relative prices can be shown to be independent of both the price level and its rate of change.

inflation variability and relative price variability. The suggestion that τ and σ are independent leads Vining and Eltowerski (1976) to investigate U.S. consumer price data. Finding that there is a positive correlation, they interpret their results in a way suggested by Barro (1976), who uses a similar localised market framework. He suggestes a chain of causality running from general price change instability to relative price change instability.

When agents are confronted with the problem of determining whether locally observed price movements are caused by general inflation or by shifts in relative demands, a greater variance of the general inflation rate causes agents to attribute more of local price movements to general price movements rather than to relative shifts.[20] Increased inflation variance causes reduced supply response, since agents only react to perceived changes in relative prices. Excess demands becomes less elastic, causing shocks to local excess demands to result in larger changes in individual prices. Therefore the dispersion of relative prices tends to increase with the variance of inflation.[21]

Cuikerman (1982) suggests a different interpretation, arguing that Lucas's model is consistent with the finding that

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[20] Barro suggests that the variance of the money supply is the reason for confusion between aggregate and local shocks.

[21] Hercowitz (1981) modifies this framework by allowing each separate market to have a unique excess demand elasticity. His model is supported by empirical evidence which uses a price dispersion measure which is equally weighted. The use of this kind of measure is questioned in Chapter three.

there is a positive correlation between the relative price change dispersion and general price change dispersion. Cuikerman states that it is more correct to conceptualise a framework where both the variance of the general price level and the variance of relative prices are influenced by some common exogenous shock, such as the variance of aggregate income.

A submission by Parks (1978), where the underlying structure of demand-supply relationships plays a role in the determination of relative price variability, postulates that quantities supplied depend on relative prices, unanticipated inflation, and supply conditions. The smaller the elasticity of supply, the greater will be the price change, and the less will be the quantity change, associated with a given increase in unanticipated nominal income. In his multimarket framework, he shows that the change in relative prices can be decomposed into supply-demand parameters, plus an expression that involves the rate of change of real income and unanticipated inflation.[22] He concludes that unanticipated inflation is a better predictor of relative price variability than is anticipated inflation.

Cuikerman and Wachtel (1982) use a framework that builds on Parks except that they allow inflation expectations to vary across markets. Since equilibrium prices (and their rates of change) in different markets may differ, inflation expectations across markets may also vary. They show that there may be a positive relationship between relative price variability and the

[22] For example see his equation (6).

variance of inflation expectations across markets. They show that changes in the variance of either aggregate demand or supply shocks will cause increased relative price variability. They also find some supporting empirical evidence by utilising the survey data in Carlson (1977).

Amihud and Mendelson (1982), suggest that relative price dispersion is caused by the variance of aggregate economic shocks. They rely on the inventory adjustment policy of firms to show that relative price dispersion depends on the variability of aggregate demand shocks and the variability of industry specific shocks. Their result is generated through different pricing responses of each industry to the aggregate shock, even when there is no confusion between aggregate and relative shocks. Economic shocks affect each industry's inventories to a different extent, inducing price responses that may vary across industries. This leads to the relationship between the variance of aggregate shocks and relative price variability.

2.3(v) Contracting Practices and Supply Shocks

In contrast to the isolated market/informational imperfection approach, an explanation of relative price variability has been proposed by Taylor (1981), utilising contracting practices and supply shocks as an important source of relative price variability. In his model, both relative price variability and inflation variability react in the same positive direction to a supply shock. [23] This model, in contrast to Lucas, stresses supply shocks, and although constructed very differently, it suggests a positive relationship between relative price variability and inflation variability.

A more obvious and intuitively pleasing way in which unanticipated and relative price variability may be correlated is through the effect of a dominant sub-index. A price shock will simultaneously raise the variance of relative prices and the average inflation rate, if the sub-index is an important (high weight) element of the CPI. Therefore any supply shock, such as the oil price hikes of the seventies, will be responsible for some of the observed correlation.

2.3(vi) Adjustment Costs

In this section we turn to a class of model that emphasises either incomplete adjustment of relative prices, or focuses on the welfare loss involved in adjusting relative prices. These explanations assume that there is some real cost to changing prices, either in terms of administering price adjustments, or in the resources required to renegotiate contracts. A shared characteristic of the papers reviewed is that inflation is fully anticipated. Relatively technical expositions preclude detailed description, and we report the main conclusions of the papers

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[23] By invoking rational expectation with no aggregate/local confusion, the variance of monetary policy shocks does not appear in Taylor's model to be responsible for relative price variability.

without formal proof.[24]

Sheshinski and Weiss (1977) consider a monopolistic firm which adjusts nominal price at discrete intervals, focusing on the effect of expected inflation on the frequency and magnitude of price changes. The firm fixes the nominal price of its output over intervals of constant duration. The size of adjustment, it turns out, is proportional to the length of the period. The real price fluctuates between two bounds, decreasing continuously each period, as inflation erodes the real price. Increased inflation results in increased variance of relative prices if the timing of firms' price adjustments are independent. Hence the inflation level, rather than its variability, causes increased relative price variability.

In an inquiry into the welfare costs of inflation, Mussa (1977) suggests that the conventional analysis which treats the triangle under the demand curve as representative of the welfare loss due to inflation is incomplete. Furthermore, results similar to those above for the variability of relative prices are derived. In his paper there are relative and aggregate demand shocks, reminiscent of the Lucas model presented earlier, although this similarity is not necessary for the generation of his result. There are two costs. The first is related to the divergence between the price set and the equilibrium price that would prevail in a costless situation. Secondly, the process of

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[24] A criticism that can be made of both papers is that they make the heroic assumption that unit costs of adjustment are independent of the inflation rate.

changing prices is in itself costly. Therefore increasing the frequency of price adjustment reduces losses but also imposes costs. The model is solved by selecting the optimal frequency of price adjustment which minimises total loss. As inflation increases, more price changes beyond those required for relative price adjustment are warranted. The way this induces increased variability of relative prices can be explained by ignoring ongoing relative price adjustments (which is an aspect considered in the paper) and focusing on movement away from an aggregate inflation rate of zero. Initially at zero inflation, price adjustments are unnecessary since all prices are set at their equilibrium levels without any further need for adjustment. Aggregate demand pressure induces the need for periodic adjustment of all prices. When the distribution of costs and benefits across firms is not the same, this results in heightened variability of relative prices since they are adjusted at various discrete intervals. [25]

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[25] Although the loss function increases with inflation or deflation, its shape is determined by the dispersion of relative demand shocks, which are assumed to be unrelated to inflation. If the variance of demand shocks is high, the function will be raised and flattened. This is because when inflation is zero there remain costs associated with adjusting prices due to relative demand shifts. This kind of cost is not normally considered to be a welfare loss. When the variability of relative prices is zero, the characteristics of the loss function change. Since no price adjustments are required in the absence of relative demand shocks, all prices are set at their equilibrium levels without further need for adjustment. The function flattens because small movements of inflation away from zero induces some prices to adjust more frequently, but it allows others to adjust less.

2.3(vii) Summary

Of the theoretical work reviewed, it is apparent that unanticipated inflation, anticipated inflation and inflation variability seem to be the most recurrent factors postulated as being related to relative price variability. This narrows the prospective field of enquiry to these areas. Furthermore, with the exception of Cuikerman and Wachtel, studies seem to take the theoretical position that it is either demand side or supply side factors which determine relative price variability.

2.4 Thesis Objectives

This review of the literature is indicative of several considerations. It is evident that there is a broad diet of disparate explanations of relative price variability, and that empirical regularities seem to be quite robust. [26] However, in the many studies that focus on the theme of unanticipated inflation being associated with relative price variability, an important concern is ignored, No question is raised regarding whether its source is a demand and/or supply surprise. This would seem to invite a fundamental identification error, because coefficient estimates assigned to unanticipated inflation are a hybrid of the demand supply parameters. There is the implicit

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[26] Fischer (1981) is the only example we can find which makes a systematic survey of the literature and also undertakes comparative empirical study on U.S. price data. He finds that supply shocks appear to be a dominant influence on relative price variability, with demand shocks having little effect. We shall have more to say on this in Chapter six.

assumption in the literature that demand and supply shock effects are identical. In this thesis our intent is to unravel these effects by specifying independently shocked aggregate demand and supply functions, in order to disaggregate unanticipated inflation into demand and supply shock categories. This allows inquiry into the relative strengths of these shocks on relative price.

Secondly, although several studies note the empirical regularity of an association between the variance of relative price changes and the variability of inflation, surprisingly the measurement of relative price change variability has not been subject to scrutiny. Many studies have used as a measure of the dispersion of relative price inflation a variance or standard deviation calculated by weighting each sub-index or relative price equally, which from a sampling perspective is questionable. It would make more sense to weight each sub-index by its expenditure weight. If a random sample of a dollar's worth of expenditure were drawn from total expenditure, the probability that we would observe any given commodity price would be given by its expenditure weight in the basket of commodities. It is apparent that potentially serious biases may exist in studies which ignore this fact. It is our intention to compare weighted and unweighted measures of relative price dispersion, to see whether it does matter which of these measures is used.

2.5 A Methodological Postscript

Little has been said regarding the compartmentalisation of anticipated and unanticipated inflation. It might be envisaged that competing expectations theories could be resolved by comparative critique, and that the "best" theory would emerge relatively unscathed until a "better" one emerges. Unfortunately, the criteria for determining what constitutes a "good" theory have themselves been the focus of considerable debate.

The acceptance of logical positivism as an appropriate research paradigm in economics dismisses the reasonableness of assumptions as irrelevant. The only test of a theory is its predictive accuracy, which is subject to empirical refutation. The only meaningful question concerning assumptions becomes whether they are sufficiently good approximations for the purpose at hand, which can only be determined by comparing the theories' predictions with the available evidence.

> Even the most extreme proponents of realistic assumptions are thus necessarily driven to reject their own criterion and to accept the test by prediction when they classify alternative assumptions as more or less realstic. (Friedman, 1953, p33)

It would seem that methodological necessity requires that theories we consider to be good be tested. However, observability is a problem in the field of expectations enquiry. Since there is no independent evidence concerning the values of expected inflation, tests of models that contain inflation expectations have proceeded in two distinct stages. [27] First, some mechanism whereby agents form their unobserved expectations is postulated.[28] Next, these generated forecasts are used in further tests, which often consist of estimating parameter values attached to the inflation forecast, as well as other variables. These mechanical tests can be criticised because a small estimated inflation coefficient can have two meanings. It could be that the generated inflation forecast is in some sense correct, but that expectations are not an important element in the process being examined. Alternatively, the generated expectations forecast could be incorrect, because although the model should include expectations as an influence, the estimated coefficient is biased towards zero since the wrong expectations forecast is included in the regression. [29] The only sensible test of a theory is its predictive accuracy. However, when the theory fails, it is impossible to know at which level the problem occurred. Does the problem lie in generated inflation

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[27] The Livingston survey data of inflation expectations in the U.S. is an exception. However, the validity of the data and its interpretation have in turn been subject to question.

[28] For example, expected inflation can be estimated in an autoregressive scheme, where current inflation is regressed on its own lagged values.

[29] Fama (1975) has attempted to unravel inflation expectations through market behaviour by holding the implied short term real interest rate in a long term bond constant. Variations in the implied short term nominal interest rate are interpreted as changes in the expected inflation rate. The empirical evidence in his paper suggests, however, that "fixed price" models of the real interest rate are only partly capable of isolating inflation expectations.

expectations or specification of the larger model or both?

Theories in general, as a matter of logic, are unprovable and can only be found to be consistent with the facts. [30] Friedman has stated that " if there is one hypothesis that is consistent with the available evidence, there are always an infinite number that are" (1953, p9) adding that such criteria as simplicity and fruitfulness may enable the researcher to chose among alternative hypotheses that are equally consistent with the data. The testing of hypotheses is the domain of the applied econometrician, and there are strong arguments from careful researchers for caution. Feige (1975, p1291) points out that "we have all too often come to associate 'poor' results with lack of achievement of statistical significance and 'good' results with the achievement of statistical significance." As a minimum standard, Feige suggests that data and procedures be fully reported, regardless of final result. Furthermore instead of thinking of econometric results as disconfirming or not disconfirming, we should think of them as "circumstantial evidence", where the more times a theory is not disconfirmed the more strongly we begin to believe in its postulates. It is this perspective that we adopt in acessing the results from econometric tests in this thesis.

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[30] One is reminded of the story of the economics professor and a student who were both walking across campus. The student noticed a five dollar bill on the ground to which observation the professor responded: "It cannot possibly be there. Somebody would have picked it up by now"

III. ON AN APPROPRIATE MEASURE OF RELATIVE PRICE VARIABILITY

3.1 Introduction

This chapter is a relatively unglamorous but important component of the puzzle to be pieced together. It is necessary to define and discuss one of the tools to be used in this enquiry. Some discussion of the construction of index numbers is required to facilitate understanding of problems inherent in the proposed measure of relative price dispersion. Accordingly, we examine problems associated with the formation of chain indices using splicing techniques, where changes in the base reference period have occurred. With this accomplished, a measure of relative price dispersion is developed. We begin by examining the attributes of a "true" cost of living index.

3.2 Index Numbers and Economic Theory

A true cost of living index measures the solution to the consumer choice problem:

(1) $\quad \text{Max } U(Q) \quad \text{s.t. } P'Q = Y$

Where Q is a column vector of (flow) commodities and (stock) assets. The "price" of assets is their rental cost over the period. [1] The solution for the optimal values of Q takes the form:

(2) $Q^* = f(P,Y)$

Where Q^* is a vector of demand functions. Substituting (2) into the utility function yields the indirect utility function:

(3) $V(P,Y) = U(f(P,Y))$

Solving for total expenditure yields the total expenditure function: [2]

(4) $Y = Y(U^*,P)$

This denotes the minimum level of expenditure required to attain the utility level U^*, given prices P. The true cost of living index (CLI) is defined as:

(5) $$CLI = \frac{Y(U^*,P(1))}{Y(U^*,P(0))}$$

The bracketed subscript refers to time period. Although this

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[1] The same is true for consumer durables or any commodity that has a stock dimension.

[2] The expenditure function is defined as Min $P'Q$ s.t. $U^* = U(Q)$.

concept serves as an ideal for comparative purposes, the use of much simpler methods in the evaluation of changes in consumer prices have been used. This topic is discussed in the next section.

3.3 Index Numbers in Practice

Period to period changes in the (Laspeyres) consumer price index (CPI) can be defined as:

$$(6) \qquad CPI = \frac{\Sigma\ P(1).Q(0)}{\Sigma\ P(0).Q(0)}$$

We note that the CPI provides an upper bound to the true CLI based on the reference utility level U*. The two indices coincide in the limit where i) the elasticity of substitution between commodities is zero, and ii) relative price changes are zero. [3]

Index numbers in general are defined as ratios of value aggregates and are computed in equivalent form as weighted arithmetic means. By simple manipulation, the index can be explicitly expressed in the weighted mean form:

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[3] The true index is normally between the Laspeyres and Paasche indices. For an interesting discussion of this topic see Allen (1975) and references therein.

$$(7)\quad CPI = \frac{\Sigma P(0).Q(0).\frac{P(1)}{P(0)}}{\Sigma P(0).Q(0)}$$

$$= \frac{\Sigma W(0).\frac{P(1)}{P(0)}}{\Sigma W(0)}$$

$$\text{where } \Sigma W(0) = \Sigma P(0).Q(0)$$

The weights $\Sigma W(0)$ are are equal to the cost of the fixed budget in base year (0). As demonstrated in (7), the weights attributed to each commodity in an aggregate index are determined by their relative share of total consumer expenditure in a fixed base period.

Changes in relative prices, tastes, or the introduction of new commodities, require that the base year is periodically updated in order to correspond to a representative basket of goods. Table 3.1 enumerates the base weight reference year and the date of incorporation of new weights in the Canadian CPI in the post war period. [4]

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[4] The "Base Weight Period" indicates the date of the family expenditure survey. "CPI Index Changes" indicates the date of implementation of new weights into the index.

Table 3.1 - CPI Base Weight Changes 1949-1982

CPI Index Changes	Base Period
Jan. 1949 - Feb. 1961	1947
Mar. 1961 - Apr. 1973	1957
May 1973 - Sep. 1978	1967
Oct. 1978 - Mar. 1982	1974
Apr. 1982 - to date	1978

Source: Prices and Price Indexes. Statistics Canada DBS 62-002. Various Issues.

3.4 Splicing Indices With Updated Base Periods

We next examine the arithmetic process of splicing index numbers in order to facilitate the discussion of chain indices that follows in the next section. This process can easily be illustrated by the example in Table 3.2.

Table 3.2 - Illustration of Splicing to form Chain Index

Date	1965=100	1966=100	1969=100	Chain
1965	100	...	...	100.0
1966	100.2	100	...	100.2
1967	...	96.9	...	97.1
1968	...	96.0	...	96.2
1969	...	97.2	100	97.4
1970	...	...	99.8	97.2
1971	...	...	96.5	94.0
1972	...	...	92.2	89.8

The series are spliced together in 1966 and 1969. The 1966 figure in the "chain" column is obtained by multiplying 100.2 by the next series which starts at 100 in 1966. [5] Similarly, the 1969 figure is derived by multiplying (100.2)(97.2)(100)= 97.4

Table 3.3 below shows that this example can be extended to illustrate the following: although any aggregate index of an unlinked series can be calculated as a weighted arithmetic average of the corresponding price indexes for all sub aggregates, the published aggregate index in the main CPI series (being a chain index) cannot be interpreted as weighted arithmetic averages of the corresponding sub-indices. This is because of the properties of the linking procedure previously discussed.

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[5] In practice, the spurious zeros are dropped for continuity.

Table 3.3 - Example of Unchained Indices

	Weight					
	(.6)	(.4)		(.5)	(.5)	
Date	i(11)	i(12)	I(1)	i(21)	i(22)	I(2)
1965	66.6	150	100	...	...	...
1966	80.0	150	108	100	100	100
1967	...	...	...	120.1	100	110.05

Some explanation of notation is warranted. Let i denote a sub-index of the main aggregate index I. The numbers in parenthesis above each series indicates the weight accorded to each respective sub-index. The aggregate series from 1965 to 1966 is denoted I(1), while the notation I(2) is reserved for the aggregate series from 1966 to 1967. It can be verified that I(1) and I(2) are weighted averages of the sub-indices, by checking horizontally along the table. The weights are 0.6 and 0.4 for I(1), 0.5 and 0.5 for I(2).

Suppose that in 1966 a change of base weight occurs as a result of revisions in the family expenditure survey. The weights change from (.6),(.4) to (.5),(.5) in the sub-indices as indicated. Although the 1966 - 1967 index I(2) obviously retains the property that it is the weighted sum of the new sub-indices, it is no longer comparable to the I(1) index. In practice, the simple splicing technique illustrated in Table 3.2 is used to join (at 1966) the index i(11) to i(21), i(12) to i(22), and I(1) to I(2). The result is shown in Table 3.4.

This simple example illustrates the contention that the aggregate linked index cannot be interpreted as a weighted arithmetic average of the linked sub-indices. A simple calculation for the true 1967 value of I(1,2) using the new weights yields:

$$(.5)96.1 + (.5)150 = 123.05$$

This, as asserted, does not correspond to the 1967 value of 118.854 for the aggregate index.

Table 3.4 - Chain Indices Derived From Table 3.3

	i(11,21)	i(12,22)	I(1,2)
1965	66.6	150	100
1966	80.0	150	108
1967	96.1	150	118.854

3.5 Limitations of Coverage of the CPI

Before concluding this necessary discourse on the chaining of index numbers, the problem involving the lack of coverage of items that comprise the individuals' utility functions requires consideration. Alchian and Klein (1973), discuss the problems associated with using indices that do not embody the concept of utility as a claim to present and future consumption. They suggest that a more appropriate measure of the price of consumption would include a vector of asset prices. An index that only attempts to measure changes in the prices of a fixed basket of current consumption flows fails to measure whether the present money cost of consumer utility (which includes changes in the individual's wealth) has changed, as would a more "general" index.

As a consequence the CPI probably fails to accurately measure the impact of monetary policy, because the index focuses on a narrow spectrum of flow services and ignores the stock dimension, the valuation of which changes in response to interest rate changes. For example, a monetary impulse may be expected to be transmitted initially through the demand for assets, and later through increased spending on flow services. An increase in the supply of money would cause agents to attempt to adjust their portfolios by running down excess money balances, while simultaneously bidding up the price of assets. The concurrent fall in interest rates would cause wealth to rise relative to income. Thus the direction of the monetary impulse may be correctly measured, but the full wealth effect may not. Furthermore, the variability of relative prices may be understated as a result of the ommission of systematic changes in long versus short lived assets. The CPI does not measure inflation correctly and for the purpose of this and other inquiry the error may be significant.

A possible alternative measure might be the GNP deflator. This is a broader index, including the price of newly produced physical assets. However, it ignores the prices of previously existing assets, which may be more flexible since they are no longer related to past production costs. Revision of the CPI to incorporate a measure of wealth would be very costly, however. Some futures markets do not exist, and current flow services are related to asset prices only through implicit real rates of interest. Alchian and Klein suggest that a crude adjustment to the CPI may be to include stock prices. However, they concede that it is possible that agents may be myopic, in the sense that they are only concerned with a small bundle of assets for present consumption, which would perhaps explain why the CPI has been retained in its current, albeit imperfect form. Thus, although less obvious problems with respect to coverage of the CPI are exposed, there is little short of an expensive reconstruction of the CPI that can be accomplished as a result of these comments. [6]

To summarise, the theoretical basis of index numbers bears little resemblence to their practical construction. Furthermore, there exists an important distinction between chained and unchained index numbers vis-a-vis the proposition that aggregate indices are a weighted average of the constituent sub-indices in

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[6] These comments are amplified by a host of well known problems in the practical use of price indices. These include sampling errors, problems (other than interest rates) with the valuation of implicit service flows from housing and other durable goods, quality changes, seasonality, the exclusion of government services paid for by taxation, exclusion of health care financed partly though medical premiums. A discussion of these problems is contained in The Consumer Price Index Reference Paper, Concepts and Procedures. Updating on 1978 expenditures. (Occasional) from Statistics Canada.

the published data. The arithmetic process of chaining results in the violation of this property in chained indices. Finally, it was pointed out that well known coverage limitations aside, there is a virtual absence of a wealth (stock) concept in conventional indices, resulting in further measurement errors.

3.6 Measuring the Dispersion of Relative Prices

The remainder of this chapter develops a measure of the dispersion of relative price inflation and examines some of its properties. In early studies, Glejser (1965) computes a measure by dividing sub-index (levels) by the main aggregate index in a multi country study of consumer price behaviour. The standard deviation of these ratios is weighted by the appropriate sub-index expenditure weight, giving a weighted measure of relative price dispersion. Although this method circumvents the chain index problem, the standard deviation computed suffers from the limitation that it cannot be conceptualised as an "average" rate of inflation deviation from the aggregate index. Other widely cited studies (Logue and Willet, 1976, Vining and Eltowerski,1976) use a standard deviation that ignores expenditure weights.

As stated in Chapter two, it makes sense to weight each sub-index by its expenditure weight. First, an unweighted (or more correctly, equally weighted) measure wrongly treats each index as equally important. Secondly, it does not incorporate substitutions away from items whose prices increase (in real terms) towards items whose prices fall, since the weights are not periodically updated to reflect changes in expenditure patterns which occur as a result of changes in relative prices.

Parks (1978), and Bleijer and Lederman (1981), are among the few researchers who have been concerned with this problem, proposing a measure of relative price dispersion which incorporates substitution effects along the following lines: w(i,t) denotes the expenditure weight ascribed to the i'th sub-index, DP(i,t) is the inflation rate of the i'th sub-index, and DP(t) is the average inflation rate as measured by the consumer price index. [7]

$$(8) \qquad SDW(t) = \Sigma\, (w_{i,t} \cdot (DP_{i,t} - DP_t)^{**}2)^{0.5}$$

The price data used in this study consist of nine sub-indices, quarterly, covering the period 1949Q1 to 1982Q4. Over this 33 year period, the base weights have been changed four times, giving a total of five base weight reference periods

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[7] There still remain some points with regard to this measure. Ideally, rather than measure relative price variability by the variance of the individual rates of inflation of components of the CPI about the average rate as below, it would be desirable to measure it by variation of individual prices around some appropriate path for the relative price of individual components. The problem arises, of course, in the determination of the appropriate paths. Secondly, the measure adopted cannot distinguish between mistakes and price changes that are appropriate. Furthermore, it doubly penalises changes in a relative price that is reversed. This is desirable because inappropriate changes in relative prices which can be equated with changes that are later revised, are emphacised relative to permanent changes.

and expenditure weights. Table 3.5 illustrates the expenditure weights accorded to each index.

Table 3.5 - Index Category and Expenditure Weight

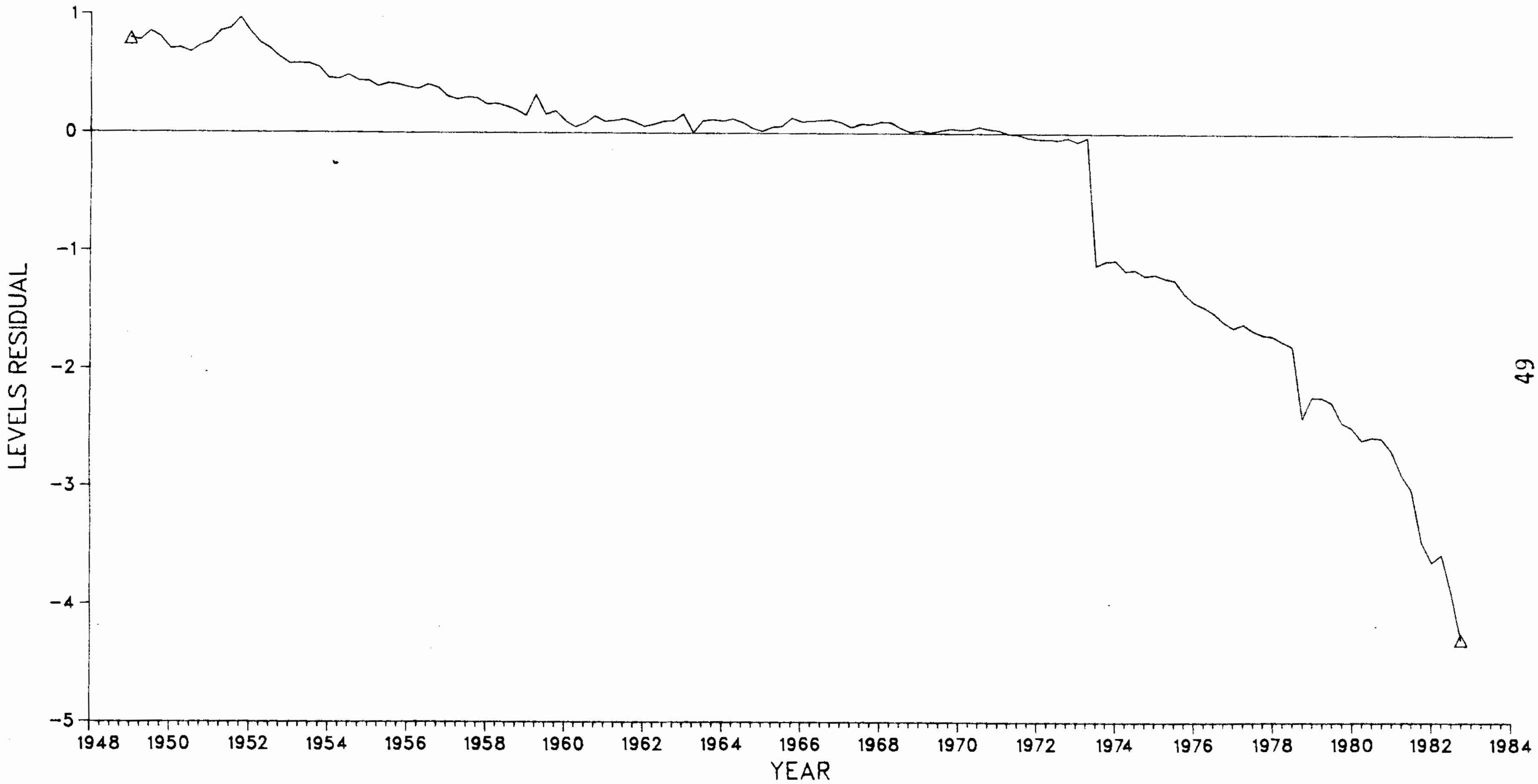
Category	Expenditure Weight				
	49-61	61-73	73-78	78-82	82-date
Personal Care.......	1.9	2.2	2.3	2.2	2.3
Tobacco Products and Smokers Supplies....	2.9	2.6	2.7	1.9	1.7
Alcoholic Beverages.	4.2	3.9	3.2	4.3	3.7
Health Care.........	4.5	4.4	1.7	1.7	1.4
Recreation, Reading and Education.......	4.1	4.7	6.9	8.3	8.6
Clothing............	12.8	11.3	11.3	10.1	9.5
Transportation......	7.1	12.0	15.2	15.8	16.2
Food................	31.7	26.7	24.8	21.5	21.2
Housing.............	30.8	32.2	31.4	34.1	35.3

Source: Prices and Price Indexes. Statistics Canada. DBS 62-002. Various Issues.

Of interest are secular changes in the weights. Some of the most apparent changes include the reduction in clothing and food as a percentage of calculated consumer expenditure, while weights on housing, personal care and transportation have increased substantially.

As demonstrated in previous sections, it is expected that some systematic error will occur when the level of the aggregate index, being a chain index, is computed using the weighted sum methodology. An understanding of error autocorrelation and magnitude would be useful in gaining some insight into the attributes that an appropriate measure of price dispersion should not have. Accordingly, a simulation using the weighted sum methodology is undertaken to derive the aggregate CPI index.

FIG.3.1 RESIDUALS, SIMULATED AGAINST ACTUAL LEVELS



Of more interest, however are the residuals when the CPI is subtracted from its simulated values, illustrated in Figure 3.1.

From 1971Q2 to 1982Q4 all errors are increasingly negative. In 1982Q4 the CPI simulated value is 266.1 whilst the CPI is 270.4. The error can be explained, given the insights of previous sections. Successive linking of the aggregate and sub-indices tends to magnify errors at either end of the index because these values are further away from the base year which is 1971. Hence it is not surprising that the CPI simulation becomes increasingly inaccurate at both ends of the index.

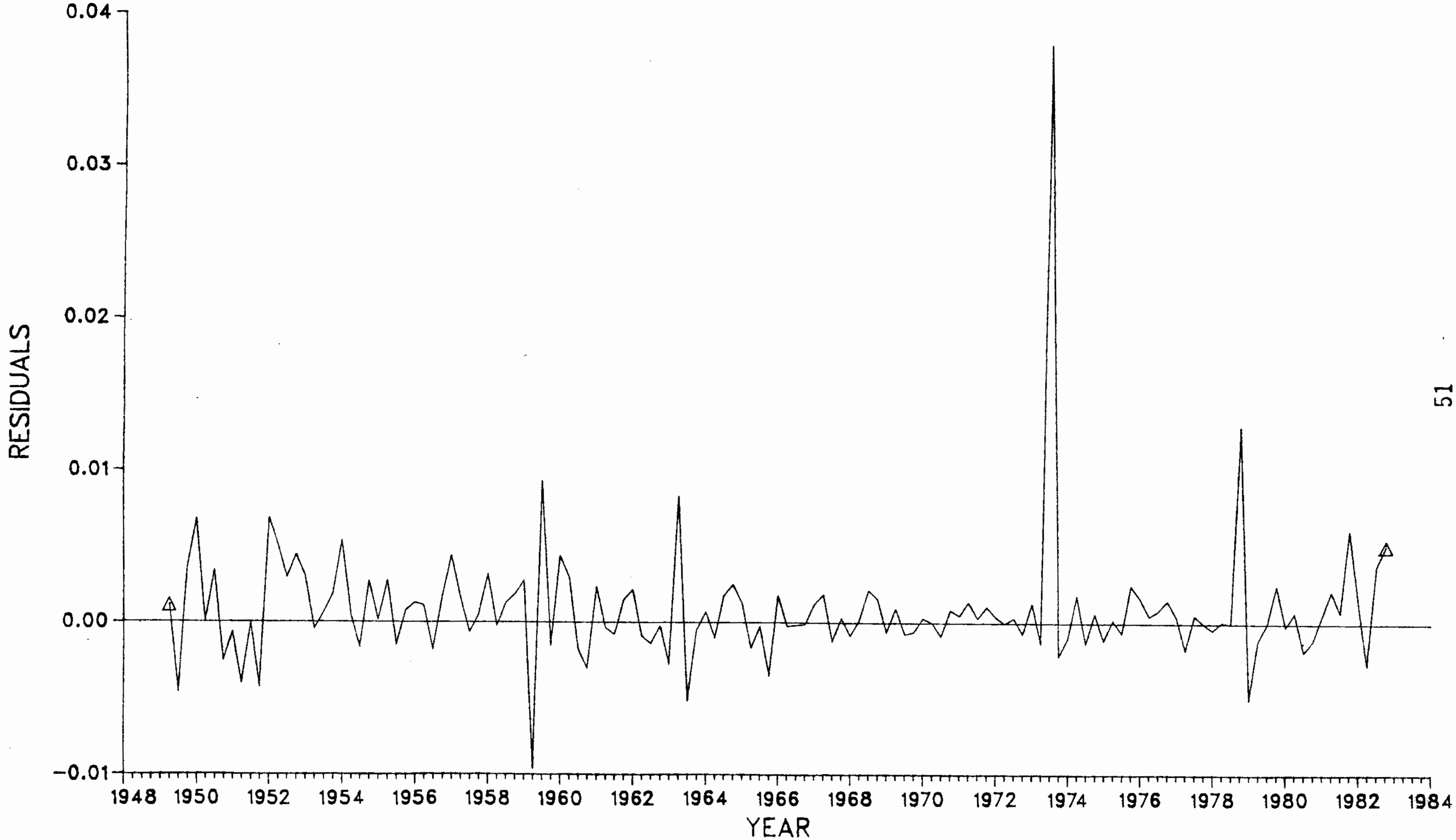
However, since the purpose of this study is to develop a measure of the dispersion of relative price inflation, levels of the index per se are of secondary importance. The degree of error autocorrelation and magnitude can be usefully examined when the aggregate and sub-indices are transformed into rates of change, and the same weighted sum methodology is applied again to simulate the rate of change of the main CPI. It is to this that attention is focussed.

The rate of change of the i-th index is calculated:

$$(9) \qquad DP(i,t) = 4(\log P(i,t) - \log P(i,t-1))$$

Multiplication by the scalar 4 is optional, and simply expresses the quarterly rates of change as an annual rate. The actual and simulated values derived for the rates of change of the index are again used to derive the error residuals. These are plotted

FIG.3.2 RESIDUALS, SIMULATED AGAINST ACTUAL INFLATION



in Figure 3.2. A striking feature that emerges when the two sets of residual plots are compared is the reduction of autocorrelation that occurs when the "rate of change" residuals are compared to the "levels" residuals. Systematic error is largly eliminated in Figure 3.2, as is verified in Table 3.6, which shows the simple correlations of current errors on their own lagged values for levels of the CPI and its rate of change.

The reason for examining the properties of residuals from simulated values of rates of change and levels is because an aggregate index is to be used as the "mean" from which weighted squared deviations of the sub-indices are to be calculated. It is apparent that as suspected, the chaining problems associated with linked indices tend to invalidate the use of an aggregate CPI in levels, because it is a "biased" estimate of the weighted sum of the sub-indices.

The large reduction of the systematic component in the rate of change residuals lends support to the adoption of rates of change in the main CPI and sub-indices as an appropriate starting point in the construction of a weighted measure of relative price change dispersion. However, as can be seen in Figure 3.2 and Table 3.6, error autocorrelation is not entirely eliminated. Indeed, autocorrelation becomes slightly negative.

Table 3.6 Simple Correlation of Residuals On Own Lagged Values

Lag	(1)	(2)	(3)	(4)	(5)
Levels	0.994	0.990	0.986	0.982	0.978
Rate of Change	-0.177	-0.002	-0.029	-0.040	-0.053

This problem is circumvented by adopting the simulated values of the CPI as the appropriate weighted "mean" rate of price inflation. This is a standard Divisia price index formulation frequently used in econometric work. [8] Hence, the average rate of inflation is defined:

(10) $$DP_t = \Sigma\, w_{i,t} . DP_{i,t}$$

where w(i,t) is the average expenditure share on the ith index in period t-1 and t. A measure of the weighted standard deviation of relative price inflation can now be written:

(11) $$SDW_t = (\Sigma\, w_{i,t} . (DP_{i,t} - DP_t)**2)^{0.5}$$

SDW(t) can be conceptualised as a measure of the non-proportionality of price change. If all prices change at the same rate (the common DP(t)), then the measure becomes zero.

[8] See Theil (1967), Chapters 5-7.

For comparative purposes, the unweighted standard deviation is calculated:

$$(12) \qquad SDU_t = (1/n\Sigma\ (DP_{i,t} - DP_t)**2)^{0.5}$$

At this juncture some broad comparisons between the two measures of relative price change dispersion can be made. [9] An unweighted measure will tend to "overstate" the variability of the prices of those indices that comprise a small share of consumers expenditure. Similarly it will "understate" the inflation variability of items which have a large expenditure share. The weighted and unweighted measures are plotted in Figure 3.3.

It is apparent that the weighted standard deviation (SDW), is significantly smaller over all of the period in comparison to the unweighted counterpart (SDU). This result makes sense if those items with relatively large inflation variability have smaller expenditure weights attached to them. [10]

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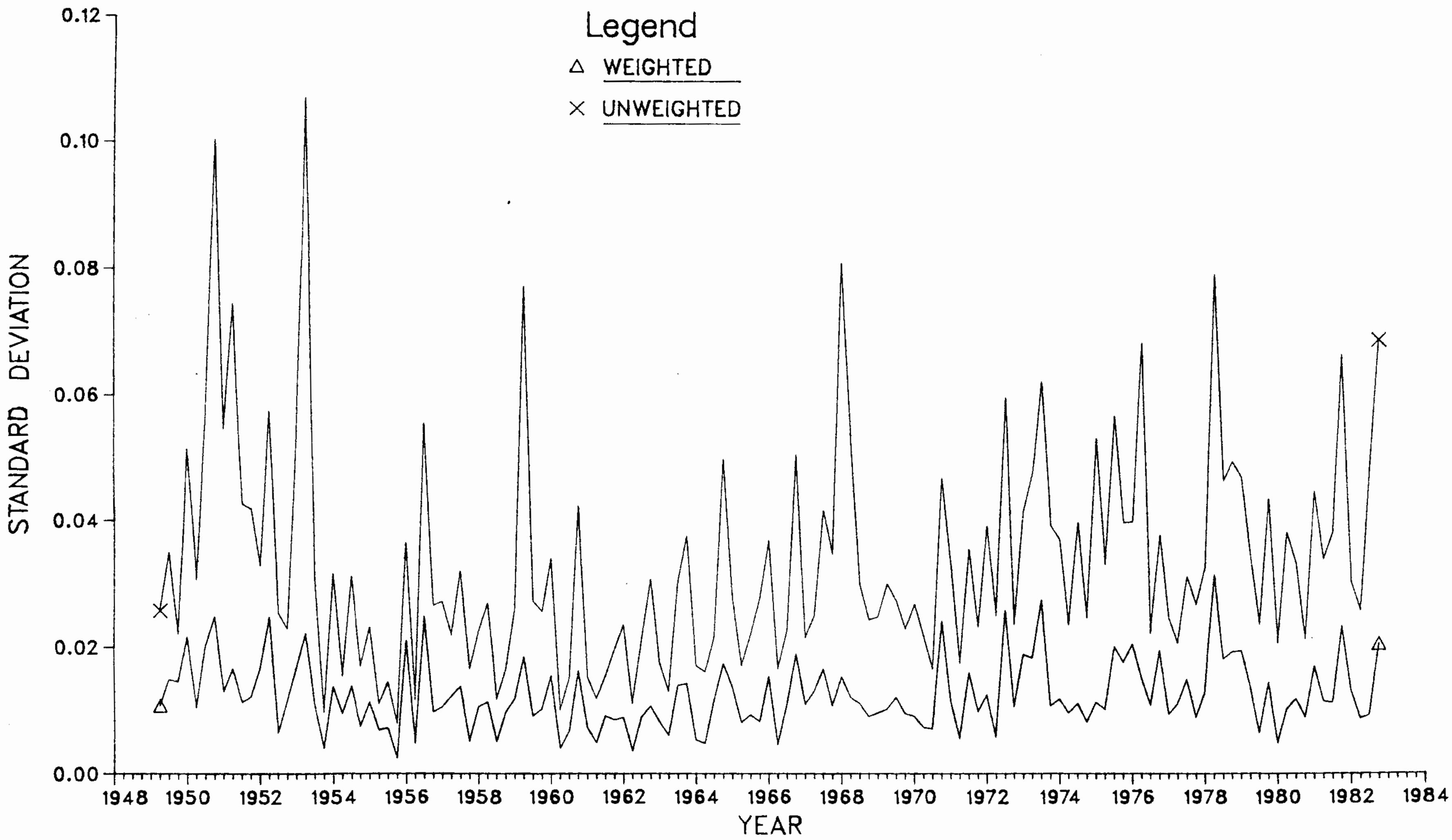
[9] The measures of SDU and SDW will be affected by the degree of aggregation of the data. The more disaggregated the data the larger the measures will be. See Theil (1967), p 162-163.

[10] This method is not identical to that of Logue and Willet, and Vining and Eltowerski. They use an equally weighted arithmetic average of the sub-indices in the calculation of the aggregate inflation rate. In an unreported simulation, I found that the standard deviation using their method was even larger and more variable than that shown in Figure 3.3. It seems quite amazing that their results have been unchallenged, given the disparities in these measures, or that this simple comparison of measures has not been made before.

FIG.3.3 WEIGHTED AND UNWEIGHTED STANDARD DEVIATION



This last point can be examined further by comparing the standard deviation of the rate of change of each sub-index with its average expenditure weight in Table 3.7. below.

Table 3.7 Standard Deviations and Average Expenditure Weights by Category

Category	Standard Deviation	Average Weight
Personal Care.......	0.039050	2.2
Tobacco Products and Smokers Supplies....	0.078966	2.4
Health Care.........	0.049562	2.7
Alcoholic Beverages.	0.059657	3.9
Recreation, Reading and Education.......	0.036626	7.3
Clothing............	0.049136	11.0
Transportation......	0.052178	13.3
Food................	0.079827	25.1
Housing.............	0.037045	32.8

Table 3.7 confirms that housing, one of the least volatile price indices has the largest expenditure weight.[11] Furthermore, categories with larger standard deviations (Tobacco Products, Alcoholic Beverages), are associated with the smaller expenditure weights. This evidence supports the contention that the weighted measure, under these circumstances, is expected to

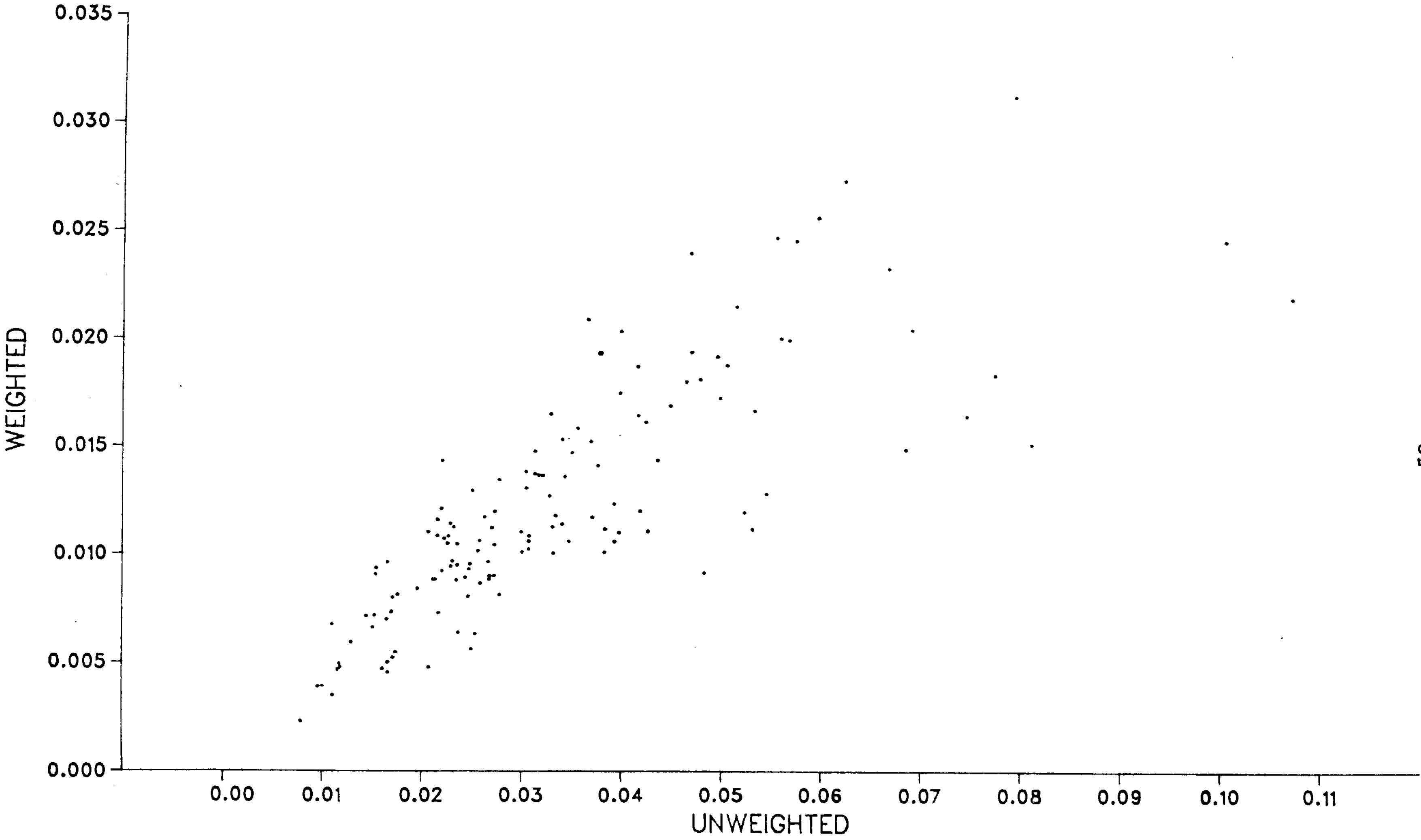
[11] The simple correlation between the standard deviation and the average weight is -0.021, which although small in magnitude has the correct sign. The negative sign is expected because the weighted measure is smaller than the unweighted measure of relative price dispersion. This difference will occur when indices with high standard deviations are associated with low expenditure weights.

result in a smaller measure of dispersion. Only food, with a relatively large expenditure weight and standard deviation, does not conform to this pattern.

Further inquiry into the relative properties of these measures reveals some interesting evidence. Figure 3.4 reveals the non-linear relationship between these measures which is a result of the relative volatility of the unweighted measure. If the relationship was linear there would be little to choose between these measures, as a linear transformation would obviously only represent a change of scale. The contention that there is a non-linear relationship between the weighted and unweighted standard deviations is confirmed in the following regressions, where a non linear functional form is fitted and compared with the linear form.

Regression (1) reports the result of SDU on SDW, where SDW is calculated according to the method outlined in equation (11). Recall that the average inflation rate is "simulated" or calculated as a weighted average of the sub-index rates of inflation. Regression (2) reports the results of SDU on SDW, where SDW is calculated using the actual CPI as the average inflation rate. The same procedure applies to regressions (3) and (4), except of course that the double log transformation is performed on both variables. It can be easily observed from Table 3.8 that the double log transformations (regressions (3) and (4)) have coefficients less than unity which confirme the proposition of non-linearity.

FIG. 3.4
SCATTER OF WEIGHTED AND UNWEIGHTED STANDARD DEVIATION



It also appears to make little difference whether actual or simulated values for the CPI are used in the calculation. However, in order to keep to a more arithmetically correct notion of the weighted average of individual sub-indices as a measure of the average inflation rate, we utilise the simulated inflation series throughout the remainder of this study.

Table 3.8 Linear and Double Log Regressions.

Dependent Variable: SDW
Bounds: 1949Q2 - 1982Q4

	Coefficient		RSQ. (unadjusted)	D.W.	F
	Linear (Simulated CPI)				
(1)					
INTERCEPT	0.004	(6.45)**	0.65	1.81	250.45**
SDU	0.251	(15.82)**			
	(Actual CPI)				
(2)					
INTERCEPT	0.004	(6.79)**	0.65	1.83	252.07**
SDU	0.246	(15.87)**			
	Double Ln (Simulated CPI)				
(3)					
INTERCEPT	-1.67	(-11.51)**	0.74	1.80	385.78**
Ln (SDU)	0.80	(19.64)**			
	(Actual CPI)				
(4)					
INTERCEPT	-1.68	(-11.50)**	0.73	1.81	375.87**
Ln (SDU)	0.80	(19.64)**			

3.7 Concluding Comments

It has been shown that a measure of relative price variability is sensitive to the specification chosen. Furthermore, the measure adopted here allows the relative importance of price variations as a percentage of consumer expenditure to be utilised in a sensible way. Also, the effects of substitutions as a consequence of relative price change are explicitly taken into account.

These results indicate potentially serious flaws in the studies conducted by Logue and Willet (1976), Vining and Eltowerski (1976) and others, where unweighted measures are used. However, these results should be tempered by further investigation, particularly on the reported correlation between inflation dispersion and its variability. What does seem curious is that there has not been any previous inquiry into the sensivity of these measures to the specification adopted, in studies where the variability of relative prices is investigated.

Appendix 3A

Price data were retrieved from the Statistics Canada CANSIM tapes. The data and their corresponding retrieval codes are listed below. Note that the data are not seasonally adjusted. Furthermore, the monthly frequency is converted to quarterly frequency by arithmetic averaging.

CATEGORY	RETRIEVAL CODE
All Items..........	D484000
Food...............	D484001
Housing............	D484126
Clothing...........	D484214
Transportation.....	D484319
Health Care........	D484345
Personal Care......	D484354
Reading,Recreation and Education......	D484372
Tobacco Products...	D484405
Alcoholic Beverages..........	D484408

Appendix 3B

Listed below are the weighted (SDW) and unweighted (SDU) standard deviations, calculated as described in equations (11) and (12) of the text. The observations begin in 1949Q2 and are read vertically.

SDW	SDU
0.010635	0.025507
0.014746	0.033282
0.014339	0.023655
0.02155	0.049638
0.010257	0.030643
0.020096	0.057432
0.024725	0.100666
0.012842	0.054317
0.0165	0.075337
0.011087	0.042568
0.012018	0.041263
0.016499	0.032226
0.02463	0.057443
0.006294	0.026537
0.011401	0.023284
0.016705	0.053683
0.02205	0.106858
0.010846	0.030972
0.003858	0.010629
0.013673	0.030125
0.009341	0.015424
0.013734	0.030678
0.007318	0.017625
0.011241	0.023171
0.006729	0.01105
0.007119	0.01406
0.002255	0.008274
0.020924	0.036354
0.004651	0.011856

0.024767	0.054847
0.00963	0.027054
0.010438	0.026704
0.012104	0.021827
0.013665	0.031842
0.00499	0.016538
0.010485	0.022597
0.011221	0.026904
0.004919	0.011593
0.009608	0.017443
0.011713	0.025742
0.018411	0.081748
0.008988	0.024755
0.010145	0.02524
0.015339	0.032876
0.003888	0.010525
0.006597	0.014685
0.016156	0.041268
0.007166	0.014687
0.004756	0.011986
0.009054	0.015852
0.008407	0.019182
0.008789	0.023854
0.003466	0.011271
0.008818	0.020708
0.010615	0.030689
0.008114	0.017299
0.005907	0.01376
0.013829	0.029366
0.014134	0.037702
0.005217	0.01713
0.004697	0.016552
0.011583	0.021782
0.017283	0.048937
0.013449	0.028226
0.007983	0.017162
0.009216	0.02195
0.008116	0.028258
0.015255	0.037218
0.004518	0.016772
0.010837	0.022632
0.018831	0.050481
0.01084	0.021551
0.012942	0.025585
0.016477	0.041179
0.010611	0.034567
0.015214	0.081314
0.011978	0.052203
0.011027	0.030592
0.008915	0.024558
0.009525	0.024528
0.010103	0.029831
0.01197	0.027144

0.009425	0.022852
0.008987	0.026854
0.007261	0.021664
0.006961	0.016154
0.024022	0.046804
0.011258	0.03311
0.005456	0.017993
0.015866	0.035612
0.009675	0.023014
0.012362	0.039279
0.005608	0.025004
0.025706	0.059688
0.010462	0.023609
0.018754	0.041749
0.018154	0.047331
0.027393	0.071141
0.010598	0.038824
0.011716	0.036651
0.009472	0.023853
0.011014	0.039125
0.008031	0.024502
0.011211	0.053455
0.010063	0.033131
0.020002	0.056351
0.017495	0.040518
0.020377	0.040176
0.014946	0.06825
0.010707	0.022229
0.01935	0.03798
0.009295	0.024834
0.011011	0.021063
0.014792	0.031237
0.008825	0.026711
0.012709	0.03265
0.031367	0.079218
0.018041	0.046356
0.019227	0.048211
0.019424	0.045714
0.01361	0.034435
0.006357	0.023672
0.014394	0.044042
0.00476	0.020771
0.010114	0.037991
0.011792	0.033149
0.008828	0.020786
0.016924	0.045064
0.011399	0.033677
0.011175	0.038309
0.023342	0.065579
0.013065	0.030935
0.008644	0.025248
0.009177	0.047129
0.020515	0.067528

IV. ON THE ROLE OF UNANTICIPATED INFLATION

> The weakest and least satisfactory part of current economic theory seems to me to be in the field of monetary dynamics, which is concerned with the process of adaptation of the economy as a whole to changes in conditions and so with short period fluctuations in aggregate economic activity.
>
> Milton Friedman
> The Methodology of Positive Economics. p. 42.

4.0 Introduction

Having developed a measure of relative price variability, our next task is to examine how an appropriate approach to measuring unanticipated inflation may best be developed. First, a brief outline of the evolution of thought regarding the ways in which unanticipated inflation is thought to influence short run fluctuations in output and employment is given in Section 4.2. Second, the issues involved in the measurement of unanticipated inflation are explored. Section 4.3 inquires into how unanticipated inflation has been, and might be measured. The results of Section 4.3 indicate that properties of optimal linear forecasts may be usefully explored. This is undertaken in Section 4.4. Sections 4.5 and 4.6 investigate applied aspects of the ARIMA model of inflation and income.

4.2 Conventional Effects of Unanticipated Inflation

It is apparent that the unanticipated inflation literature has been a bedfellow of the expectations augmented Phillips Curve literature. We can therefore focus on how expectations influence short run deviations from trend income by focusing on the expectations component of the Phillips Curve literature. It is clear that considerable resources have been expended in tests of the hypothesis that the expectations augmented Phillips Curve is vertical in the long run, and although difficulties with the empirical evidence leave the debate unresolved, many in the profession seem to agree that in the long run there may be no trade off between inflation and unemployment. However, the problem of explaining or forecasting short run deviations in output from trend has brought the role of unanticipated inflation to the centre of the inquiry.

The difficulty alluded to in the quotation by Friedman would appear to revolve around two problems. The first concerns the dynamics of short run adjustment of wages and prices. The second (although not necessarily independent) problem can be attributed to the lack of a theory of learning and hence the mechanism of expectations formation. The process of adaptation to change and the role of uncertainty are key issues here. When the paradigm of relatively fixed and certain alternatives is replaced by the notion of adaptation to continually changing and complex circumstances, rational economic agents may be confronted with incomplete information. Therefore the existence of uncertainty may be a factor in the determination of such outcomes as the deviation of real income from trend.

It is noticeable that much of the rational expectations literature regards the second moment of inflation errors as unimportant, while other fields, notably in the area of finance and portfolio theory, regard the dispersion of a distribution as an important factor in the determination of portfolio selection. A marriage of these two approaches may be a fruitful theoretical avenue and may provide useful testable hypotheses, if a suitable proxy for economy wide uncertainty can be developed. Although such an avenue would be an interesting area for future research, it is beyond the scope of this thesis.

We refer now to the expectations augmented Phillips Curve literature, and the role of unanticipated inflation. The expectations augmented Phillips Curve was of course suggested by Milton Friedman (1968), and by Phelps (1967) in a slightly different form. Both hypotheses suggest a "natural" rate of unemployment and "normal" output, which can be thought of as that level of unemployment and output associated with expectations equilibrium. Expectations equilibrium may be described as as situation where agents' plans are not frustrated because their subjective expectations and the objective opportunities available are the same. It follows that when prices are flexible, unemployment associated with the natural rate can only be the result of optimal decisions which are made while the economy is in general equilibrium. Similarly, when changes in the general price level or the inflation rate are fully anticipated, deviations from trend output and unemployment should not occur, unless some other causal variable changes.

The two versions of the expectations augmented Phillips Curve alluded to above have differing mechanisms that are used to explain short run deviations from trend output. For example, Friedman (1968), was probably the first to suggest utility maximising agents are fooled in the short run when the rate of inflation unexpectedly changes. The well known asymmetry of agents' learning with a lag of price level changes, while learning immediately of their nominal money wage change, has been countered with the suggestion that more information is required when knowledge of the general price level is considered (Friedman (1975)). Friedman's suggestion that knowledge of the prices in a basket of goods is required for the consumer can be replied to with the proposition that detailed price indices are published on a monthly basis in most industrialisd economies. This perhaps gives more plausability to the contract and short run fixed price models which we shall shortly review, when considering short run deviations from trend output.

The search theoretic explanation of the short run trade off has its seminal contribution in the work of Phelps (1967). The relative wage setting behaviour of firms is the focal point of this hypothesis. Firms adjust their wage offers relative to the perceived market wage by using their vacancy rate relative to the market vacancy rate. In this case the firms' misperception of the average market wage is the lever used to explain the short run supply function, as perceptions of market wages adjust with a lag. However, when they do catch up to the actual structure of wages, the natural rate is prevalent. In this context the firm is a price maker with incomplete information. Slightly different versions within the search theoretic paradigm have been proposed by Alchian (1970) and McCall (1970), where firms and agent are price takers. If the distributions of wage offers and wage expectations coincide, then the behaviour of agents who balance the cost of search against the expected benefit ensures the optimal level of search and the natural rate of unemployment prevails. Short run deviations from trend output are the result of expectations disequilibrium, when unexpectedly high wage offers are accepted in the short run. This reduces the duration of search and therefore unemployment. Empirical evidence from business cycles, however, does not conform to the predictions of search theory which suggest that a decline in quits will be associated with an unexpected increase in nominal wages.

The often cited contribution of Lucas and Rapping (1969) takes a different approach. Agents are hypothesised to engage in inter-temporal speculation rather than engage in search. They are assumed to speculate in an auction type of market for current nominal wages by taking advantage of deviations of current wages from their expected normal levels (or rates of change). An increase in the rate of inflation may induce agents to temporarily perceive that current wages and prices are above the present values of future levels, which results in an expectation of deflation. The expected deflation causes the perceived real interest rate to rise, which in turn results in increased labour supply through inter-temporal substitution of leisure away from the present. [1]

These models do not explain, however, the occurence of layoffs that characterise the experience of many post-war economies at the trough of the business cycle. The contribution of the disequilibrium literature does remain consistent with the empirical regularities of layoffs, but this literature suffers in many cases from the "ad hoc" assumption that prices and wages are inherently sticky. [2]

The contributions of Gordon (1974) and Azariadis (1975) are complementary to the disequilibrium literature, in that their implicit contract theory attempts to provide the microfoundations for wage stickiness which occurs as a result of

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[1] It seems that the nominal rate of interest does not move with the rate of inflation in order for this perception of a rise in the real rate of interest to occur. It is also assumed that the substitution effect of the rise in the perceived real rate of interest is greater than an income effect that may occur in the opposite direction.

[2] Drazen (1980) provides an excellent survey of developments in this field. The seminal contributions are Clower (1965), and Barro and Grossman (1971). Heijdra (1984) presents a disequilibrium model with Bayesian learning as an attempt to reconcile short run price inflexibility with long run price flexibility.

maximising behaviour. [3] When there is fluctuating demand for output and employee services, contracts are negotiated where wages are fixed at a lower rate in return for partial tenure in employment. It is only when there is a severe reduction in demand for output that employees are laid off. [4] Barro (1977) has pointed out that freely negotiated contracts that result in layoff cannot really be regarded as involuntary unemployment in the sense of Keynes (1936). [5] Although this brief discourse is barely more than an introduction to the problem, further discussion digresses from the task of examining explanations of short run deviations from trend in output and employment, and

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[3] These models however, make the "ad hoc" assumption that the population is heterogeneous with respect to risk preference, with employees being more risk averse than employers.

[4] Chant (1980) suggests that the layoff may be an efficient way of monitoring the actions of the firm since knowledge of its true financial position may not be perfect. If the only way of reducing costs is to lay off workers, since workers will not accept wage cuts as a monitoring strategy, it is impossible for firms to bluff employees into taking wage cuts when time are supposedly hard.

[5] Although the explanations discussed have either extreme price flexibility or extreme quantity flexibility, the problem of price dynamics has not been ignored. When the postulate of the fictitious auctioneer is abandoned, the problem of determining how prices adjust is addressed by Samuelson (1949), where the speed of price adjustment is positively related to the amount of positive or negative excess demand in a given market. There is however, no real explanation of <u>who</u> sets the price or <u>how</u>, other than the "ad hoc" mechanism described above, it is set. One of several approaches to this problem can be found in Arrow (1959), where it is suggested that a partial monopoly model may be a useful way of describing price setting, where prices are set and transactions are realised in quantities. Gordon and Hines (1970) suggest that price dynamics should have embedded a theory of learning, although such a theory seems to be difficult to concieve. See Boland (1982) for more on this problem.

the allied problem of measuring expected and unanticipated inflation.

We now turn to the most recent contribution which has caused a great deal of excitement in the profession, and which shall be shown to have some useful properties in terms of tractability. With this accomplished, we can go on to consider an appropriate technique for generating an unanticipated inflation series.

Rational expectations are at the forefront of macroeconomic theory at this time. [6] As is well known, the insight of Muth (1961) was not taken up in the literature until Lucas (1972,1973) proposed a rational expectations approach to the short run trade off between the price level and output. Subsequently, Sargent and Wallace (1975) suggested that if expectations are formed utilising information as if the model were known, then expectations will be unbiased. Since this point is crucial to the way that time series data can be manipulated, it is useful to formally demonstrate this result. A simple model is sufficient to illustrate the main point in a straightforward way. It is not however an integral point for what follows.

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[6] See McCallum (1980) for a review of recent developments. Buiter (1980) provides a critical appraisal of the literature.

Notation

$(.)^e$ Expectations operator, this refers in this example to the expectation of P formed in period t-1.

Y_t Observed real income.

$\bar{Y}_t$ Trend output. Often conceptualised as a mean rate of output growth applied to income.

P_t Observed inflation rate.

P^e_t Expected inflation rate.

M_t Nominal money stock percentage rate of growth.

M^e_t Expected rate of growth of nominal money stock.

Stochastic Errors are:

m_t Money supply disturbance, distributed $N(0,\sigma^2_m)$

a_t Aggregate supply disturbance, $N(0,\sigma^2_a)$

u_t Aggregate demand disturbance, $N(0,\sigma^2_u)$

Coefficients are:

c0 Autonomous growth rate of the money stock

c1 Authorities' reaction function adjustment coefficient.

b Inflation response to excess demand.

c2 Autocorrelation coefficient.

1> a0, a1, b, c2 > 0

The Exogenous Variables are:

a0, a1, b, c2, and $\bar{Y}_t$

The Endogenous Variables are:

P^e_t, P_t, Y_t, M_t, and M^e_t

<u>The model is written as:</u>

(1) $P_t = P^e_t + b(Y_t - \bar{Y}_t) + a_t$ (The aggregate supply function)

(2) $P_t = M_t + m_t$ (Nominal aggregate demand)

(3) $M_t = c0 + c1.(Y_{t-1} - \bar{Y}_{t-1}) + c2.m_{t-1} + m_t$

(The monetary authority's reaction function)

Taking the expectations of (1), (2) and (3) yields:

(4) $P^e_t = M^e_t$ (Expected nominal demand)

(5) $M^e_t = c0 + c1.(\bar{Y}_{t-1} - Y_{t-1}) + c2.m'_{t-1}$ (The expected monetary rate of growth)

Rearranging (1) yields:

(6) $Y_t - \bar{Y}_t = {}^1/_b\{(P_t - P^e_t) - a_t\}$

Combining equations (2),(3),(5), and (6) yields:

(7) $P_t - P^e_t = u_t + M_t - M^e_t = u_t + m_t$

Substituting back into (4) gives:

(8) $Y_t - \bar{Y}_t = {}^1/_b(u_t + m_t - a_t)$

Substituting (8) back into (1) gives the solution for the deviation of actual from expected inflation.

(9) $P_t - P^e_t = u_t + m_t + a_t(1 - b)$

It is clear that any deviation of actual from expected inflation consists only of unforecastable stochastic disturbances. It is also evident that deviations from normal or expected income occur as a result of these disturbances. [7] In Muth's (1961) article, he argues that rational agents will have expectations which are unbiased estimates of prices or inflation. Although we again appear to encounter the problem that some knowledge of the system generating the outcomes is required, rational expectations does not assert - according to Muth - that expectations of all agents are the same. Nor does "knowing" the system explicitly imply solving systems of equations that characterise the model being considered. What rational expectations does assert is that it is only necessary that competition ensures behaviour as if the system were being solved.

This argument is similar to that of Milton Friedman (1953), who suggests a Darwinistic defense of the notion of perfect competition. He appeals to the example of the leaves on a tree

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[7] We note that the deviation of actual from expected inflation comprises demand, supply, and monetary disturbances. As is mentioned in Chapter 1, shifts in relative demands and supplies may cause heightened relative price variability, which is considered to be the essential role of the price system in its dissemination of useful price information. The disturbances in this model are aggregate shocks. The distinction between aggregate and local shocks is that local shocks constitute a reallocation of demands-supplies and do not therefore contribute to inflation, and are not caused by unanticipated inflation. The model presented in Chapter 5 aggregates the monetary and demand disturbances into a common "demand shock", and although it would be desirable to be able to discriminate between these, we make no attempt to refine the analysis further. This would however, be an interesting avenue for further research.

not knowing how to maximise their exposure to sunlight, but behaving through competition _as if_ they did. Tobin (1980), as we might expect, is somewhat skeptical. A quotation from his paper, which is a response to Lucas (1980), would seem to convey a thought-provoking element of concern.

> Natural selection, enforced by entry and competition may ultimately insure that only optimal rules survive. But the process of learning and adaptation are probably much slower and much less efficient than Lucas assumes.

The issue of whether the emperor has no clothes has been addressed by Lucas (1972, 1975), who has considered the problem of information acquisition and learning by tracing the implications of exposing agents to information with a lag. Agents expectations are unbiased in the context of a once and for all change in the process generating outcomes only after the new information has been revealed. In his (1976) paper, Lucas makes damaging criticisms of large scale econometric models because no allowance is made in these models for agents "rationality". Coefficient estimates in these models are shown to be unstable, because expectations are often proxied by using lagged actual outcomes. Agents may actually utilise more information than these naive forecasting schemes imply.

The problem of explanation for rational expectations posed by the factual existence of serially correlated deviations of income from trend is an empirical complication again addressed by Lucas and others. In his (1972) paper, positively correlated deviations in trend output are modeled by utilising a lagged output term. [8] This notion is developed further in Lucas (1975), where increased output in an initial period which may occur as a result of a price surprise, which induces increased investment in that period. A larger capital stock carried forward to the next period raises the marginal productivity of labour in that period which, even in the absence of further price surprises, results in output above trend. An inventory theoretic approach is used by Blinder and Fischer (1979) in an attempt to model persistence in the deviations from trend income. Costs of adjusting employment to fluctuations in aggregate demand lead to production smoothing through inventory adjustment. A price surprise in the initial period results in a reduction in inventories because of higher than expected demand. Even in the absence of further price surprises, it is necessary to restock inventory levels to their optimal levels, which results in increased persistence of income above trend.

Other explanations which attempt to explain persistance through wage rigidities have been proposed by Fischer (1977), and Phelps and Taylor (1977), where wages are set with reference to expected future prices over the term of non-indexed labour contracts. When prices are lower than expected, real wages are as a result higher, which results in employee layoffs and reduced output.

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[8] We have examined this paper in detail in Chapter 2, where the effects of a variable inflation rate on relative price dispersion are discussed.

To conclude, we have selectively sampled a wide literature in which attempts are made to explain both the role of unanticipated inflation, and the observed serial correlation in the deviation from trend income. Since unanticipated inflation is a key element in any explanation, we turn to the issue as to how this may be measured. [9]

4.3 The Measurement of Unanticipated Inflation

Having now considered the characteristics of a simple rational expectations macro model, it is necessary to consider how actual inflation expectations series have been generated empirically. We therefore digress briefly in this section to consider the alternative techniques which have been proposed. Thereafter, we explore the properties of the model to be used in Chapter 5. Of the myriad of techniques presented, it is possible to divide these into three principal categories:

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[9] There is much more that can be said regarding the rational expectations literature, particularly when the authorities may have an informational advantage over the public. In this case of course, the posibility of fooling the public in the short term does imply that the authorities may be able to produce temporary real effects. Barro (1976) provides an authoritative treatment of the possible role of monetary policy in this context. An illustration of a rational money demand function is given in Sargent and Wallace (1973), where the theorem of iterated expectations is demonstrated. Shiller (1978) has also given an authoratative review of the literature.

i) "Ad hoc" generating mechanisms.

ii) Direct survey techniques.

iii) "Market revealed" techniques.

4.3(i) Ad Hoc Generating Mechanisms

We begin by surveying some of the better known studies which have "ad hoc" generating mechanisms. It would seem that any expectations mechanism defined *a priori* cannot be rational in the sense of Muth (1961) for all processes. The only mechanism that is rational is the one that is the same as the actual process generating the outcome. [10] Carlson (1977) has stated:

> ...looking for neat, robust, invariant formulas to characterise the formation of expectations may be a futile exercise. p.49.

The contribution of Cagan (1956) in his study of the money demand function in the German hyperinflation, presents an error learning or adaptive expectations mechanism. In this procedure there is a money demand function where real interest rates and income are assumed to be dominated by the effects of expected inflation, and are therefore omitted from the specification.

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[10] Taylor (1979) claims to circumvent the "ad hoc" treatment of expectations. He uses a minimum distance estimation technique which takes account of the restrictions implied by rational expectations in a small macro model, in developing a technique for selecting macroeconomic policy.

P^e denotes expected inflation and P denotes actual inflation. Let M denote the nominal money supply.

$$(10) \quad \log\left(\frac{M_t}{P_t}\right) = a - b.P^e_t + u_t$$

Furthermore, it is assumed that:

$$\frac{dP^e}{dt} = c(P_t - P^e_t)$$

Cagan's procedure amounts to generating alternative series for expected inflation corresponding to selected values for the parameter c, and selecting the value for c which yields the best fit in the money demand function.

Expected inflation series have often been generated in conjunction with econometric tests of the expectations augmented Phillips Curve. These tests may take the form of two regressions, where an expected inflation series is generated by a) regressing actual inflation on its own lagged values and b) using the fitted values for inflation from the regression in a second regression which takes the form:

$$(11) \qquad P_t = f(U \ldots) + a.P^e_t + u_t$$

where $P^e_t = g(P_{t-1}, P_{t-2}, \ldots . P_{t-i})$,

and U is unemployment or it's deviation from trend.

Tests of whether the estimate for the coefficient on the expected price series "a" have been conducted, with a result of a<1 supposedly lending support to the suggestion that there is a short run trade-off between inflation and unemployment, and as evidence against the rational expectations hypothesis. Of the studies that conduct this kind of test, those that obtain the result that a<1 include Gordon (1970), Turnovsky and Watcher(1972) and Cuikerman (1974). Studies unable to reject the hypothesis that a=1 include Parkin (1973), and Wachter(1976).

A tendency for "a" to increase secularly has lead to the inference that when inflation becomes a persistant and significant facet of economic life, adaptation becomes more sensitive to inflation. However, many of these equations have been routinely estimated by ordinary least squares, which ignores the problem of simultaniety bias in a system of simultaneous equations. Surprisingly few studies have noted this problem. Wantanabe (1966) is a rare exception, where single and multiple equation estimates are compared. He notes significant differences between single and multiple equation models and between the estimation techniques employed.

4.3(ii) Direct Survey Techniques

We turn now to tests that have been conducted on survey data with regard to inflation expectations. Most studies have used the data compiled by Joseph Livingston whose column has appeared in the Philadelphia Bulletin.[11] Because directly observed expectations data are utilised, in principle the problem posed by utilisation of an "ad hoc" expectation formation mechanism is avoided. Unfortunately however, the representativeness of the data has been questioned. Pesando (1975) has been a critic of the rationality of the data. Carlson (1977) has no qualms accepting the data as representative of agents' expectations, having made an adjustment for the following reporting problem.

In early November Livingston prepares questionaires for mailing. Data available at the time of mailing are the US Consumer and Wholesale price indices for September. If the questionaire is mailed in mid-November, the October Wholesale price index may have been released which is followed by the release of the Consumer price index about a week later. Before the December column is published, the November figures for the Wholesale and Consumer price index have been released.

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[11] Livingston has conducted semi-annual surveys of economists in business, academia, and government, in which forecasts for many economic series including price level changes are requested. Gibson (1972) lists the respondents to these surveys.

When there are substantial price changes in the indices between September and December, ambiguity arises with regard to the forecast interval. Livingston made adjustments on the assumption that most respondents based their forecasts on the September data given in the questionaire. Turnovsky (1970), Turnovsky and Wachter (1972), Gibson (1972), Pyle (1972), and Pesando (1975), apparently computs the percentage change over the next six and twelve month period assuming the December (and June) index is known. However Carlson (1977) suggests that participants are generally constrained to earlier information. Participants in a December survey typically know the October index before before forecasts were made for June and December indices for the following year. The forecasts cover an eight month span from October to June, and a fourteen month span from October to December. In an informal survey of his own, Carlson (1977) askes the respondents the latest information to which they are privy. The results indicate that the duration of the forecast is incorrectly measured. We conclude that there may be serious deficiences in the survey data, when available. However, since Canadian survey data of this kind are unavailable, we are unable to utilise this imperfect measure of anticipated inflation.

4.3(iii) Market Revealed Approaches

Examples of the market revealed approach can be found in Fama (1975) and Frenkel (1977). Frenkel proposes a direct measure of inflation expectations based on the observed forward premium in foreign exchange markets. The premium on a forward contract is postulated to represent the anticipated depreciation of the domestic currency. Using data from the German hyperinflation, he shows that inflation expectations dominate all other factors in a money demand function. The application of this technique is, however, not easily transposed to situations other than a hyperinflation. This is because when the domestic price levels of two countries are inflating at approximately the same rate, the forward exchange premium (net of transactions costs) may be expected to reflect technical factors such as interest rate differentials in the two countries.

In principal other futures markets may be used to reveal inflation expectations. Fama attempts to unravel inflation expectations interpreting variations in the implied nominal rate of interest on short term bonds as changes in the expected rate of inflation. However a confusion between changes in relative prices and absolute prices is present. The nominal/relative confusion is addressed by assuming that on average, the short term real rate is constant. However, subsequent papers by Nelson and Schwert (1977) and Shiller and Siegel (1977), have shown that Fama's claim that the expected real interest rate is constant cannot be supported. It is evident that none of these techniques are flawless. Preference for the "ad hoc" generating mechanism is therefore born out of empirical convenience, combined with desirable characteristics that can be attributed to optimal linear forecasts which are investigated in the following sections.

4.4 Weak Rationality and the Optimal Linear Forecast

Inasmuch as data on inflation expectations is not directly observable, there has been an increasing tendency in applied research to generate "ad hoc" expectations series under various assumptions regarding the variety of information utilised in formulating agents expectations.

"Weak" rationality assumes that agents efficiently exploit information contained in the past history of the series about which expectations are to be formed. "Part" rationality concentrates upon information that is assumed to be readily available. "Full" rationality postulates that agents expectations coincide with the forecast of an econometric model. In the chapter that follows, we utilise the notion of "weak" rationality. It is therefore important to explore its properties. [12]

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[12] This discussion draws in part from the contributions of Nelson (1975a,1975b). Further discussion of the optimal linear forecast can be found in McCallum (1976), where an instrumental variable technique which presumes the disturbances in an equation are free of autocorrelation is used. This seems to be a special case of Nelson's argument, since unlike Nelson, the presumption of zero autocorrelation of shocks to an equation is required for this result.

Operationally, the proposition developed by Muth takes the form of an exponentially weighted moving average. Our intention is to show that this scheme is a special case of Muth's original proposition where there is a uniquely simple specification for the shock term. The purpose of this discussion is to show that even under the assumption of "weak" rationality, where there is more than one stochastic shock to the endogenous variable of interest, an ARIMA model is the most appropriate means for generating a rational expectations proxy.

In Muth's heuristic model, it turns out that the only function served by knowledge of its structure is to provide the appropriate weights which a rational economic agent would apply to past prices in order to form expected future prices. If the system has more than one shock, in this case a disturbance to both the demand and supply equations, then the expectation of price cannot be reduced to a function of past prices alone. This is significant to the methodology in Chapter 5, since it begs the question of which extrapolative predictor is chosen as a proxy for the mathematically rational expectation.

We begin with a re-examination of Muth's contribution and compare that model to a more general version. Demand C(t) depends upon current price P(t). Supply is produced with a lag of one period and is therefore based on the mathematical expectation of price, given information based on the preceding time interval. Supply is subject to the stochastic disturbance x(t). The model is written as:

(12) $C_t = -b.P_t$ (demand)

$S_t = c.P^e_t + x_t$ (supply)

$C_t = S_t$ (equilibrium condition)

All variables are expressed in terms of deviations from mean values. Solving for P(t) and taking expectations yields:

(13) $$P^e_t = \frac{-x^e_t}{b + c}$$

$x^e(t)$ denotes the mathematical expectation of x(t) conditioned on information available for the previous period. Muth suggested that x(t) is a discrete random linear process which can be written as:

(14) $x_t = u_t + a_1.u_{t-1} + a_2.u_{t-2} + \ldots,$

where u(t) is a sequence of zero mean disturbances. The expectation of x(t) given information available up the previous period can therefore be written as:

(15) $$x^e_t = E\{x_t \mid \ldots, u_{t-2}, u_{t-1}\}$$

$$= \Sigma\, a_i \,.\, u_{t-i}$$

Therefore:

(16) $$P^e_t = \Sigma \frac{-a_i \,.\, u_{t-i}}{b + c}$$

It is clear that P(t) is a discrete linear process.

(17) $$P_t = - \frac{1}{b} u_t - \frac{1}{b + c} \Sigma\, a_i \,.\, u_{t-i}$$

This can be written in autoregressive form as:

(18) $$P_t = \Sigma\, a'_i \,.P_{t-i} + z_t$$

where $z = \frac{-1}{b} . u_t$, and the a'_i are functions of

b,c and the u(i).

Since the expectation of u(t) = 0, the expected price can be written as:

$$(19)\quad P^{e}_{t} = \Sigma\, a'_{i}.P_{t-i}$$

The expected price is a weighted sum of past prices. This result hinges on the fact that P(t) is expressed as a weighted sum of u(t) alone. As outlined, we have shown that the mathematical (rational) expectation of price depends on past price alone for a simple shock structure.[13]

We now analyse the more general case where shocks to both demand and supply functions are permitted. This is of direct relevance to the model presented in Chapter 5, where such a regime is contemplated. Rewriting the demand function as:

$$(20)\quad C_{t} = -b.P_{t} + y_{t}$$

where y_t is again a discrete linear process.
Solving for P_t yields:

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[13] The empirical application is that the a(i) can be estimated directly utilising lagged P(i). Note also that this optimal extrapolative forecast coincides with the true mathematical expectation of P(t).

$$(21)\quad P_t = -\frac{c}{b}.P^e_t + \frac{1}{b}(y_t - x_t)$$

Taking expectations yields:

$$(22)\quad P^e_t = \frac{1}{c+b}(y^e_t - x^e_t)$$

The rational expectation of price depends on both shock terms. Assume that the process generating y(t) can be written as:

$$(23)\quad y_t = v_t + c_1.v_{t-1} + c_2.v_{t-2} + \ldots,$$

and v and u are independent.

$$y^e_t = E\{y_t|\ldots,v_{t-2},v_{t-1}\}$$

$$(24)\quad = \Sigma\, c_i.v_{t-i}$$

Substituting (22),(24) and (15) into (21) yields:

$$(25)\quad P_t = \{\frac{1}{b}.v_t + \frac{1}{c+b}.\Sigma c_i.v_{t-i}\}$$

$$- \{\frac{1}{b}.u_t + \frac{1}{c+b}.\Sigma a_i.u_{t-i}\}$$

Hence P(t) is the sum of two linear processes. Noting that (25) is of the form:

$$(26)\quad P_t = \Sigma c_i^*.v_{t-i}^* + \Sigma a_i^*.u_{t-i}^*$$

The rational expectation of price is therefore

$$(27)\quad P_t^e = \Sigma c_i^*.v_{t-i}^* + \Sigma a_i^*.u_{t-i}^*$$

Unlike the previous example with one shock, the rational expectation of (27) cannot be expressed as a function of past prices alone because there are two shocks to be taken into account.

This crucial point can be brought out by reference to the "weakly rational" expectation of P as an expectation of P conditioned on a subset of information I(t-1). Denote the weakly rational expectation of P as E{P(t)|past history of P} by P¢, and its error in predicting P(t) by z(t). Then the two predictors are related by:

$$(28)\quad P^{e}_{t} = E\{(P¢_{t} + z_{t})|I_{t-1}\}$$

$$P^{e}_{t} = P¢^{e}_{t} + z^{e}_{t}$$

z(t) is the portion of P(t) which cannot be predicted from the past history of P, but which can be predicted from the full information set I(t-1). From the general result that a conditional expectation is uncorrelated with realised error, it follows that P¢(t) as a measure of Pe(t) will be uncorrelated with the measurement error ze(t). Therefore although weakly rational expectations is a less efficient estimator of the rational expectation of P(t), it is still a consistent estimator. The specification of the extrapolative predictor is then the predictor based on time series analysis which leaves white noise error z(t).

4.5 Applied Aspects of the ARIMA Model

We have demonstrated that a requirement of the specification of the extrapolative predictor is that the residual z(t) is white noise. Such a result is derived from the ARIMA technique, which indicates an appropriate expectations proxy. It is necessary however, to discuss further aspects that arise in the operational utilisation of inflation data in the generation of a rational expectations proxy for anticipated inflation. We assume that the time series characteristic of inflation can be characterised by the following AR(1) process.

$$(29) \quad P_t = b.P_{t-1} + e_t$$

b is a parameter and e is a white noise error term with constant variance. As we have seen, an approach consistent with the assumption of rational expectations is to fit an ARIMA model to the inflation data. Paultier (1980) fits such a model to inflation data over the entire sample to generate rational forecasts for each period. Pearce (1979) assumes that agents know the process which generates inflation at the beginning of the sample period, but they revise their estimates of b as more outcomes are revealed. Hence a sequence of b's are re-estimated as more information is added to the sample. Pearce fits an ARMA (1,1) model to semi-annual US consumer price data. However, as sample size increases, parameter estimates become asymptotically stable which imparts spurious stability in later estimates of b.

Smirlock (1982) fits an ARIMA (0,2,1) model, utilising inflation data from the forty quarters preceeding the quarter in question, to reflect the notion that only past information can be utilised in determining the current inflation forecast. A similar arbitrary choice of time bounds can be found in Klein

(1978) where annual data is used to fit an AR(1) process to the inflation data for the twelve years preceeding the year in question. In this case a proxy for inflation variability is the object of inquiry.

Throwing away data has been defended on the grounds of empirical convenience, or by assuming that the inflation generating mechanism is changing over time, which allows the presumption that past data is less important. Perhaps clear evidence that the inflation generating mechanism is changing with time might justify discarding old data. However, without such evidence and given the assumption in Chapter 5 of a fixed generating mechanism, we conclude that the entire sample data set is best exploited.

4.6 Interpretation of the Income ARIMA model

The reason for this section will become clear when the model designed to disaggregate unanticipated inflation is presented in Chapter 5. We can however, indicate that we shall be interested in the co-movements of the residuals derived from ARIMA models of inflation and income, which will be necessary ingredients of the disaggregation. It is therefore necessary to investigate the characteristics of an income ARIMA model.

Under a rational expectations regime expected or normal income is invariant to the government policy rule. Furthermore, since our rational expectations proxy requires that expectational errors on the inflation series be uncorrelated, it follows that deviations from expected income might reasonably be expected to be serially uncorrelated, because deviations from expected inflation are responsible for effects on real output. The empirical evidence (Hall (1975)), suggests that deviations from trend income are highly serially correlated. In earlier work, Lucas (1973) has to allow for serially correlated deviations in trend income by using an estimating equation of the form:

$$(30) \quad Y_t - Y_{n,t} = \theta\gamma(P^e_t - \bar{P}_t) + \lambda(Y_{t-1} - Y_{n,t-1})$$

Y(n,t) is trend income. The estimate of λ for the US is .887 which suggests that forecast inflation errors are still influencing current output up to eight years from the initial error. Attempts to rationalise why errors made some time ago are still influencing current output have already been examined (see Section 4.2 of this Chapter).

Utilising an ARIMA model for the income series is a useful way of purging the data of these lagged effects, since serial correlation in the income series is removed. The justification for modeling income (and inflation) in this way hinges on the point that <u>we will wish in Chapter 5 to study only the effect of current inflation surprises on current deviations from expected or normal income</u>.

We conclude that ARIMA models of inflation and income have desirable properties which enable them to be regarded as rational expectations proxies. Furthermore, they allow the study of simultaneous deviations from expected values in both series, which is a central theme of the analysis to follow. We are now in a position, in the following core Chapter to present a simple rational expectations model, where unanticipated inflation is disaggregated into demand and supply components.

V. TOWARDS AN IDENTIFIED MODEL OF UNANTICIPATED INFLATION

5.1 On The Identification Of Demand-Supply Shocks

In this chapter we develop a technique designed to aid in the identification of aggregate demand-supply shocks. This identification will facilitate the test of the hypothesis that differential effects on relative price variability result from differences in the sources of the shocks. The model presented in this analysis can be regarded as a simplification of the contributions of Barro (1976) and Lucas (1973). Before presenting our model in detail, it is instructive to review the micro foundations of the rational expectations-cum-natural rate hypothesis. [1]

The Phillips Curve has been described as an empirical generalisation in search of a theory. As noted in the previous Chapter, there are a host of rationalisations to describe the mechanism whereby deviation of actual from expected inflation results in deviations from trend output. These can be summarised as: (i) fooled workers; Friedman (1968), (ii) asymmetries in the decision criteria of workers and firms; Friedman (1975), (iii) search models; Sargent and Wallace (1976), Barro (1976), Lucas

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[1] A perceptive critique of the micro foundations of these models can be found in Cherry, Clawson and Dean (1984). Parts of this introduction have benefited from this source.

(1973), (iv) intertemporal substitution; Lucas and Rapping (1969). In cases (i) to (iii), prices change at a different rate than money wages which produces real output effects. In case (iv) money wages diverge from the long run expected wages, resulting in intertemporal substitutions between leisure and work.

We consider a highly stylised representation of Barro's impressive attempt to provide micro foundations for the short run price/output function. The stochastic elements are surpressed for expositional ease. The log-linear functions contain both substitution and wealth effects on aggregate demand and supply. These are written:

$$(1) \qquad Y_t^d = k_t^d - a_d (P_t - P_t^e) + b_d (M_t - P_t^e)$$

$$(2) \qquad Y_t^s = k_t^s + a_s (P_t - P_t^e) + b_s (M_t - P_t^e)$$

$$a_d, b_d, a_s, b_s > 0$$

The "k" expressions in both equations denote systematic effects on aggregate demand and supply attributable to changes in technology, population, etc. Y(s,t), Y(d,t), P(t), and M(t) denote percentage changes in output supplied, output demanded, the price level, and money supply, respectively. P(e,t) is the expectation of current inflation. [2]

Once solved, Barro's model yields a "well behaved" upward sloping short run aggregate supply function whenever the condition b(s).a(d) < a(s).b(d) holds. Lucas avoids this problem by eliminating wealth effects on supply (ie b(s) = 0). In the model to be presented, it is implicitly assumed that b(d) = b(s) = 0. Thus wealth effects, in the tradition of Sargent and Wallace, Friedman and others are surpressed. Output adjustments reflect labour market adjustments where workers respond less (perhaps through nominal contractual rigidities) in changing nominal money wages to unanticipated inflation than do firms in changing their prices. Furthermore, inventory adjustments are excluded.

We begin by considering an aggregate demand-supply framework, where we assume that the relationships can be approximated by linear functions over the relevant range. [3]

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[2] Barro actually uses E(Pt+1) in his representation. Our simplification does not materially change any of these results.

[3] Abstracting from a foreign sector, tax structure, wealth effects etc., the correct theoretical specification for the demand function should exhibit an elasticity of unity in a simple neoclassical world. An iso-expenditure function of this nature can be represented by a function that is linear in the logarithms of price and quantity. Our specification can be regarded as a linear approximation to the log function, where small changes in inflation and quantities are consistent with small moves along the more correct function. As we shall see, when working with deviations from equilibrium values, this objection loses much of its relevance, because the portion of the function being effectively considered is diminished by this transformation. It is useful to conceptualise the aggregate supply function as a short run "suprise" function, in that only unanticipated inflation is allowed to cause real effects. Therefore we remain consistent with the more traditional conception of a vertical long run supply function. Note also

This model may be regarded as a simplification of the version presented in Chapter four, where the relevant equations (8) and (9) containing three stochastic elements are simplified to equations (11) and (12) of this Chapter which contain two stochastic elements.

Let Yd and Ys denote real output demanded and supplied respectively. P denotes the percentage rate of change of the price level. The errors are random normal and are independent of each other. [4]

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[3](cont'd) that we consider the simplest rational expectations paradigm, where the demand function closes the model. The expectation of aggregate demand is exogenously determined. A more sophisticated treatment would entail the formation of expected aggregate demand by incorporating a monetary growth rule. For a very readable discussion on the "bootstrap" problem in rational expectations models, see Parkin (1982), pp 387.

[4] Although there are no obvious a priori theoretical objections to the assumption that shocks to the aggregate demand and aggregate supply functions have zero covariance, as shown in (5), from an empirical perspective it is not as innocuous as it may at first appear. Nominal Gross National Expenditure is transformed into constant dollar expenditure by a deflator which, although consisting of a broader category of representative commodities in the typical basket than in the CPI, has historically moved closely with the CPI. Hence shocks to the inflation series as measured by the CPI may be correlated with shocks to the GNE deflator, resulting in the potential for negative observed covariance in the shocks to deflated GNE and the CPI series. This is a common, albeit infrequently alluded to problem in empirical studies which explore inflation and real output/expenditure relationships. A second objection may lie in the suggestion that increased Government expenditures financed by payroll or sales taxes may result in the demand and supply functions tending to be shocked in opposite directions, leading to negative covariance of the shock terms.

(3) Demand: $Yd_t = \delta_t - \psi.P_t + u_t$

(4) Supply: $Ys_t = \eta_t + \phi(P_t - P^e_t) + a_t$

$\delta, \psi, \phi > 0 > \eta$

Equilibrium Condition:

$Yd_t = Ys_t$

(5) u is distributed $(0, \sigma^2_u)$

a is distributed $(0, \sigma^2_a)$

cov (u, a) = 0

Setting (3) equal to (4) yields the quasi-reduced form solution to these equations:

(6) $$P_t = \frac{(\delta_t - \eta_t) + (u_t - a_t) + \phi.P^e_t}{\phi + \psi}$$

Substituting the expression for P_t in (6) into equation (3) yields:

$$(7) \quad Y_t = \frac{(\eta_t.\psi + \phi.\delta_t) + (\phi.u_t + \psi.a_t) - \psi.\phi.P^e_t}{\phi + \psi}$$

Taking the expectation of (6) yields:

$$(8a) \quad E\{P_t\} = E\{ \frac{(\delta_t - \eta_t) + (u_t - a_t) + \phi.P^e_t}{\phi + \psi} \}$$

This can be simplified to yield:

$$(8b) \quad P^e_t = \frac{\delta_t - \eta_t}{\psi}$$

Substituting (8b) into (6) yields the full reduced form:

$$(9) \quad P_t = \frac{(\delta_t - \eta_t) + (u_t - a_t) + \phi.\{\frac{\delta_t - \eta_t}{\psi}\}}{\phi + \psi}$$

Similarly, substituting (8b) into (7) yields:

$$(10)\quad Y_t = \frac{\eta_t.\psi + (\phi.u_t + \psi.a_t) - \psi.\phi.\left\{\frac{\delta_t - \eta_t}{\psi}\right\}}{\phi + \psi}$$

These solutions can easily be expressed in terms of deviations from the expectation of P and Y, since the stochastic components of equations of (9) and (10) are the remaining elements when actual and expected values are subtracted. This yields:

$$(11)\quad P_t - E(P_t) = \frac{u_t - a_t}{\phi + \psi}$$

$$(12)\quad Y_t - E(Y_t) = \frac{\phi.u_t + \psi.a_t}{\phi + \psi}$$

The model is well behaved in the sense that only stochastic deviations from expected inflation are associated with deviations from expected real output. [5]

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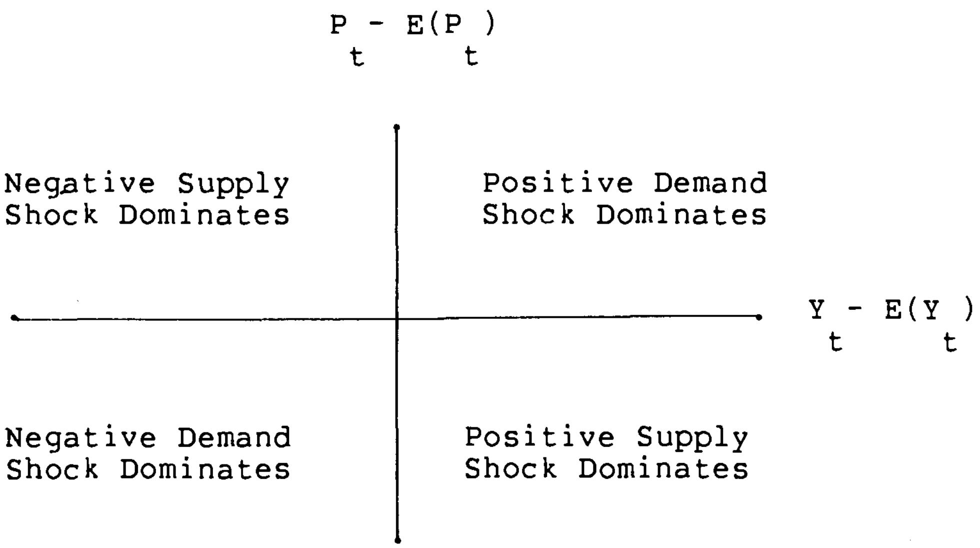
[5] Strictly speaking E(Y(t)) is output when stochastic components of price expectations are zero. That is when P(t)=E(P(t)). We retain the notation used above for its convenience. Unlike more sophisticated models, the expectation of future price increases is not explicitly taken into account in forming today's expected

It is evident from (11) and (12) that demand shocks (perturbations in "u") will be associated with positive co-movements in $P - E(P)$ and $Y - E(Y)$. Similarly, supply shocks (perturbations in "a") will be associated with negative co-movements in $P - E(P)$ and $Y - E(Y)$. Four possible cases are illustrated in Figure 5.1

Figure 5.1: Schematic Representation of Supply-Demand Deviation From Expected Values.



For notational convenience we shall refer to $P - E(P)$ and $Y - E(Y)$ as p and y respectively. The variances of p and y, shown

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[5](cont'd) price. For details, see Mussa (1978).

in equations (13) and (14), can be expressed in terms of the unknown variances of the demand-supply shocks by re - expressing equations (11) and (12), together with the assumption in (5) which results in zero shock covariance: [6]

$$(13) \qquad \sigma_p^2 = \frac{1}{(\phi + \psi)^2} \{\sigma_u^2 + \sigma_a^2\}$$

$$(14) \qquad \sigma_y^2 = \frac{1}{(\phi + \psi)^2} \{\phi^2 \sigma_u^2 + \psi^2 \sigma_a^2\}$$

Division of equation (11) by the square root of equation (13) yields the Z score for p, hereafter referred to as Z(p). Similarly, division of equation (13) by the square root of (14)

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[6] Since we will be attempting to infer the relative preponderence of demand-supply shocks, through investigation of p and y, it is instructive to report the effects on p and y of the relaxation of the assumption of a nonzero covariance expression for u and a in equations (13) and (14). Let us assume as a pedagogical aid, that the covariance expression is positive. This results on average in a tendency for the aggregate demand function to be shocked in the same direction as the aggregate supply function. Attempts to identify aggregate demand-supply shocks in the way represented in Figure 5.1 results in error due to a downward bias that could result in the observations in p, because of a negative sign that would appear on a non zero covariance expression in equation (13). Correspondingly, upward bias could result in the observations on y, because of a positive sign that would appear on a non zero covariance expression in equation (14). Of course any model requires some simplifying assumptions, and the gain in theoretical tractability by assuming a zero covariance between u and a is convenient.

yields the Z score for y, referred to as Z(y). Some of the benefits that occur as a result of this standardisation procedure can be outlined.

In a comparison of the Z(p) and Z(y) series, the problem of unit of measurement has been obviated. We avoid making comparison between deviations from expected inflation (measured in percent), against deviations from expected income (measured in 1971 constant dollars). Second, as can be seen from equations (11) and (12), the parameters of the demand-supply functions have a direct bearing on the magnitudes of the calculated p and y. Normalisation of these distributions to have a common mean 0 and unit standard deviation, makes an adjustment which allows relative comparison of deviation from expected values in the two series.

5.2 The Identification Problem

Our next task is to convert the Z(p) and Z(y) pairs of observations into an empirically tractable form. The identification problem inhibits meaningful inferences regarding the source of shocks, because observed deviations in income and inflation are a hybrid of both demand and supply disturbances.

It is useful to examine the conditions which will prevail when the demand-supply functions are identified, as this will later assist in consideration of the non-identified case. Assume that the supply function is identified by a positive or negative demand shock. Setting the shock expression (a) (the shock to the supply function) and its variance equal to zero, and referring back to equations (11),(12),(13), and (14) yields:

$$(15) \quad p_t = \frac{u_t}{\phi + \psi}$$

$$(16) \quad Var(p) = \left\{\frac{1}{\phi + \psi}\right\}^2 \sigma_u^2$$

$$(17) \quad y_t = \frac{\phi . u_t}{\phi + \psi}$$

$$(18) \quad Var(y) = \left\{\frac{\phi}{\phi + \psi}\right\}^2 \sigma_u^2$$

The square root of equation (16) is referred to as $\phi1$, which represents the standard deviation of p when the variance of supply shocks is zero. Similarly, the standard deviation of y from equation (18) is written $\phi2$. The Z scores for p and y then reduce to:

$$(19) \quad Z(p_t)_{|a=0} = \frac{u_t}{(\phi + \psi).\Phi 1}$$

Similarly, the Z score for y reduces to:

$$(20) \quad Z(y_t)_{|a=0} = \frac{\phi.u_t}{(\phi + \psi).\Phi 2}$$

It can be shown that the Z scores for p and y are identical when the supply function is fully identified, by explicitly evaluating (19) and (20), where σu refers to the standard deviation of the shock expression u, and $\Phi 1$, $\Phi 2$ are fully written. This gives (21) and (22).

(21) $$Z(y_t)_{|a=0} = \frac{\phi . u_t}{\phi + \psi} . \frac{\phi + \psi}{\phi . \sigma_u}$$

(22) $$Z(p_t)_{|a=0} = \frac{u_t}{\phi + \psi} . \frac{\phi + \psi}{\sigma_u}$$

The expressions in (21) and (22) are identical. We therefore write:

(23) $$Z(y_t)_{|a=0} = Z(p_t)_{|a=0}$$

We use the same procedure where the demand function is fully identified by supply shocks. Again, in order to simplify notation the standard deviation of p when the variance of demand shocks is zero is referred to as $\phi 3$. Similarly, the standard deviation of y is referred to as $\phi 4$. Setting the shock expression (u), and its variance equal to zero, and referring to the same equations (11), (12), (13), and (14) yields: [7]

$$(24)\qquad Z(p_t)_{|u=0} = \frac{-a_t}{(\phi + \psi).\Phi 3}$$

$$(25)\qquad Z(y_t)_{|u=0} = \frac{\psi.a_t}{(\phi + \psi).\Phi 4}$$

Inspection of (24) and (25) reveals that the same result holds, except of course that the expression in (24) is negative. We do not repeat the synonymous derivations, where (19) and (20) were re-written in full. We can therefore write:

$$(26)\qquad Z(y_t)_{|u=0} = -Z(p_t)_{|u=0}$$

These results can be illustrated by referring to Figure 5.2, where we show the conditions that hold for the fully identified cases.

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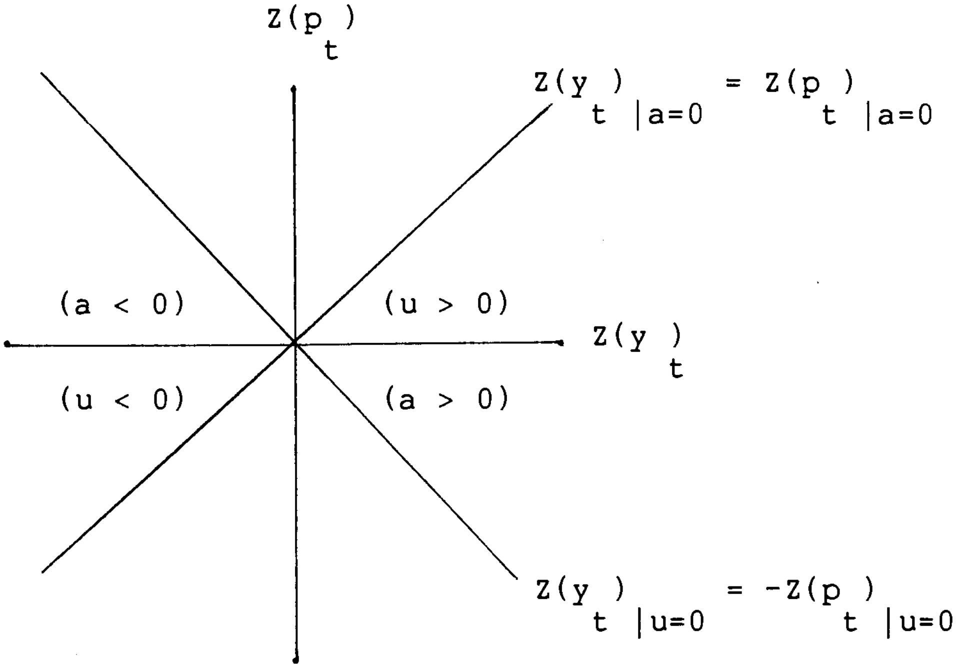
[7] We do not repeat the parallel derivations of equations (15), (16),(17), and (18). The results are of course perfectly symmetric.

Figure 5.2 Illustration of Fully Identified Conditions



We see that the two equalities in Figure 5.2 describe the behaviour of the Z scores where the demand function <u>or</u> the supply function is fully identified. In the case of demand shocks, the Z scores for p and y move exactly together. For supply shocks, their relationship is the same but with a negative coefficient.

We now consider the more complex case where neither of the demand or supply shocks can be assumed to be zero and furthermore, where information regarding separate knowledge of the demand-supply shock variances is not available. Instead we have only an estimate of the variances of p and y. Although these estimates incorporate the variances of the demand and supply shocks, these individual shock variances cannot be extricated without more information than is available from the sample data. The question then arises as to how to deal with the general case, when the shock variances are unknown and the shocks occur simultaneously.

Before presenting the procedure proposed to circumvent this problem, it is necessary to examine a property of the model developed to this point. Covariance in the Z(p),Z(y) series may occur even when both stochastic disturbances in (3) and (4) are uncorrelated, as is assumed in (5). Formally, this can be shown by reference to the following expression, where the co-movements in Z(p) and Z(y) (from equations (11), (12), (13) and (14)) are represented.

$$(27) \quad Cov(Z(p),Z(y)) = E\left\{\frac{(u_t - a_t)(\phi.u_t + \psi.a_t)}{(\phi + \psi)^2 \sigma_p^2 \sigma_y^2}\right\}$$

$$= \frac{\phi \sigma_u^2 - \psi \sigma_a^2}{(\phi + \psi)^2 \sigma_p^2 \sigma_y^2}$$

Substituting fully for σp and σy from (13) and (14) yields:

$$= \frac{\phi\sigma_u - \psi\sigma_a}{\phi\sigma_u + \psi\sigma_a}$$

The final expression is the correlation coefficient. The importance of the correlation will become apparent later, when we present the notion of identifying vectors in analysis that to isolates demand and supply shocks. It turns out that bias may result from a non-zero correlation, which could in principle have potentially serious implications. This is one reason for careful pre-testing of the data which is undertaken in Section 5.5. For purposes of exposition we shall assume for the moment that the correlation is zero.

We can now return to the development of the technique to aid in the identification of demand and supply shocks. To investigate the relationship between the Z scores, when the assumptions regarding knowledge of the individual demand-supply shock variances and the separation of individual demand-supply shocks are relaxed, it is instructive as a starting point to examine equation (28), which shows the general relationship between Z(p) and Z(y). It is evident that the relationship is a complicated function of stochastic shocks, their variances, and the structural parameters.

$$(28) \qquad \frac{Z(p_t)}{Z(y_t)} = \frac{\dfrac{u_t - a_t}{(\phi + \psi).\sigma p}}{\dfrac{\phi.u_t + \psi.a_t}{(\phi + \psi).\sigma y}}$$

$$= \frac{(u_t - a_t).\sigma y}{(\phi.u_t - \psi.a_t).\sigma p}$$

$$Z(p_t) = \frac{(u_t - a_t).Z(y_t).\sigma y}{(\phi.u_t + \psi.a_t).\sigma p}$$

We wish now to derive some empirically tractable propositions. Refer back to Figure 5.1 and consider the the upper right hand quadrant. Because there are positive deviations from expected values for inflation and income, a positive demand shock dominates. As a result of the assumption of zero covariance between demand and supply shocks, the expected values of the Z scores given a positive demand shock can be evaluated. The expectations of the Z scores are shown below in equations (29) and (30). What (29) shows is that given a positive demand shock, the average Z(p) does not depend on supply shocks since they are assumed to be independent of demand shocks. Furthermore, it is assumed that the expected value for supply shocks is zero.

(29)

$$E\{Z(p)\}_{|u > 0} = \frac{E(u) - E(a)}{(\phi + \psi).\sigma p}$$

$$= \frac{\bar{u}}{(\phi + \psi).\sigma p}$$

Equation (30) shows the evaluation of Z(p) given a negative demand shock.

(30)

$$E\{Z(p)\}_{|u < 0} = \frac{-\bar{u}}{(\phi + \psi).\sigma p}$$

Next consider the lower right hand quadrant, where the same procedure is used. Since output is greater than expectation, and inflation is less than expectation, a positive supply shock dominates. Applying the expectations operator, conditioned on the occurance of the positive supply shock, yields equations (31) and (32):

(31) $$E\{Z(y)\}\Big|_{a > 0} = \frac{\psi.E(u) + \psi.E(a)}{(\phi + \psi).\sigma y}$$

$$= \frac{\psi.\bar{a}}{(\phi + \psi).\sigma y}$$

(32) $$E\{Z(y)\}\Big|_{a < 0} = \frac{-\psi.\bar{a}}{(\phi + \psi).\sigma y}$$

Note that the expectation of Z(p) in (29) and (30) has the same absolute value. The expectation of Z(y) in (31) and (32) can be similarly described. Taking the expectations for the remaining quadrants in the same way yields results which can be summarised:

(33) $$E\{Z(p)\}_{|u>0} = -E\{Z(p)\}_{|u<0}$$

$$E\{Z(p)\}_{|a<0} = -E\{Z(p)\}_{|a>0}$$

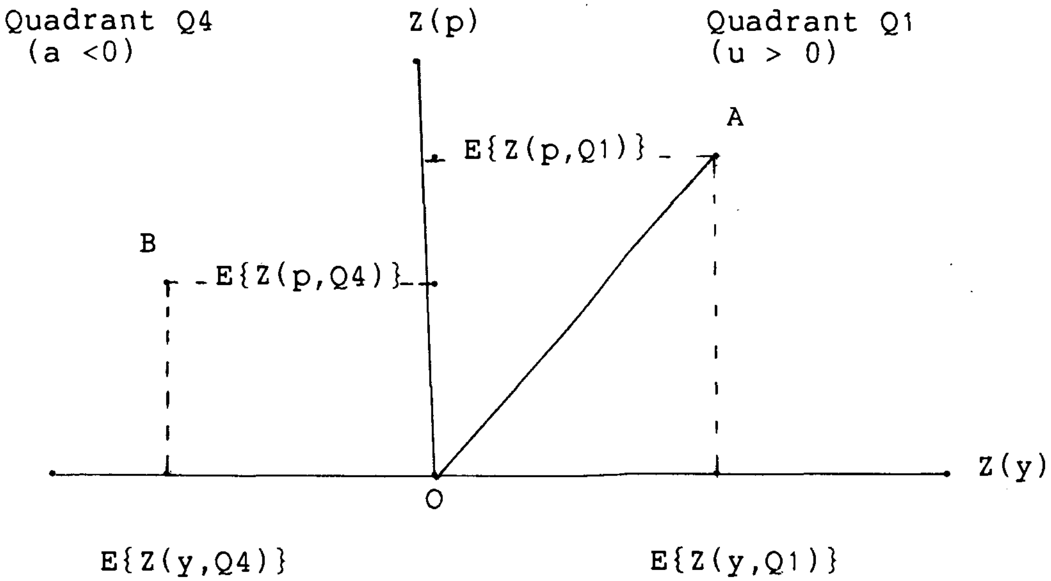
$$E\{Z(y)\}_{|a>0} = -E\{Z(y)\}_{|a<0}$$

$$E\{Z(y)\}_{|u>0} = -E\{Z(y)\}_{|u<0}$$

It is now possible to show how these derivations aid in the identification of aggregate demand and supply shocks. In order to smooth exposition, we refer to the upper right, lower right, lower left, and upper left quadrants as Q1, Q2, Q3, and Q4, respectively. Recall that we have no knowledge of the parameters of the model other than estimates of the variances of p and y. These variances are used to convert the p and y pairs of observations into their respective Z scores Z(p) and Z(y).

Equation (33) indicates that the expected value for Z(p) in quadrants Q1 and Q3 are equal in absolute value. Similarly, the expectation of Z(y) in quadrants Q1 and Q3 are equal in absolute value. With reference to Figure 5.3, consider quadrant Q1, where the expectation of Z(p) and Z(y) are shown. To recapitulate what these expected values show, the expectation of p in Quadrant Q1,

Figure 5.3 The Derivation of The Identifying Vectors



written as E(Z(p,Q1)), indicates the Z score for p when the average positive demand demand shock occurs <u>and</u> the shock on the supply function is zero (since by definition its expected value is zero). Similarly, E(Z(y,Q1)) indicates the Z score for y in Quadrant Q1, when the average positive demand shock occurs <u>and</u> the shock on the supply function is zero. Since ϕ, ψ, σu, σa are constants, any deviation from the average shock can be represented as a movement along the ray OA from the initial position A. It is therefore possible to conceptualise OA as an <u>IDENTIFYING</u> <u>VECTOR</u> for positive demand shocks, in the sense that it indicates how the Z scores for p and y move together when the shock to the supply function is zero. Consider now Quadrant Q4.

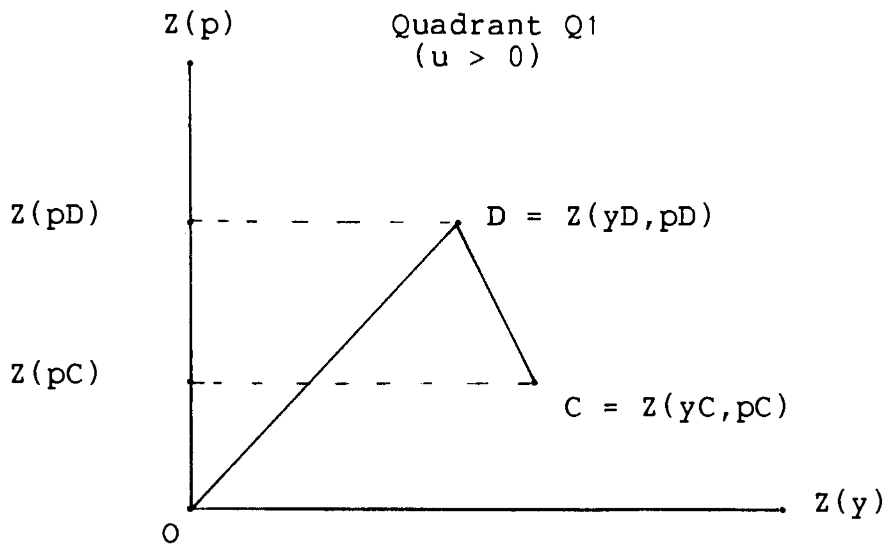
It is possible to locate a second IDENTIFYING VECTOR with regard to supply shocks. This vector indicates how the Z scores of p and y move together when the shock to the demand function is set to zero. In a parallel manner, the vector can be arbitrarily lengthened or shortened from point B, to reflect deviations from the average negative shock.

It is well known that any point in two dimensions is uniquely defined by two linearly independent vectors. Hence we combine the information given by the two identifying vectors. We refer for expositional simplicity to Quadrant Q1 in Figure 5.4, dropping the Q1, Q2 notation used in Figure 5.3. Assume that an observation on unanticipated inflation and unanticipated income is characterised by point C. Measuring unanticipated inflation as O, Z(pC,) fails to reflect the problem inherent in the fact that simultaneous shocks to both demand and supply functions may occur. The procedure to circumvent this problem can be conceptualised as "sliding" the identifying supply shock vector horizontally rightward, so that it passes through the observation at point C, thus decomposing unanticipated inflation into demand shock and supply shock categories. The intersection of the identifying demand shock vector OD, with the supply shock vector DC, determines the disaggregation. [8]

----

[8] The parallel procedure in Quadrant Q4 is to "slide" the identifying demand vector so that it passes though the observation in this quadrant. The intersection with the identifying supply vector determines the decomposition as above.

Figure 5.4 The Identification Of Demand-Supply Shocks



We are now in a position to state the key result. Vector OD indicates the co-movements in Z(p) and Z(y) which occur as a result of a demand shock. Similarly, vector DC indicates the movements in Z(p) and Z(y) that occur as a result of an (inferred) negative supply shock. It is possible to decompose unanticipated inflation into that which would have occurred, had the negative supply shock been set to zero. This is measured as O,Z(pD). The reduction in unanticipated inflation that occurs as a result of the positive supply shock, is measured as O,Z(pC) minus O,Z(pD). Once these magnitudes are determined, the Z scores can be converted back to give raw demand and supply shock inflation through multiplication by their respective standard deviations.

This concludes the discussion of the identification problem, and of the proposed procedure to isolate demand and supply shock inflation. Having considered the properties of the expected values of the Z scores, we now demonstrate that they can be extracted from the sample data.

5.3 Computation Of Expected Values From Sample Data

It can be seen from the derivations as shown in (33) that the means of, for example, Z(p) calculated from the observations in Quadrants Q1 and Q3 should theoretically be the same. It is also efficient to combine information from more than one sample whenever possible. We therefore pool the information from the two sample means for Z(p) in quadrants Q1 and Q3, by weighting a combination of the two sample mean estimates. This procedure is also used in the calculation of the overall means for Z(p) in quadrants Q2 and Q4, and for the overall means for Z(y) in Quadrants Q1,Q3 and Q2,Q4. This technique also imposes the symmetry required of the model. The means are calculated as shown in (35). Define the overall weighted mean Z(p), for Quadrants Q1 and Q3 as:

$$\bar{E}\{p(Q1+Q3)\}.$$

Similar notation describes the weighted means for the four

Quadrants. [9]

$$(34) \quad \bar{E}\{p(Q1+Q3)\} = \frac{n1.E(p,Q1) + n3.E(p,Q3)}{n1 + n3}$$

$$\bar{E}\{p(Q2+Q4)\} = \frac{n2.E(p,Q2) + n4.E(p,Q4)}{n2 + n4}$$

$$\bar{E}\{y(Q1+Q3)\} = \frac{n1.E(y,Q1) + n3.E(y,Q3)}{n1 + n3}$$

$$\bar{E}\{y(Q2+Q4)\} = \frac{n2.E(y,Q2) + n4.E(y,Q4)}{n2 + n4}$$

We have described the techniques employed in the identification of unanticipated inflation. Furthermore, we have shown how the overall mean Z scores are calculated. It is now possible to report on the empirical procedure used to generate the deviations in income and inflation from expected values. [10] In Section 5.4, ARIMA models of inflation and income are reported. Deviations from the forecast values in each series can

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[9] Note that n1,n2,n3,n4 refer to the number of observations in quadrant Q1,Q2,Q3,Q4 respectively.

[10] The mathematics to this solution are shown in Appendix 5B. Furthermore, the computer algorithm is reported in Appendix 5C.

be regarded as the unanticipated time series components of inflation and income. Section 5.5 reports pre-tests of the data which were promised in the theoretical discussion earlier in this Chapter.

5.4 ARIMA Models Of Expected Inflation and Income

Since the model is expressed in terms of deviations from expected values, it is necessary to pursue the time dependent form of the model which we now develop and later test. From a sampling perspective, each inflation (and income) observation is regarded as being drawn from a normally distributed population. In any given period, repeated observations on the inflation (and income) series would yield on average a stochastic error of zero. Furthermore, since the expected rate of inflation (and income) is changing over time, it is necessary to allow these expectations to drift. This can be accomplished using standard time series techniques.

The method presented by Box and Jenkins (1970), where all of the information in a series is used to extract expected values, is appropriate for our purpose. The ARIMA technique is particularly appropriate, since once the series is modelled, serially uncorrelated expectational errors remain. This property is required of rational expectations models. Furthermore, since deviations from expected values are temporally uncorrelated, estimates of their variance are unbiased. [11]

Having established the desirability of ARIMA techniques in the generation of residuals in Chapter 4, Sections 4.4 and 4.5, we now report the time series models used in the estimation of expected values for income and inflation. The estimated equation for expected income is written in standard notation in equation (35), where B is the backshift operator:

$$(35) \quad (1 - 0.4178B^{4})(1 - B^{1})(1 - B^{4})Y_{t} = (1 + .1045B^{1})e_{t}$$

The inflation equation can be expressed in the same way, yielding:

$$(36) \quad (1 - B^{1})(1 - B^{4})P_{t} = (1 + 0.27B^{1} + 0.8327B^{4})e_{t}$$

The standard deviations of the series are calculated by re-integrating the series back to the original data. The standard deviations of these series are then calculated as

----

[11] The exact characteristics of the ARIMA models for inflation and income are reported, together with anticipated inflation E(P), unanticipated inflation p, expected income E(Y), the deviation in income y, in Appendix 5A.

usual. The standard deviations of p and y were found to be .024 and 398.927 respectively.

5.5 Pretesting The Data

To this point we have ignored the question of whether the assumptions of parameter stability and constant demand-supply shock variances, are valid approximations. It is possible to perform a simple test which indicate how robust, as a group, these assumptions are. Secondly, it is possible to test whether the covariance of the standardised observations over the sample period is significantly different from zero. Recall the discussion that surrounds equation (27) regarding the covariance of these terms. A positive covariance, for example, would tend to be reflected in observations being grouped in the upper right and lower left hand quadrants, with bias resulting in the calculation of the expected values of the Z scores. Therefore the earlier assumption that the correlation between the Z scores on p and y is zero requires testing.

A straightforward means of testing for systematic behaviour in the data is to fit a line by OLS, regressing the Z values of y on those of p, and testing for intercept and slope coefficients which differ significantly from zero. Note that in the case of simple linear regression, the coefficient on the independent variable is also an estimate of the correlation coefficient, which in turn consists of the covariance in the Z(p) and Z(y) series divided by the product of their respective standard deviations. Hence the reported prob-value is a means of testing the significance of the correlation (covariance) in the data.

Table 5.1: OLS Regressions of Z(p) and Z(y).

Dependent Variable: Z(p)

Period	Intercept	Z(y)	CRSQ	F	D-W
49Q2-82Q4	-.0152 (-.17)	-.0547 (-.63)	-.004	.402	1.97

PROB>F = 0.535

Dependent Variable: Z(y)

		Z(p)			
	- 0.048 (-0.56)	-.0550 (-0.63)	-.004	.402	1.97

The results of the test shown in Table 5.1 indicate the absence of any systematic relationship in the data.

<u>It is this test that validates earlier assertions that the covariance can be assumed to be zero.</u> [12]

---

[12] Strictly speaking, however, it should be pointed out that even when the covariance is statistically insignificant, we cannot rule out the possibility that this error might cause bias relative to that which is being measured. The orientation of the Z(p), Z(y) distribution has many possibilities. It is therefore important to evaluate the coefficient magnitude as well as its significance. In the first regression we would ideally have a

A further test which provides circumstantial evidence on whether the assumptions of the model are violated, examines the time invariance of the sample variances of the p,y series. This test can be performed by separating the data sets for p and y into two sets of observations (denoted p1,p2 for the price series and y1,y2 for the income series) covering the periods 1949Q2-1966Q1 and 1966Q2-1982Q4, and testing to see if the variances of p1,p2 and y1,y2 differ significantly from each other. Explicitly, two sample variances for p and y are calculated and two sets of hypotheses tested.

Ho: Var(p1) = Var(p2)

Ha: Var(p1) > Var(p2)

Ho: Var(y1) = Var(y2)

Ha: Var(y1) > Var(y2)

We regard the first populations (p1) and (y1), as the ones which may, according to Ha, have the larger variance.[13] Operationally, the hypotheses are tested using the ratios shown below, which are distributed according to the F distribution.

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[12](cont'd) coefficient of zero on Z(y). The magnitude of -.0547 gives additional "circumstantial evidence" indicating that any potential bias is very small relative to what is being measured.

[13] See Kmenta (1971), Ch. 5, Sect. 2.

$$\frac{Var(p1)}{Var(p2)} = F_{n1-1,\ n2-1} \quad \text{(with df)} \qquad \frac{Var(y1)}{Var(y2)} = F_{n1-1,\ n2-1} \quad \text{(with df)}$$

The test consists of determining whether the ratios are significantly different from unity. The calculated variances and test statistics are reported in Table 5.2

Table 5.2: Temporal Variance Stability Test

Period	49Q2 - 66Q1	66Q2 - 82Q4
Sample Variances	(p1) = 0.000729	(p2) = 0.000447
	(y2) = 142342	(y1) = 177768

$$\frac{Var(p1)}{Var(p2)} = 1.63 \qquad \frac{Var(y1)}{Var(y2)} = 1.24$$

The critical value for the F statistic at the 1% level is 1.84. We conclude that the variances of p1,p2 and y1,y2 are drawn from the same respective populations, since the test ratios do not exceed this value.

Appendix 5A

In this appendix the time series models and data used are fully reported. The inflation series (tagged DP) pertains to the inflation rate of the simulated CPI series derived and explained in Chapter 3. The estimation period is 1949Q2-1982Q4, and is read horizontally.

The autocorrelation (acf) and partial autocorrelation (pacf) functions are first shown for the undifferenced inflation series, and non-stationarity of the data indicates the requirement of differencing the data. The acf and pacf functions pertaining to the first and fourth differenced inflation data follow, and are indicative of stationarity in the data. Spikes at lags 1,3 and 4 in the acf and at 3 and 4 in the pacf indicates the model requires moving average components at lags 1 and 4. The estimated model immediately follows. The next acf and pacf functions pertain to residuals from the model. A check of the Q statistic indicates that the remaining information in the series is white noise. The model is therefore tolerably well specified.

The same sequence of reports follow with regard to the Gross National Expenditure data. [14] This data is recognised by the tag GNE. The acf and pacf functions on the undifferenced

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[14] Gross National Expenditure in 1971 constant dollars, not seasonally adjusted. Source: National Income and Expenditure Accounts. Statistics Canada DBS 13-531. Cansim retrieval code: D40561.

data are first reported. Stationarity is achieved by taking first and fourth differences of the original series, and the acf and pacf functions are next reported for the differenced data. Spikes at lag 4 in both the acf and pacf functions are indicative of a need for autoregressive and/or moving average components to be included in the model. The estimated model is next reported and is selected on the basis of minimum residual mean square error. Diagnostic checks of the residuals reveals white noise for both acf and pacf functions. The model is therefore tolerably well specified.

```
..PRINT VARI=DP./
```

VARIABLE = DP NUMBER OF CASES = 135

-0.010	0.037	0.017	-0.018	0.039	0.077
0.112	0.107	0.124	0.105	0.077	-0.011
-0.050	-0.007	-0.008	-0.025	-0.027	0.041
0.014	-0.023	0.002	0.033	-0.001	-0.018
-0.007	0.011	0.015	-0.013	0.015	0.064
0.045	0.003	0.023	0.046	0.022	0.014
0.045	-0.001	0.031	-0.015	-0.003	0.025
0.052	-0.031	0.008	0.014	0.053	-0.017
-0.003	0.003	0.016	0.003	0.017	0.026
0.019	0.012	0.007	0.036	0.011	0.015
0.020	0.024	0.004	0.029	0.033	0.032
0.023	0.050	0.044	0.037	0.021	0.018
0.054	0.064	0.012	0.046	0.037	0.044
0.035	0.031	0.074	0.049	0.024	0.037
0.036	0.020	-0.008	0.020	0.054	0.058
0.027	0.047	0.035	0.079	0.041	0.072
0.091	0.074	0.074	0.096	0.129	0.120
0.108	0.087	0.086	0.135	0.079	0.051
0.060	0.057	0.057	0.085	0.095	0.085
0.086	0.074	0.096	0.100	0.050	0.095
0.105	0.078	0.088	0.088	0.109	0.114
0.113	0.127	0.121	0.116	0.091	0.098
0.123	0.082	0.059			

```
..ACF VARI=DP./

AUTOCORRELATIONS

  1- 12      .77  .63  .61  .59  .44  .35  .38  .45  .40  .35  .41  .47
  ST.E.      .09  .13  .15  .17  .18  .19  .19  .20  .21  .21  .22  .22
   Q        81.4 137. 189. 238. 265. 283. 304. 334. 358. 376. 401. 434.

 13- 24      .36  .27  .33  .36  .27  .23  .29  .34  .33  .29  .34  .35
  ST.E.      .23  .23  .24  .24  .24  .25  .25  .25  .25  .26  .26  .26
   Q        454. 466. 483. 503. 514. 523. 536. 554. 571. 585. 604. 625.

 25- 36      .31  .26  .30  .29  .21  .15  .20  .19  .11  .09  .09  .10
  ST.E.      .27  .27  .27  .27  .27  .28  .28  .28  .28  .28  .28  .28
   Q        641. 652. 668. 683. 691. 695. 702. 709. 711. 712. 714. 716.

           -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
             +----+----+----+----+----+----+----+----+----+----+
                                      I
  1    0.768                      +   IXXX+XXXXXXXXXXXXXXX
  2    0.634                    +     IXXXXX+XXXXXXXXXX
  3    0.609                   +      IXXXXXX+XXXXXXXX
  4    0.587                  +       IXXXXXXX+XXXXXXX
  5    0.438                 +        IXXXXXXXX+XX
  6    0.354                 +        IXXXXXXXXX
  7    0.383                 +        IXXXXXXXX+X
  8    0.454                +         IXXXXXXXXX+X
  9    0.399                +         IXXXXXXXXXX
 10    0.349                +         IXXXXXXXXX+
 11    0.411               +          IXXXXXXXXXX+
 12    0.470               +          IXXXXXXXXXX+X
 13    0.365               +          IXXXXXXXXX +
 14    0.274               +          IXXXXXXX   +
 15    0.331              +           IXXXXXXXX   +
 16    0.358              +           IXXXXXXXXX  +
 17    0.271              +           IXXXXXXX    +
 18    0.231              +           IXXXXXX     +
 19    0.286              +           IXXXXXXX    +
 20    0.336              +           IXXXXXXXX   +
 21    0.328              +           IXXXXXXXX   +
 22    0.290             +            IXXXXXXX     +
 23    0.336             +            IXXXXXXXX    +
 24    0.355             +            IXXXXXXXXX   +
 25    0.311             +            IXXXXXXXX    +
 26    0.259             +            IXXXXXX      +
 27    0.302             +            IXXXXXXXX    +
 28    0.295             +            IXXXXXXX     +
 29    0.212             +            IXXXXX       +
 30    0.153            +             IXXXX         +
 31    0.200            +             IXXXXX        +
 32    0.191            +             IXXXXX        +
 33    0.114            +             IXXX          +
 34    0.088            +             IXX           +
 35    0.092            +             IXX           +
 36    0.102            +             IXXX          +
```

```
..PACF VARI=DP./

PARTIAL AUTOCORRELATIONS

  1- 12      .77  .11  .23  .10 -.24 -.01  .17  .27 -.03 -.07  .11  .11
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24     -.16 -.09  .16  .04 -.05  .03  .02  .05  .16 -.02 -.04 -.06
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36      .09  .03  .03 -.09 -.12 -.05  .10 -.04 -.16  .02 -.07  .04
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
            +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    0.768                     +   IXXX+XXXXXXXXXXXXXXX
  2    0.107                     +   IXXX+
  3    0.228                     +   IXXX+XX
  4    0.104                     +   IXXX+
  5   -0.235                   XX+XXXI   +
  6   -0.007                     +   I   +
  7    0.168                     +   IXXXX
  8    0.266                     +   IXXX+XXX
  9   -0.029                     +   I   +
 10   -0.065                     + XXI   +
 11    0.113                     +   IXXX+
 12    0.106                     +   IXXX+
 13   -0.156                     XXXXI   +
 14   -0.093                     + XXI   +
 15    0.156                     +   IXXXX
 16    0.042                     +   IX  +
 17   -0.050                     +   I   +
 18    0.027                     +   IX  +
 19    0.017                     +   I   +
 20    0.046                     +   IX  +
 21    0.157                     +   IXXXX
 22   -0.021                     +   I   +
 23   -0.036                     +   I   +
 24   -0.064                     + XXI   +
 25    0.090                     +   IXX +
 26    0.030                     +   IX  +
 27    0.026                     +   IX  +
 28   -0.086                     + XXI   +
 29   -0.117                     +XXXI   +
 30   -0.052                     +   I   +
 31    0.095                     +   IXX +
 32   -0.037                     +   I   +
 33   -0.162                     XXXXI   +
 34    0.017                     +   I   +
 35   -0.074                     + XXI   +
 36    0.043                     +   IX  +
```

```
..ACF VARI=DP.DFORDERS ARE 1,4./

AUTOCORRELATIONS

  1- 12     -.17 -.02  .17 -.47 -.04  .03 -.08 -.04  .06  .06 -.02  .09
  ST.E.      .09  .09  .09  .09  .11  .11  .11  .11  .11  .11  .11  .11
   Q        3.90 4.00 7.90 38.0 38.1 38.3 39.1 39.3 39.8 40.2 40.3 41.5

 13- 24      .05 -.12  .10 -.01 -.13  .05 -.11 -.07  .16  0.0  .03 -.01
  ST.E.      .11  .11  .11  .11  .11  .11  .11  .12  .12  .12  .12  .12
   Q        41.8 43.8 45.4 45.4 47.9 48.3 50.1 50.9 54.9 54.9 55.0 55.0

 25- 36      0.0  .03  0.0  .03  .02 -.15  .10 -.02 -.07  .11 -.15  .10
  ST.E.      .12  .12  .12  .12  .12  .12  .12  .12  .12  .12  .12  .12
   Q        55.0 55.1 55.1 55.3 55.3 59.0 60.7 60.7 61.6 64.0 67.9 69.7

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
            +----+----+----+----+----+----+----+----+----+----+
                                     I
  1  -0.171                      XXXXI   +
  2  -0.021                      +   I   +
  3   0.171                      +   IXXXX
  4  -0.470              XXXXXXX+XXXXI    +
  5  -0.036                     +    I    +
  6   0.032                     +    IX   +
  7  -0.076                     +  XXI    +
  8  -0.044                     +    I    +
  9   0.056                     +    IX   +
 10   0.056                     +    IX   +
 11  -0.017                     +    I    +
 12   0.091                     +    IXX  +
 13   0.045                     +    IX   +
 14  -0.117                     + XXXI    +
 15   0.103                    +     IXXX  +
 16  -0.009                    +     I     +
 17  -0.129                    +  XXXI     +
 18   0.046                    +     IX    +
 19  -0.109                    +  XXXI     +
 20  -0.071                    +   XXI     +
 21   0.159                    +     IXXXX +
 22   0.005                    +     I     +
 23   0.027                    +     IX    +
 24  -0.011                    +     I     +
 25   0.001                    +     I     +
 26   0.026                    +     IX    +
 27  -0.001                    +     I     +
 28   0.033                    +     IX    +
 29   0.016                    +     I     +
 30  -0.145                    + XXXXI     +
 31   0.099                    +     IXX   +
 32  -0.019                    +     I     +
 33  -0.071                    +   XXI     +
 34   0.114                    +     IXXX  +
 35  -0.148                    + XXXXI     +
 36   0.099                    +     IXX   +
```

```
..PACF VARI=DP.DFORDERS ARE 1,4./

PARTIAL AUTOCORRELATIONS

  1- 12     -.17 -.05  .16 -.44 -.20 -.05  .05 -.31 -.16  .04  .02 -.14
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24     -.04 -.05  .10 -.02 -.12 -.09 -.06 -.09  .04 -.03 -.06 -.19
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36      .04  .09 -.02 -.17  .14 -.06  .07 -.08  .04 -.02 -.08  .08
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

           -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
             +----+----+----+----+----+----+----+----+----+----+
                                      I
  1  -0.171                       XXXXI   +
  2  -0.052                       +   I   +
  3   0.164                       +   IXXXX
  4  -0.438                XXXXXXX+XXXI   +
  5  -0.197                      X+XXXI   +
  6  -0.054                       +   I   +
  7   0.048                       +   IX  +
  8  -0.314                   XXXX+XXXI   +
  9  -0.158                       XXXXI   +
 10   0.043                       +   IX  +
 11   0.016                       +   I   +
 12  -0.143                       XXXXI   +
 13  -0.037                       +   I   +
 14  -0.054                       +   I   +
 15   0.098                       +   IXX +
 16  -0.019                       +   I   +
 17  -0.117                       +XXXI   +
 18  -0.092                       + XXI   +
 19  -0.059                       +   I   +
 20  -0.091                       + XXI   +
 21   0.037                       +   IX  +
 22  -0.034                       +   I   +
 23  -0.057                       +   I   +
 24  -0.193                      X+XXXI   +
 25   0.037                       +   IX  +
 26   0.088                       +   IXX +
 27  -0.015                       +   I   +
 28  -0.166                       XXXXI   +
 29   0.135                       +   IXXX+
 30  -0.055                       +   I   +
 31   0.074                       +   IXX +
 32  -0.078                       + XXI   +
 33   0.042                       +   IX  +
 34  -0.021                       +   I   +
 35  -0.081                       + XXI   +
 36   0.075                       +   IXX +
```

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
DP	RANDOM		1- 135	$(1-B^{1})(1-B^{4})$

NUMBER	VARIABLE	TYPE	FACTOR	ORDER	VALUE	ST. ERR.	T-RATIO
1	DP	MA	1	1	0.2700	0.0846	3.19
2	DP	MA	2	4	0.8327	0.0462	18.02

RESIDUAL SUM OF SQUARES = 0.761219E-01 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 128
RESIDUAL MEAN SQUARE = 0.594702E-03
--

```
..ACF VARI=RESID./

AUTOCORRELATIONS

  1- 12     0.0  -.01 -.01 -.04 -.18 -.08 -.16 -.04  .01 -.02 -.02  .13
  ST.E.     .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09
   Q       0.00 0.00 0.00 .300 4.80 5.60 9.30 9.50 9.50 9.50 9.60 12.0

 13- 24     .06 -.15  .02  .01 -.03 -.08 -.11 -.08  .20  .01  .01 -.01
  ST.E.     .09  .09  .09  .09  .09  .09  .10  .10  .10  .10  .10  .10
   Q       12.5 15.8 15.8 15.8 16.0 17.0 18.9 19.9 26.6 26.6 26.6 26.6

 25- 36     .14 -.02  .05  .03  .02 -.13  .04  .03 -.04  .03 -.09  .05
  ST.E.     .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
   Q       29.8 29.9 30.4 30.5 30.6 33.4 33.7 33.8 34.1 34.3 35.7 36.1

              -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
                +----+----+----+----+----+----+----+----+----+----+
                                         I
 1   0.005                           +   I   +
 2  -0.008                           +   I   +
 3  -0.010                           +   I   +
 4  -0.042                           +   I   +
 5  -0.178                           XXXXI   +
 6  -0.076                           + XXI   +
 7  -0.159                           XXXXI   +
 8  -0.037                           +   I   +
 9   0.011                           +   I   +
10  -0.018                           +   I   +
11  -0.021                           +   I   +
12   0.127                           +   IXXX+
13   0.059                          +    IX   +
14  -0.145                          +XXXXI    +
15   0.016                          +    I    +
16   0.011                          +    I    +
17  -0.031                          +    I    +
18  -0.081                          +  XXI    +
19  -0.110                          + XXXI    +
20  -0.076                          +  XXI    +
21   0.203                          +    IXXXXX
22   0.007                          +    I    +
23   0.008                          +    I    +
24  -0.015                          +    I    +
25   0.136                          +    IXXX +
26  -0.025                          +    I    +
27   0.054                          +    IX   +
28   0.031                          +    IX   +
29   0.021                          +    IX   +
30  -0.125                          + XXXI    +
31   0.040                          +    IX   +
32   0.028                          +    IX   +
33  -0.043                          +    I    +
34   0.028                          +    IX   +
35  -0.087                          +  XXI    +
36   0.048                          +    IX   +
```

```
..PACF VARI=RESID./

PARTIAL AUTOCORRELATIONS

  1- 12      0.0 -.01 -.01 -.04 -.18 -.08 -.17 -.06 -.02 -.07 -.08  .05
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24      .02 -.19 -.03 -.02 -.04 -.11 -.18 -.14  .12 -.04 -.06 -.15
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36      .03 -.01  .03  .01  0.0 -.12  .07  .10 -.10  0.0 -.04  .10
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
            +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   0.005                     +    I    +
  2  -0.008                     +    I    +
  3  -0.010                     +    I    +
  4  -0.042                     +    I    +
  5  -0.179                     XXXXI    +
  6  -0.079                     + XXI    +
  7  -0.171                     XXXXI    +
  8  -0.056                     +    I    +
  9  -0.019                     +    I    +
 10  -0.072                     + XXI    +
 11  -0.076                     + XXI    +
 12   0.051                     +    IX   +
 13   0.015                     +    I    +
 14  -0.194                    X+XXXI    +
 15  -0.029                     +    I    +
 16  -0.021                     +    I    +
 17  -0.036                     +    I    +
 18  -0.109                     +XXXI    +
 19  -0.175                     XXXXI    +
 20  -0.138                     +XXXI    +
 21   0.124                     +    IXXX+
 22  -0.042                     +    I    +
 23  -0.062                     + XXI    +
 24  -0.147                     XXXXI    +
 25   0.035                     +    IX   +
 26  -0.010                     +    I    +
 27   0.035                     +    IX   +
 28   0.011                     +    I    +
 29  -0.003                     +    I    +
 30  -0.120                     +XXXI    +
 31   0.069                     +    IXX  +
 32   0.102                     +    IXXX+
 33  -0.099                     + XXI    +
 34  -0.005                     +    I    +
 35  -0.045                     +    I    +
 36   0.101                     +    IXXX+
```

VARIABLE = GNE NUMBER OF CASES = 135

7450.000	9269.000	7918.000	7245.000	7860.000	10238.000
8419.000	7833.000	8428.000	10921.000	8268.000	7949.000
8945.000	12267.000	9456.000	8763.000	9543.000	12524.000
9775.000	8814.000	9623.000	11650.000	10019.000	9235.000
10346.000	13377.000	10933.000	10562.000	11424.000	13574.000
12039.000	11145.000	11851.000	13640.000	12082.000	11105.000
12043.000	14001.000	12695.000	11685.000	12511.000	14445.000
13096.000	12311.000	12706.000	14862.000	13352.000	12278.000
13374.000	14948.000	14141.000	13323.000	14017.000	16296.000
14839.000	13823.000	14712.000	17134.000	15818.000	15023.000
15930.000	17923.000	16734.000	15909.000	16971.000	19100.000
18001.000	17195.000	18319.000	20513.000	18817.000	17860.000
19116.000	20812.000	19556.000	18543.000	20043.000	22176.000
21102.000	19896.000	21133.000	23186.000	22010.000	20526.000
21875.000	23582.000	22407.000	21428.000	23178.000	25376.000
24468.000	22946.000	24907.000	26323.000	26072.000	24917.000
26581.000	28170.000	28144.000	26430.000	27831.000	28926.000
28491.000	26298.000	27913.000	29760.000	29034.000	27801.000
29640.000	31361.000	30314.000	28414.000	30130.000	32053.000
31352.000	29306.000	31085.000	33354.000	32382.000	30801.000
31887.000	34021.000	33117.000	31327.000	32375.000	34416.000
33557.000	32108.000	33883.000	36110.000	34103.000	31170.000
32256.000	34458.000	32185.000			

VARIABLE IS GNE

AUTOCORRELATIONS

1- 12	.97	.94	.93	.93	.89	.86	.85	.85	.81	.78	.77	.76
ST.E.	.09	.15	.19	.22	.24	.27	.29	.31	.32	.34	.35	.36
Q	129.	251.	373.	495.	608.	715.	820.	924.	1021	1111	1199	1287
13- 24	.73	.70	.69	.68	.64	.61	.60	.59	.56	.52	.51	.50
ST.E.	.37	.38	.39	.40	.41	.42	.43	.43	.44	.44	.45	.45
Q	1367	1441	1513	1585	1649	1708	1765	1822	1872	1916	1960	2002
25- 36	.47	.44	.42	.42	.38	.35	.34	.33	.30	.27	.26	.25
ST.E.	.46	.46	.46	.46	.47	.47	.47	.47	.48	.48	.48	.48
Q	2038	2071	2101	2131	2157	2179	2199	2219	2236	2249	2261	2272

```
            -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
             +----+----+----+----+----+----+----+----+----+----+
                                      I
  1   0.967                      +   IXXX+XXXXXXXXXXXXXXXXXXXX
  2   0.936                   +      IXXXXXX+XXXXXXXXXXXXXXXX
  3   0.932                 +        IXXXXXXXX+XXXXXXXXXXXXXX
  4   0.930               +          IXXXXXXXXXX+XXXXXXXXXXXX
  5   0.894              +           IXXXXXXXXXXX+XXXXXXXXXX
  6   0.860             +            IXXXXXXXXXXXX+XXXXXXXXX
  7   0.852            +             IXXXXXXXXXXXXX+XXXXXXX
  8   0.848           +              IXXXXXXXXXXXXXX+XXXXXX
  9   0.811          +               IXXXXXXXXXXXXXXX+XXXX
 10   0.779         +                IXXXXXXXXXXXXXXXX+XX
 11   0.770         +                IXXXXXXXXXXXXXXXX+XX
 12   0.764        +                 IXXXXXXXXXXXXXXXXX+X
 13   0.727        +                 IXXXXXXXXXXXXXXXXXX
 14   0.695       +                  IXXXXXXXXXXXXXXXXX +
 15   0.685       +                  IXXXXXXXXXXXXXXXXX +
 16   0.678      +                   IXXXXXXXXXXXXXXXXX  +
 17   0.642      +                   IXXXXXXXXXXXXXXXX   +
 18   0.610     +                    IXXXXXXXXXXXXXXX     +
 19   0.599     +                    IXXXXXXXXXXXXXXX     +
 20   0.591     +                    IXXXXXXXXXXXXXXX     +
 21   0.556     +                    IXXXXXXXXXXXXXX      +
 22   0.522    +                     IXXXXXXXXXXXXX        +
 23   0.511    +                     IXXXXXXXXXXXXX        +
 24   0.502    +                     IXXXXXXXXXXXXX        +
 25   0.468    +                     IXXXXXXXXXXXX         +
 26   0.436    +                     IXXXXXXXXXXX          +
 27   0.424   +                      IXXXXXXXXXXX           +
 28   0.415   +                      IXXXXXXXXXX            +
 29   0.383   +                      IXXXXXXXXXX            +
 30   0.352   +                      IXXXXXXXXX             +
 31   0.341   +                      IXXXXXXXXX             +
 32   0.333   +                      IXXXXXXXX              +
 33   0.300   +                      IXXXXXXXX              +
 34   0.269   +                      IXXXXXXX               +
 35   0.257   +                      IXXXXXX                +
 36   0.246   +                      IXXXXXX                +
```

```
..PACF VARI=GNE./

PARTIAL AUTOCORRELATIONS

  1- 12      .97  .02  .40  .08 -.44  .04  .12  .06 -.22  .07  .03  .03
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24     -.16  .05  .02  .02 -.11  0.0  .02  .02 -.08 -.04  .04  0.0
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36     -.04  0.0 -.02  .02 -.03 -.02  .02 -.02 -.06 -.02 -.02 -.02
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09


           -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
             +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    0.967                     +   IXXX+XXXXXXXXXXXXXXXXXXXX
  2    0.018                     +   I   +
  3    0.396                     +   IXXX+XXXXXX
  4    0.083                     +   IXX +
  5   -0.441              XXXXXXX+XXXI   +
  6    0.043                     +   IX  +
  7    0.120                     +   IXXX+
  8    0.059                     +   IX  +
  9   -0.221                   XX+XXXI   +
 10    0.067                     +   IXX +
 11    0.031                     +   IX  +
 12    0.027                     +   IX  +
 13   -0.162                     XXXXI   +
 14    0.047                     +   IX  +
 15    0.021                     +   IX  +
 16    0.021                     +   IX  +
 17   -0.107                     +XXXI   +
 18   -0.001                     +   I   +
 19    0.017                     +   I   +
 20    0.018                     +   I   +
 21   -0.084                     +  XXI  +
 22   -0.039                     +   I   +
 23    0.036                     +   IX  +
 24    0.001                     +   I   +
 25   -0.037                     +   I   +
 26    0.000                     +   I   +
 27   -0.021                     +   I   +
 28    0.021                     +   IX  +
 29   -0.031                     +   I   +
 30   -0.022                     +   I   +
 31    0.023                     +   IX  +
 32   -0.020                     +   I   +
 33   -0.055                     +   I   +
 34   -0.024                     +   I   +
 35   -0.021                     +   I   +
 36   -0.020                     +   I   +
```

```
..ACF VARI=GNE.DFORDERS ARE 1,4./

AUTOCORRELATIONS

  1- 12     -.07  .08 -.01 -.35  .04 -.15 -.05  .01  .01  .15  .07  .07
  ST.E.      .09  .09  .09  .09  .10  .10  .10  .10  .10  .10  .10  .10
   Q        .700 1.50 1.50 18.2 18.4 21.4 21.8 21.8 21.8 24.9 25.6 26.3

 13- 24     -.02 -.05 -.03 -.09 -.10  .11  0.0  .11  .13 -.15  .10 -.17
  ST.E.      .10  .10  .10  .10  .10  .10  .11  .11  .11  .11  .11  .11
   Q        26.3 26.7 26.9 28.0 29.4 31.1 31.1 33.0 35.7 39.5 41.2 45.9

 25- 36     -.05  0.0 -.12  .10  .06  .09  .10 -.01 -.01 -.06 -.04 -.07
  ST.E.      .11  .11  .11  .11  .11  .11  .11  .12  .12  .12  .12  .12
   Q        46.3 46.3 48.6 50.2 50.9 52.2 54.0 54.1 54.1 54.7 54.9 55.9

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
            +----+----+----+----+----+----+----+----+----+----+
                                     I
  1  -0.073                       + XXI   +
  2   0.076                       +   IXX +
  3  -0.010                       +   I   +
  4  -0.350                  XXXXX+XXXI   +
  5   0.041                      +    IX   +
  6  -0.146                      +XXXXI    +
  7  -0.053                      +    I    +
  8   0.006                      +    I    +
  9   0.014                      +    I    +
 10   0.147                      +    IXXXX+
 11   0.069                      +    IXX  +
 12   0.070                      +    IXX  +
 13  -0.022                      +    I    +
 14  -0.048                      +    I    +
 15  -0.033                      +    I    +
 16  -0.087                      +  XXI    +
 17  -0.096                      +  XXI    +
 18   0.105                      +    IXXX +
 19   0.005                      +    I    +
 20   0.110                      +    IXXX +
 21   0.132                      +    IXXX +
 22  -0.154                      +XXXXI    +
 23   0.102                      +    IXXX +
 24  -0.170                      +XXXXI    +
 25  -0.053                      +    I    +
 26   0.004                      +    I    +
 27  -0.118                      + XXXI    +
 28   0.098                     +     IXX   +
 29   0.060                     +     IXX   +
 30   0.088                     +     IXX   +
 31   0.103                     +     IXXX  +
 32  -0.012                     +     I     +
 33  -0.006                     +     I     +
 34  -0.057                     +     I     +
 35  -0.039                     +     I     +
 36  -0.072                     +   XXI     +
```

```
..PACF VARI=GNE.DFORDERS ARE 1,4./

PARTIAL AUTOCORRELATIONS

  1- 12   -.07  .07  0.0 -.36 -.01 -.10 -.10 -.13  .02  .08  .03  .02
 ST.E.     .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24   -.01  .01  0.0 -.04 -.11  .14  .03  .04  .08 -.10  .07 -.10
 ST.E.     .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36   -.02 -.04 -.02 -.01  .07  .03  .04  .01  0.0  .03  .03 -.03
 ST.E.     .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

          -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
            +----+----+----+----+----+----+----+----+----+----+
                                     I
  1  -0.073                      + XXI   +
  2   0.071                      +   IXX +
  3  -0.000                      +   I   +
  4  -0.360                 XXXXX+XXXI   +
  5  -0.007                      +   I   +
  6  -0.096                      + XXI   +
  7  -0.099                      + XXI   +
  8  -0.130                      +XXXI   +
  9   0.020                      +   I   +
 10   0.077                      +   IXX +
 11   0.034                      +   IX  +
 12   0.020                      +   I   +
 13  -0.012                      +   I   +
 14   0.010                      +   I   +
 15   0.005                      +   I   +
 16  -0.039                      +   I   +
 17  -0.112                      +XXXI   +
 18   0.135                      +   IXXX+
 19   0.034                      +   IX  +
 20   0.041                      +   IX  +
 21   0.080                      +   IXX +
 22  -0.105                      +XXXI   +
 23   0.067                      +   IXX +
 24  -0.101                      +XXXI   +
 25  -0.016                      +   I   +
 26  -0.044                      +   I   +
 27  -0.019                      +   I   +
 28  -0.013                      +   I   +
 29   0.067                      +   IXX +
 30   0.025                      +   IX  +
 31   0.042                      +   IX  +
 32   0.012                      +   I   +
 33   0.002                      +   I   +
 34   0.025                      +   IX  +
 35   0.031                      +   IX  +
 36  -0.025                      +   I   +
```

SUMMARY OF THE MODEL

OUTPUT VARIABLE -- GNE

SUMMARY OF THE MODEL

OUTPUT VARIABLE -- GNE
INPUT VARIABLES -- NOISE

VARIABLE	VAR. TYPE	MEAN	TIME	DIFFERENCES
GNE	RANDOM		1- 135	$(1-B^{1})(1-B^{4})$

NUMBER	VARIABLE	TYPE	FACTOR	ORDER	VALUE	ST. ERR.	T-RATIO
1	GNE	MA	1	1	0.1045	0.0896	1.17
2	GNE	AR	1	4	-0.4178	0.0873	-4.79

RESIDUAL SUM OF SQUARES = 0.210993E+08 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM = 124
RESIDUAL MEAN SQUARE = 0.170156E+06

VARIABLE IS RESID

AUTOCORRELATIONS

1- 12	-.01	.05	-.09	-.07	-.04	-.11	-.04	-.13	.04	.12	.06	.04
ST.E.	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
Q	0.00	.400	1.40	2.00	2.20	4.00	4.30	6.90	7.20	9.20	9.80	10.1
13- 24	-.06	.05	-.03	-.03	-.08	.05	.05	.04	.09	-.13	.06	-.14
ST.E.	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.10	.10
Q	10.7	11.0	11.2	11.3	12.4	12.8	13.2	13.5	15.0	17.8	18.4	21.5
25- 36	-.01	-.04	-.05	.09	.06	.13	.09	-.01	-.01	-.02	.03	-.11
ST.E.	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Q	21.5	21.7	22.1	23.4	24.1	27.0	28.3	28.3	28.3	28.4	28.6	30.6

```
              -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
                +----+----+----+----+----+----+----+----+----+----+
                                         I
  1  -0.006                          +   I   +
  2   0.052                          +   IX  +
  3  -0.085                          + XXI   +
  4  -0.066                          + XXI   +
  5  -0.035                          +   I   +
  6  -0.112                          +XXXI   +
  7  -0.045                          +   I   +
  8  -0.133                          +XXXI   +
  9   0.045                          +   IX  +
 10   0.118                          +   IXXX+
 11   0.064                          +   IXX +
 12   0.042                          +   IX  +
 13  -0.061                         +  XXI    +
 14   0.047                         +    IX   +
 15  -0.033                         +    I    +
 16  -0.030                         +    I    +
 17  -0.082                         +  XXI    +
 18   0.054                         +    IX   +
 19   0.049                         +    IX   +
 20   0.040                         +    IX   +
 21   0.095                         +    IXX  +
 22  -0.132                         + XXXI    +
 23   0.057                         +    IX   +
 24  -0.137                         + XXXI    +
 25  -0.008                         +    I    +
 26  -0.037                         +    I    +
 27  -0.049                         +    I    +
 28   0.086                         +    IXX  +
 29   0.062                         +    IXX  +
 30   0.127                         +    IXXX +
 31   0.086                         +    IXX  +
 32  -0.010                         +    I    +
 33  -0.012                         +    I    +
 34  -0.024                         +    I    +
 35   0.028                         +    IX   +
 36  -0.105                         + XXXI    +
```

```
..PACF VARI=RESID./

VARIABLE      IS    RESID

PARTIAL AUTOCORRELATIONS

  1- 12     -.01  .05 -.08 -.07 -.03 -.11 -.06 -.14  .02  .11  .03  .01
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 13- 24     -.06  .04 -.01 -.03 -.06  .10  .05  .01  .07 -.13  .05 -.12
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

 25- 36     -.03  .01 -.02  .06  .06  .05  .10 -.03 -.01  .05  .06 -.03
  ST.E.      .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09  .09

           -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
             +----+----+----+----+----+----+----+----+----+----+
                                      I
  1  -0.006                      +    I   +
  2   0.052                      +    IX  +
  3  -0.085                      +  XXI   +
  4  -0.070                      +  XXI   +
  5  -0.028                      +    I   +
  6  -0.114                      +XXXI    +
  7  -0.057                      +    I   +
  8  -0.138                      +XXXI    +
  9   0.020                      +    I   +
 10   0.109                      +    IXXX+
 11   0.029                      +    IX  +
 12   0.008                      +    I   +
 13  -0.062                      +  XXI   +
 14   0.039                      +    IX  +
 15  -0.014                      +    I   +
 16  -0.033                      +    I   +
 17  -0.055                      +    I   +
 18   0.096                      +    IXX +
 19   0.054                      +    IX  +
 20   0.014                      +    I   +
 21   0.070                      +    IXX +
 22  -0.128                      +XXXI    +
 23   0.054                      +    IX  +
 24  -0.121                      +XXXI    +
 25  -0.026                      +    I   +
 26   0.008                      +    I   +
 27  -0.022                      +    I   +
 28   0.060                      +    IXX +
 29   0.061                      +    IXX +
 30   0.048                      +    IX  +
 31   0.097                      +    IXX +
 32  -0.027                      +    I   +
 33  -0.012                      +    I   +
 34   0.052                      +    IX  +
 35   0.057                      +    IX  +
```

Appendix 5B

In this appendix we report the calculations required in the derivation of demand/supply shock components of unanticipated inflation. We furthermore present the computer algorithm for this procedure using TROLL command language. For notational convenience we use the expression "P13" to refer to the weighted mean Z score pertaining to quadrants Q1 and Q3. Similarly, "Y13" refers to the weighted mean Z score for income in quadrants Q1 and Q3. Similar notation describes the weighted mean Z scores in income and inflation for quadrants Q2 and Q4. The rationale for taking weighted means is described in the discussion around equations (34) to (37) of the text. Further notational simplification entails writing the Z(p) and Z(y) scores in quadrant Q1 as q1p and q1y, quadrant Q2 as q2p andq2y, and so on. Recall also that all observations have an implicit time subscript. This is omitted for notational convenience.

We first write the equations for demand/supply shock identifying vectors pertaining to quadrant Q1. Note that for the demand shock equation, the intercept is zero by construction since this ray emanates from the origin.

$$(1)\quad q1p = 0 + \frac{p13}{y13} . q1y \qquad \text{(demand Shock)}$$

$$(2)\quad q1p = a1 - \frac{p24}{y24}.q1y \qquad \text{(supply shock)}$$

Equation (2) can be re-expressed in terms of a1 to yield:

$$(2a)\quad a1 = q1p + \frac{p24}{y24}.q1y$$

This yields the vector of values for the intercept when the appropriate vectors for q1p and q1y are plugged into the expression. In order to solve for the intersection of the two vectors, (1) and (2) are solved simultaneously, and (2a) is substituted into the solution to yield the equilibrium values of the vector "q1pe". This is written as:

$$(4)\quad q1pe = \left(q1p + \frac{p24}{y24}.q1y\right).\frac{y24}{p24}.\left(\frac{y13}{p13} + \frac{y24}{p24}\right)^{-1}$$

Similar expressions, using the values pertaining to quadrant Q2, can be written for the identifying vectors in this quadrant. Note that by construction, the supply shock vector has an intercept of zero.

$$(5)\quad q2p = 0 - \frac{p24}{y24}.q2y \quad \text{(supply shock)}$$

$$(6)\quad q2p = a2 + \frac{p13}{y13}.q2y \quad \text{(demand Shock)}$$

$$(6a)\quad a2 = q2p - \frac{p13}{y13}.q2y$$

Using the same procedure to solve the equations yields:

$$(7)\quad q2pe = -\left(q2p - \frac{p13}{y13}.q2y\right).\frac{y13}{p13}.\left(\frac{y13}{p13} + \frac{y24}{p24}\right)^{-1}$$

For quadrant three the equations can be written:

$$(8)\quad q3p = 0 + \frac{p13}{y13}.q2y \quad \text{(demand shock)}$$

$$(9)\quad q3p = a3 - \frac{p24}{y24}.q3y \quad \text{(supply shock)}$$

(9a) $a3 = q3p + \frac{p24}{y24} .q3y$

The solution is expressed as:

(10) $q3pe = (\frac{p24}{y24}.q3y + q3p).\frac{y24}{p24}.(\frac{y13}{p13} + \frac{y24}{p24})^{-1}$

The equations for quadrant 4 are written as:

(11) $q4p = 0 - \frac{p34}{y24} .q4y$. (supply shock)

(12) $q4p = a4 + \frac{p13}{y13} .q4y$ (demand shock)

(12a) $a4 = q4p - \frac{p13}{y13} .q4y$

The solution is expressed as:

$$(13)\quad q4pe = \left(q4p - \frac{p13}{y13} . q4y\right) . \frac{y13}{p13} . \left(\frac{y13}{p13} + \frac{y24}{p24}\right)^{-1}$$

Appendix 5C

The computer program used in the solution of these equations and in the data processing is shown below.

```
r *troll
period 4;
dorange 1949 2 to 1982 4;
do zpy=dpz*gnez;
do pq1q3=(if zpy gt 0 then dpz else 0);
do yq1q3=(if zpy gt 0 then gnez else 0);
do pq2q4=(if zpy lt 0 then dpz else 0);
do yq2q4=(if zpy lt 0 then gnez else 0);
do q1p=(if pq1q3 gt 0 then dpz else 0);
do q3p=(if pq1q3 lt 0 then dpz else 0);
do q2p=(if pq2q4 lt 0 then dpz else 0);
do q4p=(if pq2q4 gt 0 then dpz else 0);
do q1y=(if yq1q3 gt 0 then gnez else 0);
do q3y=(if yq1q3 lt 0 then gnez else 0);
do q2y=(if yq2q4 gt 0 then gnez else 0);
do q4y=(if yq2q4 lt 0 then gnez else 0);
do tq1p=total(q1p);
do tq1y=total(q1y);
do tq2p=total(q2p)*-1;
do tq2y=total(q2y);
do tq3p=total(q3p)*-1;
do tq3y=total(q3y)*-1;
do tq4p=total(q4p);
do tq4y=total(q4y)*-1;
do n1=total(if q1y ne 0 then 1 else 0);
do n2=total(if q2y ne 0 then 1 else 0);
do n3=total(if q3y ne 0 then 1 else 0);
do n4=total(if q4y ne 0 then 1 else 0);
prtdata n1 n2 n3 n4;
do mq1p=tq1p/n1;
do mq1y=tq1y/n1;
do mq2p=tq2p/n2;
do mq2y=tq2y/n2;
do mq3p=tq3p/n3;
do mq3y=tq3y/n3;
do mq4p=tq4p/n4;
do mq4y=tq4y/n4;
```

```
do y13=(n1*mq1y+n3*mq3y)/(n1+n3);
do p13=(n1*mq1p+n3*mq3p)/(n1+n3);
do y24=(n2*mq2y+n4*mq4y)/(n2+n4);
do p24=(n2*mq2p+n4*mq4p)/(n2+n4);
do a1=q1p+(p24/y24)*q1y;
do q1pe=a1*(y24/p24)*(y13/p13+y24/p24)**-1;
do a2=q2p-(p13/y13)*q2y;
do q2pe=-a2*(y13/p13)*(y13/p13+y24/p24)**-1;
do a3=q3p+(p24/y24)*q3y;
do q3pe=a3*(y24/p24)*(y13/p13+y24/p24)**-1;
do a4=q4p-(p13/y13)*q4y;
do q4pe=a4*(y13/p13)*(y13/p13+y24/p24)**-1;
do ssq1=q1p-q1pe;
do dsq1=q1pe;
do ssq2=q2pe;
do dsq2=q2p-q2pe;
do ssq3=q3p-q3pe;
do dsq3=q3pe;
do ssq4=q4pe;
do dsq4=q4p-q4pe;
do dsdpz=dsq1+dsq2+dsq3+dsq4;
do ssdpz=ssq1+ssq2+ssq3+ssq4;
do dsdp=dsdpz*dpstd;
do ssdp=ssdpz*dpstd;
prtdata dsdp ssdp;
mts
```

Appendix 5D

In this appendix we report the data derived from running the computer algorithm. The data are read vertically, and begins with 1949Q2.

Demand Shock $\frac{u}{\phi + \psi}$	Supply Shock $\frac{-a}{\phi + \psi}$
-0.008097	0.003097
0.003151	0.015849
-0.016623	0.008623
-0.00341	-0.00259
0.018702	0.022298
0.023882	-0.004882
0.013053	0.035947
0.020657	0.019343
0.001786	0.004214
-0.08666	0.03666
-0.050773	0.011773
-0.113778	0.042779
-0.134239	0.054239
-0.030942	0.029942
-0.011165	0.015165
0.000956	0.021044
-0.005984	-0.001016
0.019392	0.020608
-0.005499	-0.005501
-0.016504	0.010504
0.003931	0.011069
-0.034441	0.036441
-0.070693	0.045693
0.01088	0.00012
0.012084	-0.009084
-0.041652	0.027652
-0.002588	0.015588
0.018049	-0.011049
0.006374	0.011626
-0.003318	0.027318
-0.021177	0.018177

-0.014828	0.003828
-0.007843	0.010843
-0.029159	0.019159
-0.031557	0.016557
0.001034	0.018966
0.014657	0.006343
-0.109959	0.037959
0.021018	0.005982
-0.006702	-0.004298
-0.004521	-0.003479
0.004836	0.002164
0.019196	0.015804
-0.070511	0.028511
-0.009188	0.020188
-0.021896	0.010896
0.01237	0.02363
-0.016036	-0.002964
-0.034103	0.022103
-0.021775	0.005775
0.020818	-0.016818
0.022381	0.010619
-0.001371	0.004371
-0.023551	0.017551
-0.017191	0.002191
0.009699	0.018301
-0.023144	0.008144
0.018911	-0.008911
-0.01635	-0.01165
0.019246	0.011754
-0.005126	0.004126
-0.018253	0.004253
-0.039541	0.016541
0.025393	0.021607
0.007407	-0.003407
-0.008607	-0.007393
-0.018104	0.009104
0.022118	0.021882
-0.0132	0.0072
-0.036093	0.015093
-0.026208	0.008208
-0.00445	0.00845
0.018512	0.010488
-0.010213	0.019213
-0.071128	0.027128
0.012751	0.020249
-0.028883	0.015883
-0.017363	0.011363
0.014513	-0.010513
0.	0.
0.010344	0.022656
-0.040496	0.015496
-0.009322	-0.008678
-0.006165	0.017165

-0.007959	-0.006041
-0.02346	0.00046
-0.011871	-0.007129
0.023371	-0.000371
0.029236	-0.001236
0.018558	-0.006558
-0.026521	0.015521
-0.003738	0.015738
-0.047406	0.023406
0.000256	0.035744
-0.03487	0.02687
0.017585	0.004415
0.000861	0.013139
-0.01577	-0.00523
0.023676	-0.006676
-0.003567	0.019567
-0.001383	0.026383
-0.017829	0.011829
-0.008709	0.014709
-0.039595	0.007595
-0.04015	0.01415
0.037027	0.002973
-0.026092	-0.000908
-0.087994	0.044994
-0.036625	0.020625
-0.031518	0.015518
-0.004128	0.023128
0.005687	0.026313
0.001434	0.005566
-0.028773	0.012773
0.015539	0.001461
-0.019642	0.005642
0.002442	0.004558
0.	0.
-0.018697	-0.014303
0.029215	0.004785
-0.01756	0.02256
-0.015919	-0.013081
0.010063	0.013937
-0.002105	-0.000895
-0.007615	0.013615
-0.001981	0.009981
0.010504	0.007496
0.013167	-0.003167
-0.050837	0.032837
-0.02079	0.01179
-0.041695	0.028695
-0.049524	0.043524
-0.010862	0.023862
-0.018144	-0.018856
-0.032137	0.015137

VI. TESTING FOR CAUSALITY OF RELATIVE PRICE VARIABILITY

6.1 Introduction

In this final Chapter we inquire into the question of "causal ordering" between unanticipated inflation and the variability of relative prices using the technique refined by Sims (1972). Before presenting the exact procedure utilised in testing for statistical exogeneity, we note that that this test has been criticised. The interested reader is referred to Cooley and LeRoy (1982) and references therein for an elaboration of these points. We do however, mention some of the more salient caveats suggested by Sims and others, in as far as they have clear relevance to our purpose.

Regression analysis assumes the direction of causality runs from the "exogenous" right hand side variable(s) in an equation of interest to the "endogenous" left hand side variable. In a study of this nature there is no *a priori* justification, other than the rationalisations presented in the review of Chapter 2, for asserting which variable "belongs" on the right hand side. The technique presented by Sims, which draws on the concept of causality elucidated by Granger (1969), can however, be usefully employed in our inquiry. When cause and effect can be temporally separated, a stochastic stationary process can be examined to see whether "X" causes "Y" or vice versa. To paraphrase Granger (pp 428), the variable X "causes" Y with respect to an information set "I", which includes both Y and X, if and only if the present value of Y is predicted better (has smaller forecast error variance) by using the past values of X than if the past values had not been used.

The application of this definition suggested by Sims in a bi-variate system entails a slightly modified test as follows. To quote Sims (1972):

> If and only if causality runs one way from current and past values of some list of exogenous variables to a given endogenous variable, then in a regression of the endogenous variable on past, current and future values of the exogenous variable, the future values of the exogenous variables should have zero coefficients. (pp 641)

Inquiry into the causal relationship in a bivariate system entails four possible outcomes.

1) Y is caused by X
2) X is caused by Y
3) X and Y are causing each other
4) No causal relationship

In order to test the relationship between Y and X, regress Y on past, current, and leading values of X (i.e. Y=f(X)). If leading values of X are significantly different from zero as a group, we fail to reject the hypothesis that Y causes X, since future values of X are significant in explaining Y. This is a necessary condition in establishing a causal relation. It is necessary, however, to show that X does not cause Y as a sufficient condition for unidirectional causality. This is done by regressing past, present, and future values of X on Y (ie X=f(Y)). This test requires that future values of Y are not significant in explaining X.

6.2 Caveats: pre-filtering the Data

Sims first suggests that the variables being tested for exogeneity be pre-filtered to remove serial correlation. Sims uses a filter of the following form where the transformation is performed on <u>both</u> variables.

$$(1) \quad \ln Y^{*} = (1 - kB)^{2} . \ln Y$$

This yields the transformation.

$$(2) \quad \ln Y^{*} = (\ln Y_{t} - 2K.\ln Y_{t-1} + K^{2}.\ln Y_{t-2})$$

Sims suggests a value for k of 0.75, observing that application of this filter results in most economic time series being transformed to white noise. However Mehra (1978) suggests that the choice of "ad hoc" filter proposed by Sims is not necessarily appropriate, submitting that while a filter of the same general form may be adopted, the value of k should be chosen to eliminate any remaining serial correlation after the regression has been performed.

A subsequent contributions by Feige and Pierce (1979) re-examines the choice of filter adopted by Sims. They note that his results cannot be replicated under some choices of transformation of the variables. They examine cross correlation function "innovations" of money and income, which are the residuals from separate ARIMA models for each of the variables. Unlike Sims, they cannot reject the hypothesis that there is no relationship between money and income. A subsequent contribution (Pierce (1977), rejects the hypothesis that there is a causal relationship between money and income. Elliot (1977) however, confirms Sims result. Noting this apparent contradiction Feige and Pearce catalogue the various procedures that have evolved in the literature. The three procedures commonly reported are:

i) Cross correlation techniques. {Pierce (1977)}

ii) One sided distributed lag. {Granger (1969)}

iii) Two sided distributed lags. {Sims (1972)}

Feige and Pearce apply the three tests to the same data set used by Sims, in order to give an indication of the sensitivity of causal inference to the technique employed. Since iii) is a generalisation of ii), we focus on the differences in the choice of filter used in i) and iii).

The Pearce approach is a test of independence based on the cross correlation function of the univariate innovations in the two time series of interest. The technique presented by Box and Jenkins is utilised to derive an appropriate linear filter for each series separately. The residuals from both time series models (the "innovations") are used to compute the sample cross correlation function. Schwert (1977) suggests that such a procedure "may have low power against plausible alternative hypotheses". That is, it appears to reject the alternate hypothesis of causal ordering in many cases, where *a priori* theory would suggest the opposite. Selection of appropriate ARIMA models can also perhaps be criticised on the grounds that it is somewhat of an art form.

Interestingly, for all other procedures and all filters other than that proposed by Sims, Feige and Pearce find that there is no relation between money and income. Also, an important point which Sims does recognise is that his choice of filter fails to produce white noise residuals in the regressions, and therefore the power of the F tests which support causality are brought into question. It is interesting to note that the objection to the "ad hoc" filter used by Sims is addressed by Feige and Pearce. They use an ARIMA filter which is determined by the data to prewhiten the regressand. They then apply the same filter to the regressor, and find that the regressions according to the Sims technique fail to show evidence of causality.

The sole function of pre-filtering the data is to eliminate serial correlation in the regressions because the F test is invalidated in the presence of serial correlation. However, contradictory results and negative findings appear to contradict the suggestion of a widely held body of theory which suggests sensitivity of results with with respect to the choice of filter. Feige and Pearce state:

> Thus inappropriate filters could give rise to a situation in which the baby has been inadvertently thrown out with the bath water. This phenomonon could explain the failure to reject the absence of causal relationships between economic variables typically believed to be closely related to one another.

This body of evidence suggests that tests for causality may still require further research before not being regarded as ambiguous. However, it also suggests that results which are highly significant should not be taken lightly, if serial correlation in the regressions has been sucessfully removed.

6.3 Further Caveats: Analysis of Causal Relationships

Sims notes that if movement in current or expected future values of one variable affect the expectations of another variable (for example, current movements in money supply growth may affect expected inflation) then the direction of causality may be affected, perhaps reversed. However, he suggests that a uni-directional system would more likley appear to be bi-directional than a bi-directional system appearing uni-directional. [1]

Pierce (1977) suggests that measurement error or added noise, which might be attributed to seasonality, may result in the causality test being invalidated. However when an ARIMA filter is used, seasonality is eliminated since this is part of the information contained in the series used in the construction of the time series predictor. However, the general problem of measurement error is not eliminated. Consider a bivariate system where a test for causality is undertaken. Y(m) and X(m) denote the measured values of the series, and Y(a), X(a) denote the actual or true values of the series. e(y) and e(x) denote the respective measurement errors. This can be written as:

(3)

$$Y_m = Y_a + e_y$$

$$X_m = X_a + e_x$$

Pierce shows that if e(y) is large relative to e(x), then X(m) is likely to appear exogenous in a causality test. This is particularly relevant to this study since the the sole inquiry

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[1] Blanchard (1979) shows however, that when expectations of the future affect current outcomes, causality tests of this nature appear to give misleading results, with the direction of actual causality being diagnosed as entirely reversed. Although Sims (1972) anticipates this criticism, suggesting that a bivariate causal ordering would most likely be diagnosed in these circumstances, Blanchard's evidence suggests that the influence of expectations may be more of a problem than had been thought.

into causality with regard to relative price dispersion and general inflation in the literature (Ashley (1981)), uses an unweighted measure of the standard deviation of relative prices and an unweighted mean rate of change of the CPI. Ashley states:

> There is no reason to think that (..the errors) will be outstandingly large in such cases; in fact standard sampling theory suggests that any contemporaneous relationship between (..the errors) will be weak..

In Chapter 3 we explored the differences between a weighted and unweighted measure of the dispersion of relative prices. It was found that a non-linear relationship exists between these measures. We therefore suggest that the measure adopted by Ashley may invite the possibility of spurious causal ordering between unanticipated inflation and relative price variability, with unanticipated inflation appearing to be exogenous. This may occur if the measurement error of relative price variability is large relative to the measurement error associated with unanticipated inflation.

A third causal variable omitted from the specification which drives both inflation and relative price variability (for example the monetary growth rate) may cause problems in the test procedure, resulting in spurious causal ordering. Sargent (1977) however, counters that one would be more likely to identify a feedback structure than a unidirectional system under such circumstances.

The evidence presented in this section is suggestive of two points. First, Sims test results which identify two way causality may indicate unexplained proceses, either in the form of a third unidentified causal variable, or through the effects of expectational influences. Second, measurement error may lead to faulty test indications of exogeneity.

6.4 Test Procedure

In the review of Chapter 2, we saw that in the Lucas model there was the suggestion that demand shocks may be responsible for heightened relative price variability. We also explored the suggestion that supply shocks are responsible for increased relative price variability. The existence of both explanations suggests that we have no prior expectation of the test that we now conduct, to determine whether there are differential responses in relative price variability according to the source of the shock.

The numerous problems alluded to in the literature with regard to tests of causality suggest that a conservative approach to the test procedure would be desirable. We note that this may however, result in the rejection of the hypothesis of causal ordering when it may exist. The operational simplicity of the procedure proposed by Sims is a desirable characteristic, but we choose to discard the "ad hoc" choice of filter which would appear to also give the appearance of spurious causal ordering. The modification to the Sims test proposed by Feige and Pearce, where the data determines the choice of filter first fitted to the regressand and then applied to to the regressor, is instead adopted. The procedure can be summarised as follows.

P denotes (various measures of) unanticipated inflation and RPV denotes (various measures of) the standard deviation of relative prices as described in Chapter 3. [2]

The regressions take the form:

P = f (RPV; past and present values) (1a)

P = f (RPV; past, present and future values) (1b)

RPV = f (P ; past and present values) (2a)

RPV = f (P ; past, present and future values) (2b)

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[2] Table 6.5 sumarises the appropriate ARIMA filters used in the tests that follow.

The F test is based as follows:

$$F = \frac{(SSE_r - SSE_u)/(q - p)}{SSE_u/(n - q)}$$

SSE_r = Sum of squared residuals in regression 1(b), 2(b).

SSE_u = Sum of squared residuals in regression 1(a), 2(a).

q = Number of parameters in regression 1(b), 2(b).

p = Number of parameters in regression 1(a), 2(a).

n = Number of observations.

Under the null hypothesis that the future coefficients are insignificant from zero as a group, the computed F statistic is compared with the tabled F for the appropriate degrees of freedom.

If the null is rejected, future values of the regressor are significant in explaining the regressand.

[3]

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[3] The notation used in the following Tables is as follows: P = unanticipated inflation, residuals from ARIMA model as described in Chapter 5. SDW = weighted measure of the standard deviation of relative price inflation from Chapter 3. SDU = unweighted measure of standard deviation of relative price inflation . DS = demand shock inflation as derived in Chapter 5. SS = supply

In Table 6.1 the results from Sims test regressions are reported.

Regression set 6.1 tests for temporal precedence between the conventional measure of unanticipated inflation and the weighted measure of the standard deviation of relative price variability.

Set 6.2 tests unanticipated inflation and the unweighted measure of relative price variability.

In set 6.3 demand shock inflation and the weighted measure of relative price variability is tested.

Finally, in set 6.4 temporal precedence between supply shock inflation and weighted relative price variability is examined.

[3](cont'd) shock inflation.

Table 6.1 Sims Test Regressions

Bounds 1950Q4-1981Q2

REGRESSION	SSE	DW	RSQ	
6.1				
P=f(SDW; past and present)	0.071	1.98	0.024	(1a)
P=f(SDW; past, present and future)	0.067	2.01	0.077	(1b)
SDW=f(P; past and present)	0.004	2.02	0.041	(2a)
SDW=f(P; past, present and future)	0.003	2.00	0.065	(2b)
6.2				
P=f(SDU; past and present)	0.067	2.08	0.086	(1a)
P=f(SDU; past, present and future)	0.064	2.07	0.018	(1b)
SDU=f(P; past and present)	0.036	1.71	0.045	(2a)
SDU=f(P; past, present and future)	0.033	1.79	0.125	(2b)
6.3				
DS=f(SDW; past and present)	0.097	2.07	0.042	(1a)
DS=f(SDW; past, present and future)	0.092	2.06	0.087	(1b)
SDW=f(DS; past and present)	0.004	2.01	0.036	(2a)
SDW=f(DS; past, present and future)	0.003	2.01	0.070	(2b)
6.4				
SS=f(SDW; past and present)	0.020	1.95	0.108	(1a)
SS=f(SDW; past present and future)	0.019	1.90	0.146	(1b)
SDW=f(SS; past and present)	0.003	2.05	0.056	(2a)
SDW=f(SS; past, present and future)	0.003	2.09	0.138	(2b)

The filters applied in the tests are reported in Table 6.2. Terms in parenthesis denote the order of autoregression, integration and moving average respectively.

Table 6.2 Summary of ARIMA filters used in Causality Tests

Regression	(1a),(1b)	(2a),(2b)
6.1	(0,0,0)	(0,1,1)
6.2	(0,0,0)	(0,1,1)
6.3	(1,1,1)	(0,1,1)
6.4	(1,1,1)	(0,1,1)

(Note in regression sets 6.1 and 6.2 (1a) and (1b), that unanticipated inflation is by definition white noise. Therfore no filter, as exemplified by (0,0,0) is required. A lag structure of six quarters past and six quarters future is used in all regressions.) [4] Table 6.3 shows the F statistics derived from the regressions of Table 6.1. Furthermore, a reminder of the tested causal relation is given.

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[4] Note that the filters must remove as much of the autocorrelation in the regression residuals of the transformed series as possible. The filter does not necessarily have to remove autocorrelation present in the input series themselves. See Pierce and Haugh (1977). If the prefiltering fails to remove positive serial correlation, this may be reflected in the identification of non-existant relationships since F and t statistics and RSQ will be biased upward. Fourth order autoregression of residuals from all regressions fails to reveal coefficients significant from zero. In the DS, SS regressions it may seem surprising that ARIMA filters are used since these series may be expected to be white noise, having been derived from aggregate unanticipated inflation. ARIMA analysis of these series does reveal white noise. However, the residuals derived from the unfiltered regressions are in the indeterminate region of the Durbin-Watson statistic, indicating possible positive serial correlation. These filters remove possible serial correlation. It turns out that the test conclusions are the same regardless of the use of filter.

Table 6.3 Summary of Causality Tests

Regression	Causal Relation	F
P=f(SDW)	P causes SDW	1.044
SDW=f(P)	SDW causes P	5.828**
P=f(SDU)	P causes SDU	0.820
SDU=f(P)	SDU causes P	1.591
DS=f(SDW)	DS causes SDW	0.951
SDW=f(DS)	SDW causes DS	5.828**
SS=f(SDW)	SS causes SDW	0.920
SDW=f(SS)	SDW causes SS	0.000

6.5 Summary of Preliminary Results

The combined results of these tests are quite striking in their consistency.

1) Table 6.3 reveals a unidirectional causal ordering from weighted standard deviation to unanticipated inflation. Future unanticipated inflation adds a significant degree of explanatory power. (The critical F with (6,100) d.f. are 2.19 and 2.99 at 5% and 1% respectively).

2) The way the variability of relative prices is measured does matter for Canadian data. We are unable to establish a causal ordering when an unweighted measure (SDU) of relative price variability is used.

3) A unidirectional causal ordering exists for relative price variability (SDW) on demand shock inflation, but supply shock inflation does not "cause" relative price variability, or vice versa.

6.6 Commentary on Results

It is necessary to evaluate these results in the context of previous empirical studies. We are unable to establish causal ordering when an unweighted measure of relative price variability as used by Ashley in US data is applied to Canadian data. It is not possible to evaluate whether this difference is a result of structural differences between the US and Canada, or whether the measure itself is responsible for the difference. Given the discussion that surrounds Chapter three we suggest, however, that the results from causality and perhaps other tests of the data are sensitive to the technique applied in the measurement of relative price variability.

In examining the relation between the inflation rate (not unanticipated inflation) and relative price variability, Fischer uses Granger causality tests over a number of periods using two measures of relative price variability. Although he concludes that the tests indicate no clear pattern of temporal precedence, the most statistically significant result derived from a battery of tests suggests that for the period 1956Q1-1980Q3, relative price variability does Granger cause inflation (significant at 1%). All other results are either insignificant or bi-directional, with the exception of the second measure of relative price variability that includes food and energy prices. In this case inflation causes relative price variability.

The evidence suggested by Fischer can possibly be explained through the effects of accomodative macroeconomic policy. For example, the effects on real output of disturbances that increase both relative price variability and reduce real income (supply shocks) may be mitigated by accomodative policy which may reduce, offset or overcorrect by producing (demand shock) inflation. A second rationalisation may lie in the unevenness and timing with which aggregate demand impulses are transmitted throughout the economy. The initial "symptom" of an aggregate demand shock may be heightened relative price variability followed by general co-movements in output and inflation. In any event, it is important to realise the limitations of this kind of analysis which assumes a stable relationship between inflation and relative price variability. Fischer succinctly states:

> Because disturbances sometimes originate with policy and occasionally with nonpolicy shocks, and because disturbances may often be microeconomic or macroeconomic, there is not likely to be a single stable relation between relative price variability and the inflation rate, or its absolute value, or any other characteristic of the time series of inflation. The relation will differ depending on the disturbance that predominates in particular periods. pp. 388.

In the introduction to this Chapter it was noted that tests for causality are useful in cases when cause and effect can be temporally separated. A problem occurs with this kind of test when cause and effect occur within the period of interest. Applying the Sims test to this kind of structural relationship will yield "no significant relationship" between the variables being tested.

It does seem surprising for a small open economy such as Canada, that supply shocks according to the Sims test fail to play a temporally causal role in the determination of relative price variability. Dominant commodities such as food and oil prices may, however, both change the inflation rate and cause relative prices to vary within the period, which the Sims test would fail to detect.

In order to investigate further, it is instructive to extend the analysis to examine regressions of demand shock, supply shock, anticipated and unanticipated inflation on the variability of relative prices, as reported in Table 6.4. [5] Note that in equation (1) and (2) the absolute values of various measures of unanticipated inflation signify the assumption of symmetry with regard to the effects on weighted standard deviation. The relaxation of this restriction in equations (3) and (4) does give somewhat weaker results. It is interesting to note that the symmetry restriction appears to make a large difference to the estimated coefficient on aggregate unanticipated inflation (compare (2) with (4)), but is less

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[5] Anticipated inflation P(e) is the forecast from the ARIMA inflation model presented in Chapter 5. Unanticipated inflation P, is the residuals from the model. With regard to to inclusion of anticipated inflation in these regressions, reference is made to Chapter 2, Section 2.3(vi) where the effects of adjustment costs on relative price variability are examined. Recall that adjustment costs associated with changing prices in response to anticipated inflation were submitted as being associated with heightened relative price variability. (Sheshinski and Weiss (1977), Mussa (1977)).

important with regard to the disaggregated measure ((1) and (3)).

Table 6.4 Regressions of SS, DS and P(e) on SDW

Bounds: 1949Q2-1982Q4

	CONST	|DS|	|SS|	P(e)	DW	RSQ	P>F
(1)	0.001 (11.98)**	-0.01 (-0.37)	0.064 (1.15)	0.010 (1.71)	1.94	0.036	0.018
	CONST	|P|		P(e)			
(2)	0.010 (11.38)**	0.0721 (2.26)**		0.018 (1.68)	1.97	0.061	0.015
	CONST	DS	SS	P(e)			
(3)	0.011 (13.81)**	0.020 (0.99)	0.049 (1.21)	0.023 (1.97)*	1.95	0.037	0.017
(4)	CONST	P		P(e)			
	0.011 (15.65)**	0.018 (0.91)		0.026 (2.18)**	1.95	0.036	0.012

Elasticities around means of RHS variables:

		DS	SS	P(e)	P
Equation	(1)	-.017	.075	.037	
	(2)			.066	0.112
	(3)	.019	.046	.084	
	(4)			.095	0.0004

Because many coefficients are statistically indiscernable from zero (although most coefficients are signed as expected) we limit our comments to the realm of speculation, citing this evidence as circumstantial.[6] It is interesting in light of the causality tests, to note that the coefficient on supply shock dominates that on demand shock. However, a clear indication of the relative magnitudes is gained by an examination of the elasticities about the mean values of the independent variables in question, as shown above. Although supply shock elasticity still dominates that of demand shock, it is to be noticed that the value of the coefficient is small. It is also interesting to compare the elasticities for demand and supply shock inflation in (1) with the more conventional but unidentified measure of unanticipated inflation in equation (2).

The prob-values from the regressions, combined with low elasticity estimates, indicate that the regression exercise does not add strong information concerning the relationship between contemporaneous inflation and relative price variability. It is interesting to note however, that Fischer finds that when two measures of relative price variability are used (one of which includes food and energy) that the relationship between relative price variability and inflation breaks down and is in some tests reversed, when the measure that omits food and energy prices is adopted. Thus, although statistically weak, the regressions do parallel Fischer if food and energy prices can reasonably be thought to reflect supply shocks.

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[6] We also warn that this regression makes the assumption that these inflation attributes "cause" relative price variability as noted at the beginning of this Chapter.

These results contrast with those of the causality tests which indicate that relative price variability has temporal precedence over demand shocks. The element of time appears to play a significant role in the determination of these results, indicating that there may be a complex interaction of forces at play. To summarise: when examining temporal separation, the data reveal that relative price variability is temporally prior to demand shocks. In examining contemporaneous relationships, we find that there is weak association between supply shocks and relative price variability and significant association with anticipated inflation. This implies that the relationship between relative price variability, DS and SS may be symptomatic of a deeper relationship involving supply shocks, and associated relative price variability, having temporal precedence over demand shocks. It is possible that supply shocks and associated relative price variability may induce accomodative policy response in later periods. It makes sense, therefore, to test for temporal precedence between supply and demand shocks. This is the basis for the test reported in Table 6.5. [7]

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[7] Strictly speaking, accomodative policy in this context must be regarded as discretionary rather than pertaining to a specific rule, since it would make no sense to think of demand shocks following supply shocks in a systematic way as this would, in principle, be discovered by optimising agents, and demand surprises would cease.

Table 6.5 Sims Test for Temporal Precedence: DS, SS

Bounds: 1950Q4-1981Q2

REGRESSION	SSE	DW	RSQ
DS=f(SS; past and present)	0.070	2.04	0.33
DS=f(SS; past, present and future)	0.065	2.06	0.37
SS=f(DS; past and present)	0.015	1.85	0.35
SS=f(DS; past, present and future)	0.014	1.94	0.39

REGRESSION	CAUSAL RELATION	F
DS=f(SS)	DS causes SS	1.35
SS=f(DS)	SS causes DS	1.25

The critical F at one and five percent is not exceeded, therefore we reject the hypothesis of temporal precedence in either direction between demand shock and supply shock inflation.

6.7 Suggested Research and Concluding Comments

It is of interest to note that using an entirely different technique, it appears that we derive empirical reqularities which are closely consistent with those of Fischer. Clearly, however, more research is required in order to derive a richer understanding of the implications from the data. We also note that there is evidence (as exhibited in weak regression results) suggesting that much of the variability of relative prices has not been explained by demand shock/supply shock inflation or its anticipated level. This might be interpreted as either model mis-specification or as an indication that much of the relative price variability observed may result from the re-allocation of relative demands and/or supplies as discussed in Chapter 1, or from other uninvestigated sources.

At the level of the model itself, it is apparent that the covariance of the p,y series (as disussed in the previous chapter) cannot be zero for all circumstances. If this kind of analysis is to be applied to other kinds of situations and markets, it would be desirable to take explicit account of this covariance throughout the model, rather than to rely on the empirical covariance which in this case is insignificant from zero. Another means of checking the implications of these results may lie in performing a similar kind of operation to that used by Fischer (on US data) on the Canadian data. This would provide further evidence relating to the suggestion that supply shocks may have played a dominant role in the determination of relative price variability.

There may exist additional difficulties with regard to the theoretical basis of the model. Scarth (1979) argues the conventional wisdom concerning a small open economy, that flexible exchange rates damp the effects of foreign shocks, may ignore supply side exchange rate effects. It is shown that positive "IS" shocks cause higher output and price under fixed exchange rates, but they cause higher output and lower price under flexible exchange rates. This may blur the distinction between demand and supply shocks as proposed in Chapter 5, where positive co-movements in inflation and output are defined as demand shocks, and negative co-movements as supply shocks.

An interesting possibility for extending this research lies in the application of autoregressive modelling proposed by Sims (1980). The problems addressed are the assumption that macro-models are easily identified. Sims suggests that in econometric models, what frequently belongs on the right hand side in one equation often belongs on the right hand side in all equations, except for a few popular instances in agriculture where separate factors influence demand and supply. His procedure focuses on the interaction between variables rather than specific model structure, and it can be regarded as a convenient way of summarising empirical regularities and as perhaps suggesting the predominant channels through which relations work. The exogeneity assumptions inherent in the structure of macro models (other than restrictions pertaining to the length of lag in the autoregressive scheme) are avoided.

The procedure amounts to treating all variables as endogenous in turn, by regressing innovations in each variable on the lagged innovations all the other "exogenous" variables. Coefficient estimates in such a scheme in any given regression are not parameter estimates, since they are complicated functions of the unknown structural and expectational parameters. Forecast variance decomposition provides a measure of relative importance, when right hand side variables are shocked, of the evolution of variables of interest.

It is possible therefore, to construct a vector autoregressive model incorporating relative price variability, import prices, GNP, Government expenditure, anticipated inflation, demand shock inflation , supply shock inflation and exchange rate adjustments. Such a model would provide the means for examining the relative importance of these variables, and would (through the inclusion of import prices) give an indication of domestic versus foreign influences on relative price variability. [8]

In Chapter one the question of policy implication was cited as a motivating factor for this work. It is therefore necessary to evaluate the degree to which the evidence presented here corroborates the theories reviewed in Chapter two. Recall furthermore, that the fundamental question: given that inflation, relative price variability, and output losses all seem to correlated, is there a coherent policy objective capable of mitigating these losses? This question is perhaps best broached by investigating a stylised set of empirical results which would seem to indicate a role for policy.

Our thought experiment involves Sims test results which would indicate demand shocks being temporally prior to relative price variability (which would also give grounds for regarding demand shocks as "exogenous" right hand side variables in subsequent regression analysis). Furthermore, if demand shocks had a significant coefficient (and large elasticities) relative

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[8] I thank Professor Stephen T Easton for drawing my attention to an unpublished working paper which addresses similar although not identical questions, in relation to the disaggregation of inflation shocks into domestic vs external sources.

to supply shocks, the need for control of aggregate demand shocks may be argued. Such a policy might focus on (potentially) controlable factors such as stability of monetary growth. However, it should be conceded that the occurance of demand shocks in a small open economy may be the result of external factors, which would open another debate concerning the insulating effects of fixed versus flexible exchange rates. [9]

Of course our evidence is not of this (relatively) conclusive nature. Rather than broad allusions, it is perhaps more instructive to examine which of the explanations of relative price variability are not disconfirmed as a prelude to discussing policy. In keeping with the methodological agenda described at the close of Chapter two our "circumstantial evidence" is as follows:

It is apparent from the regressions that anticipated inflation is significantly correlated with relative price variability. Hence the "adjustment cost" class of explanation cannot be rejected. The level of anticipated inflation, regardless of characteristics such as its variability, appears to impose real costs which are in principle avoidable at an inflation rate of zero. It is also clear that supply shocks dominate the effects of demand shocks. However, for reasons mentioned earlier in the discussion concerning the supply side effects of flexible exchange rates, caution is warranted in the

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[9] These points are a further indication that the modeling procedure of the autoregressive paradigm would be a useful tool in examining these problems.

interpretation of these results. However, oil and food price increases cannot be rejected as influences on relative price variability. In Chapter one it was noted that this kind of phenomenon is not necessarily "bad" from a policy perspective, since useful relative price signals may be disseminated even when output and employment are below trend.

There is no evidence as indicated by low elasticity estimates and insignificant t ratios, for suggesting that the authorities, through more stable monetary growth are capable of influencing the variability of relative prices and reducing associated costs. We are unable to find support for the class of explanation submitted by Barro and Lucas, where the variability of (implied demand shock) inflation is responsible for heightened relative price variability. The less discriminating procedure, which our technique is designed to avoid, tests aggregate unanticipated inflation. As can be seen in equation (2), aggregate unanticipated inflation is associated with relative price variability. This might be misconstrued as evidence in support of the Lucas/Barro rationalisations, which suggest a link between the variability of relative prices and inflation which is induced by the variability of monetary growth. [10]

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[10] Strictly speaking, the notion of inflation variability and unanticipated inflation may not be identical. The Lucas/Barro, argument stresses the past history of inflation variability as having a cumulative effect on the elasticity of the short run supply function. Therefore current shocks may not be actually measuring the phenomena they claim causes relative price variability.

Interpretation of the Sims test from a policy perspective is ambiguous. The evidence (which is highly statistically significant) that relative price variability is temporally prior to demand shocks indicates no clear objectives in a policy context, unless increased relative price variability can be interpreted as either demand or supply shock symptoms. In the absence of any clear evidence we regard it as imprudent to base policy suggestions on the basis of this section of the evidence. [11]

To conclude, we regard the research conducted in these pages as an outline for a more complete and satisfactory research program, which would include the autoregressive modeling procedure discussed. There are many questions not examined here which would be worthy of consideration in further research. For example, the relationship between relative price variability and the variability of the price level seems to be caused mostly by relative rather than aggregate factors. Such questions as how much of the relationship is induced by nature (both domestic and external influences) and how much by exchange rate fluctuations, would be interesting avenues for future research.

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[11] The comments made by Fischer regarding the likely instability of any relationship, prompted tests of sub-periods of time for both the regressions and the Sims tests. The unreported results indicated however, that test conclusions and significance levels are broadly preserved.

"Writing becomes not easier, but more difficult for me. Every word is like an unnecessary stain on silence and nothingness."

Samuel Beckett

(Interview in Vogue Magazine, 1969)

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