INFLATION AND RELATIVE PRICES IN AN OPEN ECONOMY

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CONTENTS

PREFACE

This study is part of a research project started in 1979 concerning the behaviour of prices in Sweden. Whereas the other part of the project was oriented towards microeconomic theory, this study results from my interest in macroeconomics, where the relationship between nominal and real variables has been the focus of interest for a long time.

During work on the thesis I have been privileged to have helpful and encouraging discussions with a lot of people, and the final version of the study appearing here, has benefited a great deal from these discussions.

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INTRODUCTION

t INTIODUCTION

1.1 General Backaround of the Studv

The neoclassical competitive model has for a long time influenced the thinking of economists. In spite of being under almost continuous attack, the neoclassical model has shown a remarkable persistence. This is examplified by the recent theoretical developments in macroeconomics.

As a description of reality, the competitive, frictionless model with instantaneously clearing markets clearly has severe limitations. The fact that markets are not always cleared is easily recognised, e.g. by observing unemployment, inventories or queues.

In neoclassical models, the urarket-clearing mechanism is not explicitly specified. However, the clearing of urarkets is made as it there was an auctioneer who could always and instantaneously find the price at which quantities supplied exactly meet the orders of the purchasers. In this set-up sellers are assumed to be price takers and quantity makers. Suppliers come to the market with a given quantity and take the price brought up in the auction.

Consumers and producers are assumed to be rational in the neoclassical model, i.e. they do not waste any opportunities available to them. In particular, their behaviour is based on relative prices and the choice of the particular unit of value, or numeraire, does not affect their behaviour. Therefore, in the frictionless model, inflation does not imply any real economic consequences. The allocation of resources is governed by relative, not by absolute prices.

In macroeconomic theory, there is a, not always clear, difference between models which embody the natural rate hypothesis (NRH) and those which do not. The former theories are based on (neo)classical economics, that are generally consistent with modern general equilibrium theory. The NRH is embodied in both classical and neoclassical, or the new classical, macroeconomics. The NRH merely amounts to saying that it is relative rather than absolute prices which govern the behaviour of economic agents. Hence, by using the

notion of natural rate theories, or models, we refer to a wide class of models, including the Walrasian model, the "classical" macroeconomic model and the new classical macroeconomic school. Macroeconomic theories which do not embody the NRH are often Keynesian in spirit, in the sense that they are based on markets which do not always clear, e.g. due to stickiness in wages or prices.

Models which embody the NRH are also said to be neutral; i.e., for a model initially in equilibrium; if all variables are multiplied by the same proportionality factor, then the model will still be in equilibrium with all real variables unaffected.

Certain natural rate models are also dichotomised, i.e. real variables are unaffected by changes in the money supply, and real variables are determined independently of the money supply. Depending on how the asset side is modelled, a variety of classical models appear; usually either the neutrality or the dichotomy property appears and sometimes both. For instance, a model may dichotomise; an increase in the money supply leaves all real variables 1~naffected, but may be out of equilibrium with the new money supply

The classical equation of exchange

$$MV=PQ \tag{1.1}$$

can embody the natural rate hypothesis. M is here the exogenously given quantity of money, V is the income velocity of money (the inverse of the desired demand for cash balances per unit of output), P is the general price level and Q is an index of real output. Assuming that M does not affect V and Q, (1.1) is the classical quantity theory of money (or of the general price level). Natural rate macroeconomics can embody a dichotomised economy where two distinct parts can be recognised: the "monetary" and the "real" part (i.a. see Sargent (1979) ch. I, XIII and XVI). The classical dichotomy, which can found for instance with Jevons and Edgeworth, is very clearly expressed in Wicksell's "Interest and prices", in which Wicksell states the independence between the real and the monetary sector, in particular between relative and absolute prices . The determination of relative prices belong to the theory of value and the determination of absolute

prices to the theory of money. Wicksell's analysis of this matter is also made in terms of different equilibrium concepts. Hence, he considered that **there were strong equilibrating forces in the system of relative prices, while the determination of absolute prices, or the general price level, was described in terms of a cumulative process.**

In **the forties,** fifties and sixties there was a long, and not particularly fruitful, debate on the classical dichotomy. The dichotomised theory was critisised by Lange and Patinkin on logical grounds[3]. The critique of Lange and Patinkin was that the classical dichotomy was inconsistent, since it violated Walras' law. The debate was partly confusing, because the critique failed to distinguish between stocks (money) and flows (rates of demands and output). It was also shown that the real balance effect would only be of significance outside equilibrium 5). I agree with Niehans in his comment on this matter:

> ...the amount of intellectual effort which, in the wake of Lange and Patinkin, was devoted to this issue, is entirely out of proportion to its economic significance. The real economic question is not whether a system can be dichotomized, but whether money is neutral."

Niehans (1978), p. 12

The neutrality proposition was questioned at an early stage, e.g. by Keynes in the thirties . The NRH has also been questioned later, and models, particularly Keynesian models, have been developed which are non-neutral. However, the NRH has been revived in the late sixties through the evolution of two different ideas about expectations. Phelps (1967) and Friedman (1968) developed models where only <u>unanticiaated</u> movements in money supply are non-neutral and where the NRH holds only <u>in the lon4 run</u>.

A position stronger than Friedman's and Phelps' is taken by the rational expectations hypothesis (REH), which is the stochastic counterpart to perfect foresight. Consequently, the NRH holds also in the short run, and anticipated movements in the money supply are neutral, i.e. exert no influence on the probability distributions of relative prices, employment or real output[?]

The classical dichotomy was perhaps 8) not held as a realistic description of an actual economy. Nevertheless, modern advocates of the joint NRH/REH have tried to test the joint hypothesis, although there there has been no consensus about the results or about the appropriate econometric method to be applied[9)]

The neutrality proposition has most frequently been expressed as the neutrality of money to reas o;tput and a number of tests of this proposition have been done [)]. The neutrality proposition, however, also implies neutrality from money to relative prices, a hypothesis which has been tested by Bordo (1980) and Hercovitz (1982).

The neutrality proposition can, however, also be stated as the neutrality of absolute prices to output, or to relative prices. The neutrality of the general price level to relative prices has been a controversial subject for quite some time. In this study we shall examine the relationship between inflation and changes in relative prices and we shall test whether inflation is neutral with respect to changes in relative prices and relative-price variability. This relationship has recently come into focus in the macroeconomic literature, particularly in connection with the development of the new classical macroeconomics, in which it is asserted that it is only unanticipated money and unanticipated inflation which affects real variables.

Whether inflation is neutral or not has been a subject of controversy for a long time. This can be further illuminated by means of two quotations from Keynes and Friedman. While the Patinkin controversy was concerned about the theoretical consistency of classical macroeconomics, Keynes' doubts were more of an empirical nature[11)]. Keynes' position, in arguing with Jevons, Bowley and Edgeworth, is that relative prices affect the general price level:

"The point of view under criticism makes the mistake of assuming that there is a meaning of price level, as a measure in some sense or another of the value of money, which retains its valne unaltered when only relative prices have changed. The abstraction between the two sets of forces, which seemed momentarily plausible when we made it, is a false abstraction, because the thing under observation, namely the price level, is itself a function of relative prices and liable to change its valne whenever, and merely because, relative prices have changed. The hypothetical change in the price level, which would have occured if there had been no changes in relative prices, is no longer relevant if relative prices have in fact changed - for the change in

relative prices has in itself affected the price level."
Keynes (1930) p. 87

Friedman takes the opposite view and has interpreted the neutrality position in the following way:

" what of oil and food to which every government official has pointed? Are they not the immediate cause of the price explosion? Not at all. It is essential to distinguish changes in relative prices from changes in absolute prices. The special conditions that drove up the prices of oil and food required purchasers to spend more on them, leaving less to spend on other items. Did that not force other prices to go down or to rise less rapidly than otherwise? Why should the average level of all prices be affected significantly by changes in the prices of some things relative to others?"

Friedman (1975) p. 73

An important point can immediately be made here. Friedman and Keynes discuss the question in different ways from the point of view of causality. Friedman states that the general price level does not cause changes in relative prices, while Keynes argues that it is changes in relative prices that cause price level changes. In the following, we shall pay particular attention to that problem and place it under formal statistical test.

As we have seen, the natural rate hypothesis, and the neutrality proposition, both from money and from the absolute price level, to real variables has survived, from Wicksell to Friedman and, more recently, to Lucas and Sargent.

The neutrality proposition has been called into question for almost as long as its considerable existence. It goes without saying, that marsy reasons can be given for the appearance of non-neutralities. In Chapter 3 of this study we will examine these reasons in some detail.

1.2 Purpose of the Study

The purpose of the present study is to analyse the relationship between inflation and changes in relative prices. In particular, the neutrality proposition, that inflation does not affect relative prices, will be examined here.

It is then important to distinguish between inflation which is anticipated and inflation which is not. This is a main point in Friedman's and Phelps' analysis and in the new classical macroeconomics, since the modern versions of the neutrality proposition embody a non-neutrality with regards to the effects of unanticipated changes in nominal variables, money or the general price level, on real variables. Hence, the purpose of this study is to empirically examine an old question in a new light; through the empirical analysis of the relationship between inflation, expected and unexpected, and changes in relative prices, we small test the hypothesis that even a fully expected rate of inflation will influence changes in relative prices and the variability of relative-price changes. The latter hypotheses, which will be discussed in detail in Chapter 3, are inconsistent with the modern versions of the neutrality proposition.

As noted in the previous section, there is no agreement on the causal order between inflation and changes in relative prices. As will be shown below, this question is ambiguous in some models, since both these variables can be affected simultaneously by other variables. Adhering to the Wiener-Granger causality concepts, the purpose of this study is also to test the causal order between inflation and the variability of relative-price changes.

The empirical analysis is carried out for Sweden and we use time-series data of consumer prices. Since Sweden is a small open economy, it is intended to take account of the influences on prices which emerge from abroad.

Although my main purpose is to test the neutrality proposition, the present study also aims at providing further evidence on the important determinants of relative-price variability and on the consequences of inflation. If it can be shown that inflation increases relative-price variability, this can, under certain conditions, be viewed as a cost of inflation. In particular, that would be the case if economic agents confuse relative with absolute prices . However, the present study does not try to explore the welfare significance of relative-price variability. An obvious effect of changes in relative prices or in the variability of relative-price changes is that the distribution of income would be affected through changes in the cost of living for different households.

1.3 Outline of the StudY

One of the most influential contributions to macroeconomic theory during the seventies is the development of the rational expectations Phillips turve. Lutas' stochastic Phillips turve model gave rise to a large number of studies, in which different features of his model were elaborated. One of these features was the presumed independence between relative--price variability and the variability of the general price level, which was the starting point for the empirical analysis of Vining and Elwertowski (1976). Their study gave rise to a number of theoretical, as well as empirical, studies on the subject, in which the relationship between these variables was analysed.

Hence, the Lutas model is a natural starting point and in Ch apter 2 we present the slightly modified version of his Phillips turve model, formulated by Cukierman and Wachtel (1979). Particular interest is paid to the relationship between the variability of the general price level and the variability of relative prices and to the causality between these variables. The causality is shown to be indirect, since both these variables are simultaneously affected by exogenous demand shocks.

In Charter 3 ron-neutral models are discussed. By ron-neutral, we are referring here to models in which even a fully expected inflation affects real variables. We show that the introduction of price adjustment costs under very general conditions implies a positive relationship between inflation and the variability of relative-price changes. The same positive relationship is also derived in the scandinavian model of wage and price formation and, in addition, it is shown that the causality runs from changes in relative productivities between sectors to these variables.

Charter 4 provides an empirical analysis of the relationship between the variability of relative-price changes and expected and unexpected inflation. Simple regression studies are made for Swedish annual time-series data on tonsumer prices for the period 1951-1979. It is assumed that inflationary expectations are based on previous inflation rates. Two alternative specifications are used: adaptive and extrapolative expectations. The results suggest that a 1: increase in the expected

rate of inflation would increase the standard deviation of relative-price changes with approximately 0.4%. The effect from unexpected inflation is stronger, with a corresponding figure of 0.7%. These results are in correspondence with earlier findings for the U.S. but contradictory to earlier results for Mexico and Argentina, where only unexpected inflation was significantly related to the variability of relative-price changes.

In Chapter 5 we develop a model of relative-price changes and the variability of relative-price changes. The model is a deterministic multi-market static equilibrium model for an open economy. Homogeneity of the supply and demand functions guarantees the property of neutrality. However, the model is based on a cleared labour market in which the equilibrium wage rate is linearly related to the expected general price level. This implies that relative-price changes are affected by unexpected inflation. It has been suggested that supply shocks have been an important source of relative-price variability in the seventies. Therefore, raw material prices are included in the supply functions. Influences from abroad are incorporated through foreign demand; the foreign price level and foreign income. The open economy formulation and the inclusion of raw materials provides an extension compared to earlier models. Compared to the Lucas model, it is more general in one respect, since it allows supply and demand parameters to vary between markets. On the other hand, expectations are more restrictive and are assumed to be identical between markets.

The model in Chapter 5 is then used in empirical tests of Swedish annual time-series data for the period 1951-1979. The formulation of the model permits the test of non-neutral effects from a fully expected inflation. In addition, the influence from raw material prices and foreign variables on relative-price changes and on the variability of relative-price changes, is tested. The results from these tests reveal significant relationships, and particularly the effects from expected inflation and relative raw material prices are strong, suggesting that previous empirical models have been misspecified.

The model and the tests in Chapter 5 presume that causality runs from inflation to relative-price changes. To test that proposition one needs a dynamic model. In Chapter 6 we use a dynamic time-series model to test the causal order between inflation and the variability of

relative-price changes. The model is a vector autoregression, recently proposed by Christopher Sims as an alternative to large-scale macroeconometric models We use five variabler in the model, suggested from the analysis in Chapter 5, and study the dynamic responses to different shocks. The simulations and the tests are somewhat inconclusive, but no feedback from relative-price variability to inflation is revealed, thus supporting the empirical specification in Chapter 5. Rather weak support is found for causality that runs from inflation to the variability of relative-price changes. The dynamic responses in the model reveal a slowly damped pattern. Relative-price change variability shows a persistent positive response to positive shocks in import prices and in the rate of inflation.

Finally, Chapter 7 presents a short summary and conclusions. Most of the tables and figures, as well as the description of data sources are assigned to appendices. This is also the case with a list of the symbols used, a summary of which is found in Appendix 1.

2 INFLATION AND.RELATIVE PRICES: NEUTRAL MO DELS

In this chapter, we shall present Lucas' version of the Phillips curve. His model has been very influential in recent macroeconomic theory and the model permits an explicit analysis of the relationship between inflation and relative prices. It throws light on the causal relationship between the latter variables and will be important for the development of the model and the tests in Chapter 5.

The Phillips curve was first established by Phillips (1958) as the empirically observed negative relationship between the rate of wage inflation and the rate of unemployment . The empirically observed Phillips curve was regarded as a stable relationship, though it obviously violated the neutrality property in natural rate theories. The Phillips curve was built into Keynesian macroeconometric models and it was envisaged that policy makers, through a suitable mix of monetary and fiscal policy, would be able to select a point on the Phillips curve.

However, the microfoundations of the negatively sloping curve proved to be unsatisfactory and in need of further development. Furthermore, in the late sixties, the tradeoff between inflation and unemployment worsened , as a result of an increase in the rate of inflation without any offsetting decrease in the unemployment rate. In the light of this well-known development, it was natural that Keynesian theory was challenged.

The main contributions to the development of the microfoundations of the negatively sloping Phillips curve were made by Phelps, Friedman and **Lucas . The basic** idea in Friedman's and Phelps' models is that workers temporarily misperceive the rate of inflation and the real wage rate and, due to this misperception, temporarily negatively sloping Phillips curves exist. However, in the long run there are no misperceptions and the vertical natural rate Phillips curve is established

Friedman's and Phelps' models were based on adaptive expectations and the formation of expectations was exogenous in their models. Lucas contribution was to build a stochastic Phillips curve model based on Muth's (1961) idea of rational expectations, in which expectations were endogenised. In the following we shall briefly present a somewhat modified version of the natural rate Phillips curve in Lucas (1973) and pay particular attention to the implications concerning the relationship between the variability of the general price level and the variability of relative prices.

In the Lucas model, it is assumed that real output is determined on the supply side of the economy. The division of nominal demand into real aggregate output and aggregate price level depends on the behaviour of suppliers. Rigidities in short-run behaviour on the supply side are a result of the suppliers' incomplete information on some of the prices relevant to their decisions. Finally, the model presumes that expectations are formed rationally, that individuals do not make systematic forecasting errors period after period. This does not imply that individuals forecast accurately, but that they do it correctly on average in a stochastic world.

Lucas assumes that there is a single good which is located in a large number of physically separated competitive markets. The modified Lucas model presented here has been developed by Cukierman and Wachtel (1979). The model contains a large number of goods with a local market clearing condition. Demand is distributed unevenly between markets and therefore prices vary between markets.

The supply in market z is

$$(2.1)\quad y_t(z) = Y\,(p_t(z) - E(P_t \mid I_t(z)))$$

where $y_t(z)$ is real output in market z at time t, y is a positive constant, $p_t(z)$ is the actual price in z at time t and $E(P_t \mid I_t(z))$ is the mathematical expectation of the general price level P conditional on the information available in z at time t. All variables are expressed in natural logs[5)]

The supply function (2.3) summarises the natural rate properties in the Lucas model, or in Lucas' own words:

'All formulations of the natural rate theory postulate rational agents, whose decisions depend on relative prices only, placed in an economic setting where they cannot distinguish relative from general price movements.'

Lucas (1973) p. 327.

Two critical aspects of (2.3) should immediately be noted:

(i) the information set $I_t(z)$ and
(ii) the assumption of asymmetrical information.

The model assumes that at time t, agents in z only know the price in their own market, $p_t(z)$, but not the general price level P_t. The expectations of P_t are formed conditionally on the information set $I_t(z)$. The agents are assumed to know the first and second moments of all probability distributions. This gives them the information needed to form least squares projections of unknown random variables on known random variables. The definition of $I_t(z)$ has some important consequences. Lucas defines $I_t(z)$ as being composed of two parts. First, it is assumed that $p_t(z)$ is known and is the only current information. Second, $I_t(z)$ includes historical information on lagged y_t and $p_t(z)$ in all markets. This information gives a prior distribution on P_t with urean P_t and variance $EP_t = o$.

The demand side of the model is represented by the stochastic demand function in z, defined by

$$(2.2)\quad y_t(z) + p_t(z) = x_t + s_t(z),$$

where x_t is an exogenous random shift variable common to all markets and $s_t(z)$ is a random shock specific to each market. $Dx_t = (x_t - x_{t-1})$ is assumed random with $EDx_t = b$ and $E(Dx_t)^2 = a_x^2$. Furthermore, $Es_t = 0$ and $Es_s = o$.

With the assumed distribution of demand we have

(2.3) $p_t(z) = P_t + v_t(s)$

i.e., the observed price in z is the sum of the common element P_t and the deviation $v_t(s)$, which depends only on the specific demand chock $s_t(z)$, with $Ev_t=0$ and $Ev_t^2=T^2$

The expected general price level in (2.3) is defined as

(2.4) $E(P_t \mid i_t(z)) = E(P_t \mid p_t(z). P_t) \_ (1-8)\ p_t(z) + 8\ P_t$

where $8=o_s^2/(o_s^2+o_x^2)$ and $(t-e)=o_x^2/(o_s^2+o_x^2)$, and where

$8(p_t(z)-E(p_t(z) \mid I_t(z))$ is the least squares projection of

$(P_t-E(P_t \mid I_t(z))$ on $(p_t(z)-E(p_t(z) \mid I_t(z))$ and

$B=Ev_t(v_t+w_t)/E(v_t+w_t)^2=o_s^2/(o_s^2+o_x^2)$, is the

least squares regression coefficient[6]. w_t is the stochastic deviation of Dxt from its mathematical expectation 6, and it2is assumed to be normally distributed with zero mean and variance o_x.

(2.4) substituted into (2.1) gives

(2.5) $y_t(z) = y8\ (p_t(z)-P_t)$

Averaging over markets gives the Lucas aggregate supply function[7]

(2.6) $y_t = 19\ (P_t-P_t)$

Some manipulations with (2.6) gives

(2.7) $Pt-Pt-t = (Y8)^{-1} yt+(\dot{P}t-Pt-1)$

which is the Lucas representation of the expectations-augmented Phillips curve, relating the actual rate of inflation to output and to expected inflation (P_t-P_{t-1}). From (2.7) one can verify that the Phillips curve will shift up with increases in the expected rate of inflation (P_t-P_{t-1}). The slope of the aggregate supply function (2.6)

varies with the fraction B. If o_s^2, i.e. the variance in specific demand shock2, is small, then the supply function is nearly vertical and when o_x, i.e. the variance in the change in nominal income, is small, then the slope of the supply function approaches y. Hence, the larger the variance of specific demand shocks relative to the variance of common demand shocks, the greater is the tendency that agents regard an unexpected change in price as a relative-price change, to which output decisions should respond, rather than a nominal-price change.

By looking at (2.3) we observe that $v_t(s)$ is independent of P_t by definition and depends only on the realisation of the stochastic term $s_t(z)$; i.e. relative prices are independent of the general price level. This was noted by Vining and Elwertowski (1976) and was the starting point for their (and others') empirical analysis of the relationship between the variance of relative prices and the variance of the general price level.

However, solution of the above L cas model reveals a systematic relationship between these variables . Substituting (2.9) into (2.1) and equating supply and demand yields the solution for actual price in z at time t as

$$(2.8)\quad p_t(z) = \frac{1}{1+y9}\left(x_t + s_t(z) + Y8\, p_t\right) = P_t + v_t(s)$$

The variance of relative prices in equilibrium, $_t^2$, then is given by

$$(2.9)\quad i2 = OS / (1+Ye)2.$$

With a suitable definition of the general price level[9], one can solve for the general price level in equilibrium as

$$(2.10)\quad P_t = P_t + \frac{w_t}{1+Y8}$$

The variance of the general price level in equilibrium 10) is

$$(2.11)\quad a2 = ax / (1+.0)2.$$

As we can see, both τ^2 and o^2 have the same denominator and both depend on $8=0^2_s/(o^2_s + a^2_x)$. Differentiating τ^2 and a^2 with respect to 0^2_x and a^2_s gives

$$(2.12)\quad \frac{\partial t^2}{30x^2} > 0, \qquad \frac{8\partial 2}{30x^2} > 0$$

and

$$\frac{2}{30s} - \frac{1+Y8(28-1)}{(1+Y8)3} \qquad \frac{302}{gaS} < 0.$$

(2.12) reveals that if, ceteribus paribus, the variance of changes in nominal income vary over time, τ^2 and a^2 will be positively correlated i2 this Lucas model. This conclusion cannot be drawn for changes in 0_S, since it depends on whether 1+18(28-1) < 0 or equivalently if 8 2< 0.5. Hence, if changes over time in 0_x are larger than changes in a^2_s, then the Lucas model embodies a positive relationship between τ^2 and

a_2. A possible interpretation of this could bethat policy makers could induce a positive relationship between a_x and a_t throug2 frequent changes in fiscal and monetary policy, which would make a_x large relative to a_s^2.

We shall make use below of some of the conclusions from the previous analysis. Ve note the form of the Lucas supply function, which depends solely on relative prices. However, aggregate output is positively related to unexaected inflation in the Lucas model. Furthermore, it was shown that the nominal variable, a_x, the variance of the general price level, is positively related to the real variable, r^2, the variance in relative prices. It is also likely that the variance in the general price level is positively related to unexpected inflation. The positive relationship between a_x and a_t was allo shown to be caused by changes in the variance of demand shocks. Hence, the previous analysis also shows that the causality might not be a direct causality from general price change to relative price change, but that the causality may be from other, exogenous, shocks. These shocks need not be excess demand shocks, as in the Lucas model, but could also be monetary shocks, as in Barro (1976), or exogenous supply shocks, as will be shown in the next chapter. However, as will also be shown in the next chapter, a direct causality from inflation to relative-price changes holds under fairly general conditions.

3 INFLATION AND RELATIVE PRICES: NON-NEUTRAL MODELS

3.1 Introduction

As the model in the previous chapter showed, a non-neutral effect from unexpected inflation to real output and to relative prices can occur when agents have incomplete information and tend to confuse relative with absolute price changes. Both the Lucas model and the earlier development of the natural rate Phillips curve by Friedman and Phelps, were based on incomplete information of the general price level.

In this chapter, we shall consider other theories which link inflation and the variability of relative-price changes . The argument is that such a link may well occur without confusions about real and nominal magnitudes. Hence, relative-price variability may also be caused by inflation which is fully anticipated. As discussed in the previous chapter, the question of causality between these variables is of importance. Hence in this chapter, we shall also try to identify the truly exogenous factors underlying the relationship between inflation and relative-price variability.

It should be pointed out here that the emphasis is on theories of market behaviour which abstract from the theory of money. Even in a rational expectations framework, anticipated money could affect real variables, if the model includes many assets. In models with more than one asset, changes in the money supply in general have non-neutral effects, through their impacts on real interest rates

3.2 Inflation and Price Adjustment Costs

Disequilibrium models with sticky prices and wages have become an important feature of recent macroeconomic theory. In many models, the rigidity is merely postulated and is not an endogenous part of the model. However, in recent theoretical work it has been shown that rigid wages and prices - implying non-neutrality - are perfectly consistent with optimising behaviour

The title of this section indicates a contradiction. How could we have inflation if prices are sticky? As we shall see, there need not be any contradiction. It will also become evident that differences in price inertia between different sectors in the economy create conditions for a dependence between nominal and real variables.

In the frictionless Arrow-Debreu economy there are no costs involved in changing prices. However, in practice, considerable costs can be associated with the adjustment of prices. A consideration of the costs of price adjustment means that one leaves the competitive model and acknowledges that agents actually prices. Some kind of monopolistic behaviour is assumed, which seems relevant for a modern capitalistic economy.

The costs associated with price adjustment can be of quite different kinds. The simplest one is the cost of re-marking price tags. In a petrol station this cost is very low and therefore we observe frequent price changes and prices that change promptly to changes in supply and demand conditions. However, the adjustment costs involved in changing the changes in parking meters or the prices in companies that sell by means of catalogues, could be considerable. Consequently, prices are more seldom changed.

other kinds of costs, that are probably far more important, are those associated with customer relations on markets for heterogenous products. The reasons for sticky prices in such markets are the incentives to keep search and information costs down. Considerable costs can also be associated with the decision process itself, e.g. when changing implicit and explicit contracts.

In labour markets, costs for screening, search and training provide good reasons for long-term contracts between employers and employees and for the downward rigidity of wages.

To be explicit, let us begin by looking at a monopolistic firm faced with costs of price adjustment and the possibility of inflation[9]. The firm's demand depends on its own price, p_t, and the prices of its competitors, P_t, the general price level. The firm expects demand and the aggregate price level to increase at a certain rate and has to decide upon when and by how much it is going to adjust its price.

The ceteris paribus considerations of the firm are the following. The firm does not change its price continuously by the increase in the general price level, but will change its price in discrete intervals[5]. The reason for that is that the firm will consider the cost of price changes in relation to the cost of maintaining a lower price. Hence, at a certain rate of inflation, it will pay to keep the nominal price constant and allow the real price to decrease in order to avoid adjustment costs. The length of the time interval, in which the nominal price is held constant, and the size of the price increase depend on the level of adjustment costs and on the rate of inflation. In equilibrium, the gain from postponing the price change - the profits immediately prior to the change and the interest saved on the adjustment costs - equals the losses - the profits immediately posterior to the change.

For our purpose, it is interesting to find out what happens if the rate of inflation or the level of adjustment costs changes. These effects are illustrated in Figure 3.1. The figure shows how the relative prices changes with the rate of inflation, over time, when nominal prices are held fixed over time intervals.

If the rate of inflation is zero, there is no need, ceteris paribus to change p t and there will be no variability in relative prices. The upper part of figure 3.1 shows the effect of an increase in the rate of inflation. The dashed line represents the inflation rate SO and the solid line the inflation rate a0, where SO > a0. The standard deviation of relative prices over time will increase in proportion to the shadowed parts in the figure, and hence an expected increase in the rate of inflation increases the variability of relative prices 6)

The lower part of figure 3.1 shows the effect of an increase in the level of adjustment costs at two different rates of inflation, a 0 and 00. The effect of an increase in adjustment costs is that the frequency of price changes decreases. Hence, relative prices change from a0 to ao and the variability of relative prices increase. Again, the standard deviation of relative prices increases when the inflation rate increases from a0 to p0. This is shown by the relatively larger shadowed parallellogram to the right in the lower part of figure 3.1.

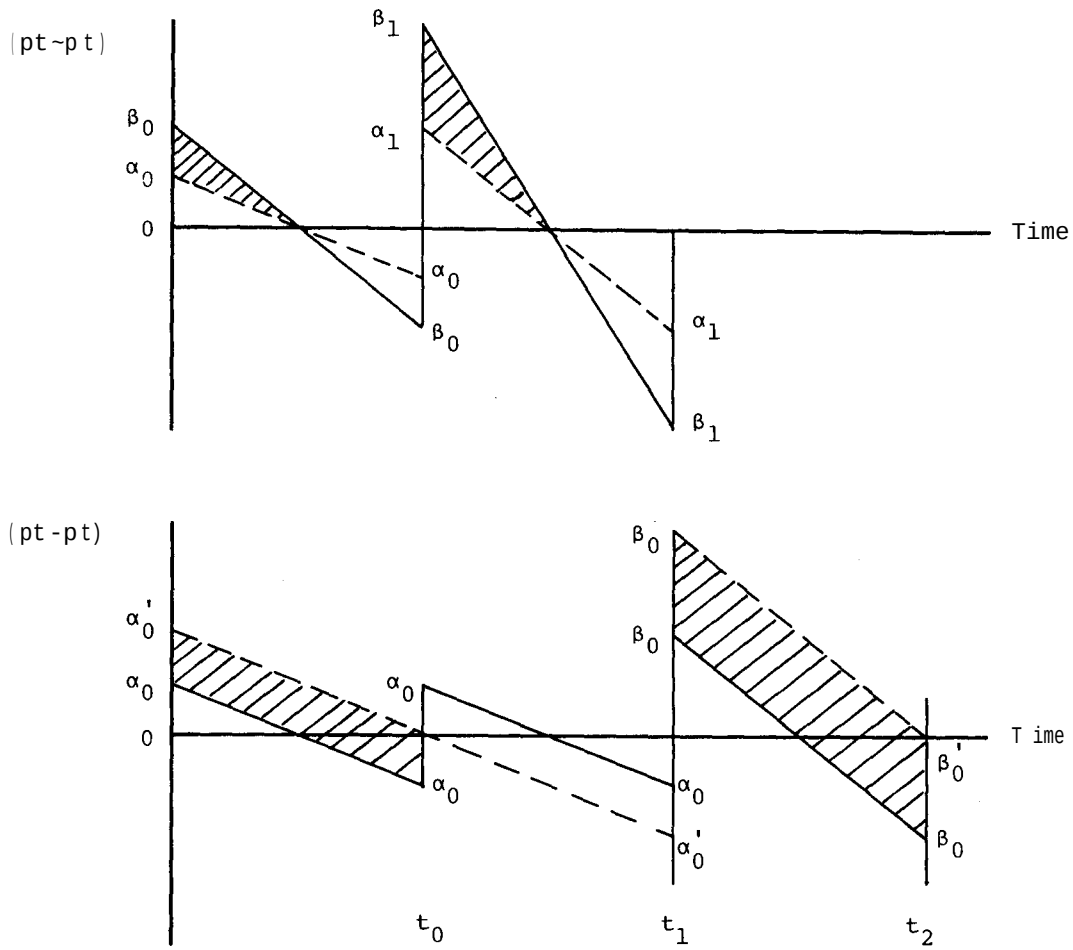


Figure 3.1. Relative prices over time depending on different inflation rates (upper coordinate system) and on differences in adjustment costs (lower coordinate system).

since there are differences in the costs of price adjustment between firas, an increase in the expected rate of inflation will increase the variability of relative price changes

Relatively innocuous assumptions were required in order for the above results to hold, i.e. a monopolistic profit-maximising fira with some resource cost for adjusting prices.

3.3 Implicit Contracts and Customer Relations

One can pursue the concept of adjustment cost further. The costs need not be associated with the marking of price tags, but can be more subtle. The discussion can be extended to all kinds of reasons for long-term contracts and constraints between parties in the inarkets. A thorough analysis of this subject is given by Okun (1981). Okun provides microeconomic explanations of the empirical evidence for rigid prices, rigid in the sense that short-run price changes are **insensitive** to changes in excess demand . In Okun (1975,1981) the relationship between inflation and relative prices is illuminated and his work, based on earlier work on search and imperfect information provides an interesting micro/macro framework.

Okun distinguishes different markets according to their degree of price flexibility. The labour inarkets are divided between markets for casual and markets for career labour. In the latter, but not in the former, wages are sticky downwards but sensitive to changes in consumer prices, and have a slowly upward growth path associated with expected career advancement. Wages in these markets are supposed to be mildly sensitive to excess demand for labour.

The product markets are divided between auction markets and customer markets. The latter markets are supposed to dominate in a modern economy. In the auction markets, prices are flexible and move quickly to clear the inarkets.

The customer markets are more like the career labour markets and their most important characteristics are the long-term relationships between buyers and sellers. These long term relations are based on the bilateral monopoly situation which arises because of the mutual advantages which lie in the possibility for buyers and sellers to

affect each other's behaviour. If the auction markets are characterised by impersonality, customer markets are characterised by personal relationships between buyers and sellers. The advantages of these long term relationships can be found in the potential economising on search and information costs. The seller is willing to lower prices somewhat, in order to keep regular customers, and the buyer is willing to pay a slightly higher price in order to avoid search and information costs. The division of the bilateral monopoly surplus is determined in implicit contracts which contain rules that will make it possible to avoid short-run exploitation of the surplus. For the price setter, the seller in the customer market, markup pricing provides a rule which ensures the stability of short-run pricing, since the offer to the customers can be fixed for a reasonable time interval, and provides him with information and the motives underlying price setting, i.e. convince the buyer of fair treatment[10)]

In an economy with heterogenous markets, there Till be non-neutral relationships between nominal and real variables . In an example we shall illustrate the relationship between relative prices and inflation by examining the accomodation to an oil price shock 12) .

Assume that the economy experiences an oil price shock. Oil prices are suddenly increased as was the case in 1973-74 and 1979. Furthermore, let us assume that the price elas3icity of demand for oil is considerably below 1 in absolute terms . Consequently, the increase in oil prices will be larger than the decrease in quantities in the market for oil and demand for other commodities will decrease. Hence, as a result of the slow adjustment in prices on customer markets, quantities will also decrease to some extent. Wages and prices will rise on customer markets due to the implicit or explicit link between wage contracts and tonsumer prices.

If these changes are viewed as Permanent, the implicit contracts may change and the economy enter a new equilibrium, where prices and wages will rise more rapidly (due to the new contracts, new pricing rules, etc.). Likewise, relative-prices will change, viz. prices in auction markets relative to prices in customer markets. The ides is that the changes in implicit contracts take time and the adjustment to the new equilibrium is slow.

Instead of an oil price shock, the shock could come from the demand side. A large increase in the money supply might induce an increase in the rate of inflation and changes in implicit contracts. Prices will rise unevenly across markets, since search and information costs and, thereby, implicit contracts vary between markets. Again, the demand shock increases both price variability and inflation[14)]

In the Okun type of theory, the causality chain goes via an exogenous disturbance, which could be either supply shocks or demand shocks. In the next section, we turn to a model for an open economy in which exogenous supply shocks cause both the inflation and the variability of relative-price changes to move in the same direction.

3.4 The Scandinavian Model of Inflation

The Scandinavian model of inflation is a model for an open economy with an implicit wage bargaining process in which wages through centralised wage contracting are equalised between sectors in the economy. That model is of interest here since it explicitly focuses on a small open economy and on the particular wage bargaining process that operates in the Swedish economy[1]

In the Scandinavian model of an open economy with fixed exchange rates, there are two goods, tradeables and non-tradeables. A production function, combining capital and labour in fixed proportions, represents technology, and technical progress occurs over time as exogenous changes in production coefficients. Relative changes in wages in the sector for tradeable goods are assumed to be such as to keep the functional distribution of income constant:

$$(3.1)\quad Dw = Dp_T + Dg_T,$$

where Dw is the relative change in wages, Dp_T the relative change in prices in tradeable goods and Dg_T the relative change in labour productivity in the sector for tradeables and T refer to the sector for tradeable goods

Because of competition in the labour market and union behaviour, wages are assumed to change at the same rate in both sectors. Hence, once again assuming the functional distribution in the non-tradeable goods sector to be constant, we have $Dw = Dp_N + Dg_N$, where N refer to the sector for non-tradeable goods.

Hence, price changes in this sector are determined by

$$(3.2)\quad Dp_N = Dw - Dg_N = Dp_T + (Dg_T - Dg_N).$$

As an empirical fact, let

$$(3.3)\quad Dg_T > Dg_N,$$

and hence $Dp_N > Dp_T$. If $Dp_T = 0$, then

$$(3.4)\quad Dp_N = Dg_T - Dg_N$$

which is the equilibrium rate of inflation or the "excess rate of inflation due to union behaviour.

Changes in $(Dg_T - Dg_N)$, the difference in productivity changes between the two sectors, cause both the rate of inflation and the variability of relative-price changes to move in the same direction. To prove that, let

$$(3.5)\quad DP = Dp_T + a_N(Dg_T - Dg_N)$$

be the rate of inflation, where a_N is the value-added share of the sheltered sector. Define the two relative-prices in logs as

$$(3.6)\quad Dp_T - DP = -a_N(Dg_T - Dg_N)$$

and

$$(3.7)\quad Dp_N - DP = (t - a_N)(Dg_T - Dg_N).$$

For simplicity, let the variability in relative-price changes be defined by the unweighted variance:

$$(3.8)\quad V_p = 0.5\ ((a^2 + (1-a)^2)\ (Dg_T - Dg_N)^2),$$

where p refers to a vector of relative prices.

It is now evident that the proposition is proven by (3.5), (3.8) and (3.3), since

$$(3.9)\quad \frac{\partial DP}{\partial(Dg_T - Dg_N)} = aN > 0, \qquad \frac{\partial V_p}{\partial(Dg_T - Dg_N)} = a(Dg_T - Dg_N) > 0,$$

where $a=(a_N)^2+(1-a_N)^2$, $a>0$ and $(Dg_T - Dg_N)^2 > 0$ by assumption, which shows that changes in relative productivity changes between sectors forces both inflation and relative-price variability to move in the same direction.

3.5 Asymmetric price Adiustments

In the price adjustment cost theory, it was inflation which caused changes in the variability of relative-price changes. In the implicit contract theory and in the Scandinavian model of inflation it was different exogenous disturbances which caused both inflation and the variability of relative-price changes to move in the same direction.

The theory of asymmetric price adjustments implies a causality in the opposite direction, from variability in relative-price changes to inflation. The idea has been put forward by Schultz (1959) and by Tobin (1972) and is consistent with Reynes' thoughts on this matter[17].

Consider an economy which experiences relative shocks, creating excess demands and excess supplies on different markets. Without asymmetric price adjustment, such relative shocks, by definition, would leave the aggregate price level unaffected. The theory then assumes that some prices are sticky <u>downwards</u>, while others adjust fully. Hence, rising prices, due to excess demands, are not offset by decreasing prices on markets with excess supply. The result is increased relative-price variability and inflation.

The downward stickyness could be related to a zero inflation rate, implying that prices are not decreasing on markets with excess supply. However, it could also be related to some positive inflation rate (a core inflation rate). In this case, the implied relationship between the variability of relative-price changes and the rate of inflation would hold true, at least for a wide range of modest inflation rates.

3.6 Concludinq Remarks

In this chapter we have analysed some non-neutral theories, in which links between the variability of relative-price changes and the rate of inflation have been shown to exist even if inflation is fully anticipated.

By introducing costs of price adjustment, implicit contracts implied by search and information costs, a particular type of union behaviour in a fixed exchange-rate open economy and asymmetric price adjustment, we have shown that a positive relationship is likely to exist between the variability of relative-price changes and the rate of inflation.

In the empirical literature on this subject, e.g. in Vining and Elwertowski (1976), Balk (1978) and Parks (1978), it is considered that causality runs from inflation to to the variability of relative-price changes. An exception is Fischer (1981b), who explicitly recognises the causal ambiguities.

In fact, the previous analysis indicates that the relationship between inflation and relative-price variability is not a very stable one, since this relationship can be caused by different exogenous shocks, i.e. productivity and input price shocks on the supply side, or monetary shocks from the demand side.

In the next two chapters, we shall assume that causality is from inflation to relative-price variability. This assumption can be justified in terms of the price adjustment cost theory. However, in the sixth chapter, we shall empirically analyse the causal relationships and treat all variables in the analysis as endogenous.

4 INFLATION AND RELATIVE-PRICE VARIABILITY: SOME EMPIRICAL EVIDENCE

4.1 Introduction

Having reviewed the theories of the relationship between relative prices and the rate of inflation, we now turn to the empirical evidence. Starting in the middle of the seventies a number of empirical studies appeared in which this relationship was studied. However, empirical economists were interested in this relationship as early as in the 1920s

In the present chapter we focus on some simple empirical regularities, using regression studies in which we analyse the relationship between the variability of relative-price changes and the rate of inflation. The main purpose of the present chapter is to examine this relationship for Swedish data and to compare the results to earlier evidence for other countries.

The chapter starts with some important definitions. Then a review of earlier empirical findings is given. In the third section we analyse the relationship between the variability of relative-price changes and the expected and unexpected rate of inflation for the Swedish data. The definition of the formation of expectations is given here and it can be compared to other definitions in the empirical literature. In the last section we compare the results for Sweden with earlier evidence for other countries.

4.2 Review of Earlier Evidence

According to the previous analysis we can expect to find a positive relationship between

(i) the variance of relative price changes and the variance of the rate of inflation,
(ii) the variance of relative price changes and the <u>expected</u> rate of inflation, and
(iii) the variance of relative price changes and the <u>unexpected</u> rate

of inflation.

Suppose now that an increase in the variance of relative price changes causes both the variance of the rate of inflation and **the rate** of inflation to increase; then we can expect to find a positive relationship between

(iv) the variance of the rate of inflation and the rate of inflation.

The first and the third relationships are closely related, since an increased variance in the rate of inflation is likely to increase uncertainty about the inflation rate, and hence the unexpected rate of inflation 2

In this chapter we shall concentrate on (ii) and (iii), the statistical relationships between the variability of relative price changes and various concepts of inflation, though (i) and (iv) have also been studied in the literature

Before continuing, we need some notations and definitions. Let p it , be the price of commodity i at time t and let Dp it . denote the relative change in the price of this commodity, defined as

(4.1) $Dpit = \log p^{it} - \log pit\text{-}1$,

where $Dpit. = \log\left(\left(\frac{Pit}{Pit\text{-}1} - 1\right) + 1\right)$ F,9 $\approx \frac{Pit}{p_{it-1}} \quad \frac{Pit - Pit\text{-}1}{p_{it-1}}$

is approximately the percentage change in p_i from period t-1 to period t.

The logarithmic transformation is performed for analytical convenience and will be very useful in the next chapter when we work with a Cobb-Douglas technology. The logarithmic transformation has also been used in other studies and hence is advantageous when comparing empirical results.

Let P_t be the general price level and let DP t be the rate of inflation, where DP_t is a price index defined by

(4.2) $DP_t = \sum_i w_{it} Dp_{it}$.

where w_{it} will be specified in alternative ways.

The relative price of commodity i at time t is then defined as (p_{it}/P_t) and the change in the relative price as $(Dp_{it} - DP_t)$. Finally, we need a measure of the variability of relative price changes, corresponding to t in Chapter 2. We choose the variance measure in Theil (1967)[4]

(4.3) $Vp_t = \sum_i w_{it} (Dp_{it} - DP_t)^2$

where p_t refers to a vector of relative-price changes.

This measure has the property of increasing with the deviation of Dp_{it} from its urean DP_t. Observe that the urean of the relative prices changes is zero and that Vp_t is zero if all prices move in proportion. The w_{it} are weights and will be specified in alternative ways. The w_{it} are sometimes equal for each commodity, $w_{it} = 1/n$ or are defined as budget shares, $w_{it} = p_{it} q_{it} / \sum p_{it} q_{it}$.

In Tables 4.1 and 4.2 previous empirical evidence can be found. In Table 4.1 equations (1) to (4) are from Fischer (1981a), equation (5) from Fischer (1982), equations (6) to (12) from Blejer (1981), equations (13) to (17) from Parks (1978) and equations (18) to (21) from Blejer and Leiderman (1982).

In Table 4.1 we report results from regressions with Vp_t as the dependent variable and with EDP_t, DP_t, and $(DP_t - EDP_t)$ as the independent variables. EDP_t is defined in the following ways:

EDP_t (1) = Mean of price expectations of respondents to Survey Research Center Questionnaire; from Michigan Survey Research Center.

EDP (2) = Projection from five-variable vector autoregression.

EDP_t (3) = First-order autoregressive expectations, based on a projection on the basis of the rate of inflation in the previous period.

EDP_t (4) = Second-order autoregressive expectations.

EDP_t (5) = DP_{t-1}

EDP_t (6) = DP_{t-t} + Di_{t-1}

EDP_t (7) = i_t, where i_t is the nominal interest rate at time t.

In Table 4.1 Vp_t is defined according to (4.3) with different definitions of the weights w_i:

$$wi = Pigi / \pounds_j pigi$$

in equations (1) to (4) and (6) to (21), and

$$w_{it} = 1/n_t$$

in equation (5).

DP_t is defined as the consumption deflator in the national income accounts U as the consumer price index in each country, respectively.

Note that in equations (18) to (21), from Hlejer and Leiderman (1982), Vp_t has been divided between traded and non-traded goods. Equations (18) and (19) refer to traded goods and (20) and (21) to non-traded goods.

Table 4.1Results from regressions with Vp_t as the dependent variable. R^2 is the multiple correlation coefficient adjusted for degrees of freedom and D-W is the Durbin-Watson statistic. t-values are in parentheses.

Equation no.	Independent variables				Summary statistics	Sample period	Country
(1)	Constant	DP_t	DP_{t-1}		R^2=.397 D-W=1.79	1948:Q1-1980:Q1	USA
	-.081 (-2.7)	.046 (3.86)	-.008 (-.66)				
(2)	Constant	$EDP_t(1)$	$DP_t-EDP_t(1)$		R^2=.414 D-W=1.96	1961:Q2-1980:Q2	USA
	-.021 (-.62)	.018 (3.02)	.017 (2.41)				
(3)	Constant	$EDP_t(1)$	$DP_t-EDP_t(1)$		R^2=.370 D-W=1.90	1970:Q1-1980:Q2	USA
	-.48 (-.65)	.021 (1.96)	.030 (2.37)				
(4)	Constant	$EDP_t(1)$	$DP_t-EDP_t(1)$	$DP_t-EDP_t(1)$	R^2=.516 D-W=1.62	1961:Q2-1980:Q2	USA
	-.054 (-2.19)	.012 (2.72)	.074 (6.61)	-.030 (-2.43)			
(5)	Constant	$EDP_t(2)$	$DP_t-EDP_t(2)$	$DP_t-EDP_t(2)$	R^2=.212 D-W=1.74	1969:Q4-1980:Q4	West Germany
	-6.155 (-1.73)	1.082 (1.91)	4.085 (3.39)	-1.172 (-.87)			
(6)	Constant	DP_t			R^2=.352 D-W=1.56	1977:M1-1980:M4	Argentina
	-9.10 (-.86)	580.24 (4.36)					
(7)	Constant	$EDP_t(3)$	$DP_t-EDP_t(3)$		R^2=.380 D-W=1.39	1977:M1-1980:M4	Argentina
	45.71 (1.00)	-136.02 (-.23)	617.78 (4.56)				
(8)	Constant	$EDP_t(3)$	$DP_t-EDP_t(3)$	$Var(DP_t)$	R^2=.463 D-W=1.62	1977:M1-1980:M4	Argentina
	81.83 (1.79)	-751.66 (-1.21)	549.33 (4.18)	.43 (2.26)			
(9)	Constant	$EDP_t(4)$	$DP_t-EDP_t(4)$	$Var(DP_t)$	R^2=.392 D-W=1.77	1977:M1-1980:M4	Argentina
	-12.97 (-.40)	540.48 (1.18)	517.29 (3.62)	.48 (1.26)			
(10)	Constant	$EDP_t(5)$	$DP_t-EDP_t(5)$	$Var(DP_t)$	R^2=.463 D-W=1.62	1977:M1-1980:M4	Argentina
	4.56 (.36)	258.21 (1.43)	549.33 (4.18)	.97 (2.26)			
(11)	Constant	$EDP_t(6)$	$DP_t-EDP_t(6)$	$Var(DP_t)$	R^2=.533 D-W=1.73	1977:M1-1980:M4	Argentina
	6.00 (.55)	218.77 (1.41)	551.82 (4.51)	1.11 (2.79)			

Table 4.1 cont.

Equation no.	Independent variables				Summary statistics	Sample period	Country
(12)	Constant	EDPt(7)	DPt-EDPt(7)	Var(DPt)	R^2=.487 D-W=2.01	1977:M1-1980:M4	Argentina
	12.88 (.93)	-44.77 (-.17)	687.03 (4.74)	2.54 (2.92)			
(13)	Constant	DP2			R^2=.238	1921-1964	Holland
	.002 (5.85)	.254 (3.31)					
(14)	Constant	(DPt)^2	(DPt)2		R^2=.344	1921-1964	Holland
	.002 (6.32)	.094 (.97)	.387 (4.33)				
(15)	Constant	DP2			R^2=.562	1948-1975	USA
	.0001 (.91)	.258 (5.97)					
(16)	Constant	DP2			R^2=.347	1930-1941	USA
	.001 (1.66)	.288 (2.51)					
(17)	Constant	DP2			R^2=.476	1930-1941 and 1948-1975	USA
	.0003 (1.40)	.324 (5.97)					
(18)*	Constant	DPt			R^2=.362 D-W=1.43	1951-1976	Mexico
	.002 (5.00)	.111 (3.58)					
(19)	Constant	EDPt(3)	DPt-EDPt(3)		R^2=.365 D-W=1.88	1951-1976	Mexico
	.002 (4.00)	.026 (.46)	.325 (3.35)				
(20)**	Constant	DPt			R^2=.013 D-W=1.69	1951-1976	Mexico
	.001 (2.50)	.017 (.53)					
(21)**	Constant	EDPt(3)	DPt-EDPt(3)		R^2=.491 D-W=2.06	1951-1976	Mexico
	.001 (1.25)	.037 (.76)	.291 (4.10)				

Note * refer to tradeables and *- to non-tradeables

In Table 4.2 regressions of the coefficient of variation of relative price changes 5) on the rate of inflation, from Jaffee and Kleiman (1977), are reported.

In this table regressions of the coefficient of variation of relative price changes on the rate of inflation are reported for 13 different countries.

The reported regression equations are

$$vt = Vpt/2/ \quad DPt = a + b\ DPt1$$

Multiplying both sides by DP_t one obtains

$$Vp\,1/2 = a\ DPt + b$$

Hence, examination of the sign and significance of the coefficient a makes possible a comparison with the results in Table 4.1. From the regressions in Table 4.2 it can be seen that in 10 cases out of 13, a is positive and in 5 cases out of these 10, a is significantly positive at the 5 % level of significance.

Jaffee and Kleiman also report a cross-country regression of the average dispersion in relative price changes on the average rate of inflation:

$$Vp^{1/2} = 0.72 + 0.68\ DP$$

$$R2 = 0.73.$$

Table 4.2 Regressions with the coefficient of variation of relativa prices as the dependent variable. R^2 is the multipla correlation coefficient. t-values are in parentheses. The results are quotations from Jaffee and Kleiman (1977).

Equation no.	Independent variables		R^2	Sample period	Country
	Constant	DP_{t-1}			
(1)	.04 (1.33)	6.40 (11.43)	.916	1951-1966	Argentina
(2)	-.58 (-1.35)	5.21 (5.26)	.607	1952-71	Finland
(3)	.09 (.38)	4.60 (3.07)	.573	1962-70	Brazil
(4)	-.45 (-5.00)	2.84 (13.52)	.957	1963-72	West Germany
(5)	.36 (2.00)	**2.15** (5.51)	.639	1954-72	Japan
(6)	.11 (2.20)	1.73 (17.30)	.948	1954-72	Sweden
(7)	-.02 (-.29)	1.43 (11.00)	.653	1965-72	Norway
(8)	.12 (1.71)	1.34 (10.31)	.873	1965-72	United Kingdom
(9)	.07 (.37)	1.32 (.)	.463	1963-70	France
(10)	.19 (9.5)	1.27 (.)	.972	1958-72	Denmark
(11)	.37 (3.36)	1.25 (5.43)	.653	1956-72	Israel

The cross-country regression reveals a significant positive relationship between the average dispersion rate and the average rate of inflation.

Tables 4.1 and 4.2 show that there is evidence of a positive significant relationship between the variance (or the standard deviation) of relative price changes and the actual (squared) rate of inflation. This is the case for USA, Argentina, Holland, United Kingdom, Denmark, Israel, and Chile. In some cases quarterly or monthly data were used, but in most cases data were annual observations.

In addition, the actual rate of inflation was divided into different components:

1. division between actual inflation and deflation.
2. division between expected and unexpected inflation according to different assumptions on the formation of expectations.
3. division of unexpected inflation into unexpected inflation and unexpected deflation.

Finally, in Blejer and Leiderman (1982), Vp_t was divided between traded and non-traded goods.

As we can see in Table 4.1 the results are not quite unambiguous. These tests are joint tests of the hypothesis of inflation exerting a positive influence on the variability of relative price changes and the hypothesis of the formation of inflationary expectations, except when actually observed expectations are used.

According to the models of inflation discussed above 6) , prices may be rigid in some markets of the economy and hence inflation and the variability of relative price changes may both increase in response to an increase in excess demand.

In Parks (1978) the coefficients for squared inflation and deflation both are positive, but only <u>deflation</u> is significant . Turning to Fischer (1981a), the division between unexpected inflation and deflation was accomplished in another way. $(DP_t - EDP_t)$ equals $(DP_t - EDP_t)$ if greater than zero, and equals zero otherwise. Negative unexpected inflation is $(DP_t - EDP_t)^- = (DP_t - EDP_t) - (DP_t - EDP_t)^+$. In this

case the coefficient for the deflation variable is expected to be negative. It turns out that the coefficients have the expected signs, but in one case the deflation variable is not significant.

These findings are consistent with the hypothesis of downward price rigidity in some sectors of the economy, since an increased excess supply would lead to ever falling prices in some sectors and to fixed prices in the price-rigid sectors. However in the case of increasing excess demand, prices in all sectors would rise, but at different rates.

As for the division of DP_t into EDP_t and $(DP_t - EDP_t)$, the expected and unexpected rates of inflation, the results are somewhat mixed.

In the first place, the negative intercepts found in equations (1) to (5) in Fischer (1981a) and Fischer (1982) and in equations (6) and (9) in Blejer (1981), does not make sence since Vp_t by definition always must be non-negative. This probably reflects misspecifications; e.g. the wrong functional form may have been used.

Secondly, a general finding is a positive significant relationship between Vp_t and $(DP_t - EDP_t)$, while in only two cases is EDP_t significant at the 5 t level of significance. The significant EDP_t are from Fischer (1981a): in both cases the constant term was negative. Since these results hold for a number of different assumptions of how expectations of the rate of inflation are formed, the indication is strong that the variance of relative price changes is most heavily linked to the unexpected rate of inflation.

We now turn to the Swedish evidence.

In this section the analysis in Chapters 2 and 3 on the hypothesised relationship between the variability of relative price changes and various concepts of inflation is given empirical content. The empirical exercises will follow the line of the previous section, and hence will be a means to accumulate evidence on a particular point. However, it should be pointed out that these simple regressions, as in Tables 4.1 and 4.2, are by no means exhaustive, but are performed to

provide comparisons with evidence for other countries and to give a first indication of the relationship between the variables concerned. A more complete framework will be given in Chapters 5 and 6.

According to the previous analysis we should expect to find a positive relationship between the variability of relative price changes and the rate of inflation. Hoth expected and unexpected inflation might influence the variability of relative price changes.

First, we must introduce the definitions of Vp_t, DP_t, and EDP_t, i.e. the variability of relative price changes, the actual rate of inflation and the expected rate of inflation, respectively.

Vp_t is defined according to (4.3), i.e. as

$$Vp_t = \sum_i w_{it}(Dpi_t - DP_t)^2$$

where the w_{it} are weights or budget shares.

Three different measures of Vp_t have been used. In one case we have used the six aggregate commodities in the CPI . A problem in this case, apart from the disadvantage of the highly aggregated data, is that the quality of the different goods has changed over time. In general, there does not exist any known method by which these quality changes can be incorporated consistently into a cost-of-living index or into a measure like Vp_t. In order to avoid this problem we define Vp_t for a set of (approximately) constant-quality commodities, C. For the sample period 1951-1979 we were able to select 44 such commodities, whose budget shares in the CPI were calculated in 1955, when the commodities accounted for 24 t of total private consumption. These commodities are listed in Appendix 3.

The variability measure for the aggregate six commodities is defined as

$$(4.4)\quad Vpt = \sum_{i=1}^{6} wit\,(Dpit - DPt)^2.$$

where $wit = pitgit / \sum_j pjtgjt.$

The constant-quality variability measure is defined as

$$(4.5)\quad VPa = \sum_{i \in C} w_i\,(Dpit - DPt)^2,$$

where $wi = P_i g_i / \sum_{j \in C} pjgj'$

where C is the set of constant-quality commodities.

Now we have two variability measures, one which is highly aggregated and one which consists of only constant-quality commodities. Ignoring quality changes, we can define a third variability measure, used also by Vining and Elwertowski (1976), in which all the commodities in the CPI are used:

$$(4.6)\quad VPt = \sum_{i=1}^{n_t} wit(Dpit - DPt)^2$$

where w it= 1/n t for all i. This is the <u>unweiahted</u> variability measure and incorporates all commodities in the CPI. The nutuber of commodities varies over time, with a minimum of 212, and a maximum of 335. Further description of the data is given in Appendix 2.

The actual rate of inflation is here measured by the Swedish CPI, and the expected rate of inflation, EDP_t, is defined in two alternative ways. It is supposed that the expected rate of inflation at time t, EDP_t, is a function of the lagged actual rate of inflation:

$$(4.7)\quad EDPt = f(DPt\text{-}1, DP_{t-2}, \ldots).$$

(4.7) is specified as

$$(4.8)\quad EDPt = DPt\text{-}1 + a0(DPt\text{-}1 - DP_{t-2}) + a1(DPt\text{-}2 - DPt\text{-}3)$$

and as

$$(4.9)\quad EDDA = (1\text{-}b)DPt\text{-}1 + (1\text{-}b)bDP_{t-2} + (1\text{-}b)b2DPt\text{-}3 .$$

(4.8) is known as extrapolative expectations and (4.9) as adaptive expectations. Under the adaptive expectations hypothesis, the individuals are assumed to revise their expectations according to their most recent forecast error (and hence it is a learning process):

$$EDPt\text{-}EDPt\text{-}1 = Ä(DPt\text{-}1 - EDP\ t\text{-}1)$$

which can be solved for EDP_t as

$$EDP_t = (1-b) \sum_{k=0} b^k DP_{t-1-k}$$

where b=1-X.

The extrapolative and adaptive expectations hypotheses have been widely used in theoretical and empirical work. The extrapolative hypothesis is due to Metzler (1941) and was later used by Goodwin (1947). The adaptive expectations hypothesis is due to Cagan (1956).

The adaptive expectations hypothesis has also been supported by empirical evidence. Valentine (1977), Defris and Williams (1979), Jacobs and Jones (1980) and Jonung (1983) have found some empirical support for this hypothesis in their empirical work with actually observed expectations in Australia, USA and Sweden. Theoretical support for the adaptive expectations is given in Turnovsky (1969), who shows that a decision maker, forming expectations by using a Bayesian sampling procedure, will change his expectations adaptively.

The estimations of the expected rate of inflation to be used subsequently resulted in the following predictions[10].

$a_0 = -0.32$ (0.17) $\qquad a_1 = -0.47$ (0.18)

$b = 0.41$ (0.14)

Note. Standard errors in parentheses.

The Bums of the lagged coefficients are unity for the extrapolative scheme and 0.93 for the adaptive scheme. Hence the adaptive scheme adopted here systematically underestimates inflation. Note also the negative signs for the a-coefficients: this means that the expected rate of inflation is revised <u>downwards</u> if the rate of inflation has <u>increased</u> for the last three years. This is quite reasonable if agents perceive the business cycle.

Before turning to the regressions we should inspect the development over time in Vp_t, DP_t and $(DP_t - EDP_t)$. This is shown in Figures 4.1 to 4.3. In Figure 4.1 we have depicted Vp_t^a, DP_t and $(DP_t - EDP_t^A)$ for the period 1951-1979. In Figure 4.2 wc have depicted Vp_t^d, DP_t and $(DP_t - EDP_t^A)$, and in Figure 4.3 Vp_t^u, DP_t and $(DP_t - EDP_t^A)$. $(DP_t - EDP_t^A)$, the unexpected rate of inflation, has been measured in <u>absolute</u> terms, since, according to the hypothesis, it should not matter whether it is positive or negative.

For the aggregated Vp_t^a in Figure 4.1 there seems to be a closer relationship between Vp_t^a and DP_t than between Vp_t^a and $(DP_t - EDP_t^A)$.

There are two major increases in Vp_t^a during the sample period, between 1955-60 and in the 1970s. During the first of there periods there is a peak in DP_t and $(DP_t - EDP_t^A)$ in 1956. In the 1970s both Vp_t^a and DP_t rise and are closely related. Both Vp_t^a and DP_t show an increasing trend during the latter period.

Turning to the highly disaggregated data of Vp_t^u in Figure 4.3 it turns out that there is a much closer correspondence between Vp_t^u and the inflation variables.

Looking again at Figure 4.3 it is clear that Vp_t^u follows a procyclical pattern. The peaks in 1951, 1955, 1959, 1962, 1965, 1970-71, 1974 and 1979 can be recognised. This finding reinforces the finding in the Luras model of Chapter 2, in which both the variance of the general price level and the variance of relative prices were driven by the variance of exogenous demand shocks.

It is hard to discover trendlike movements in the constant-quality data in Figure 4.2. But both in Figure 4.1 and in Figure 4.3, with a bit of imagination, the trends in both Vp_t^u and DP_t seem to be U-shaped. This is particularly evident for Vp_t^a and Vp_t^u.

Figure 4.1. pta, DPt and (OPt-EDPA), 1951-1979. x 100

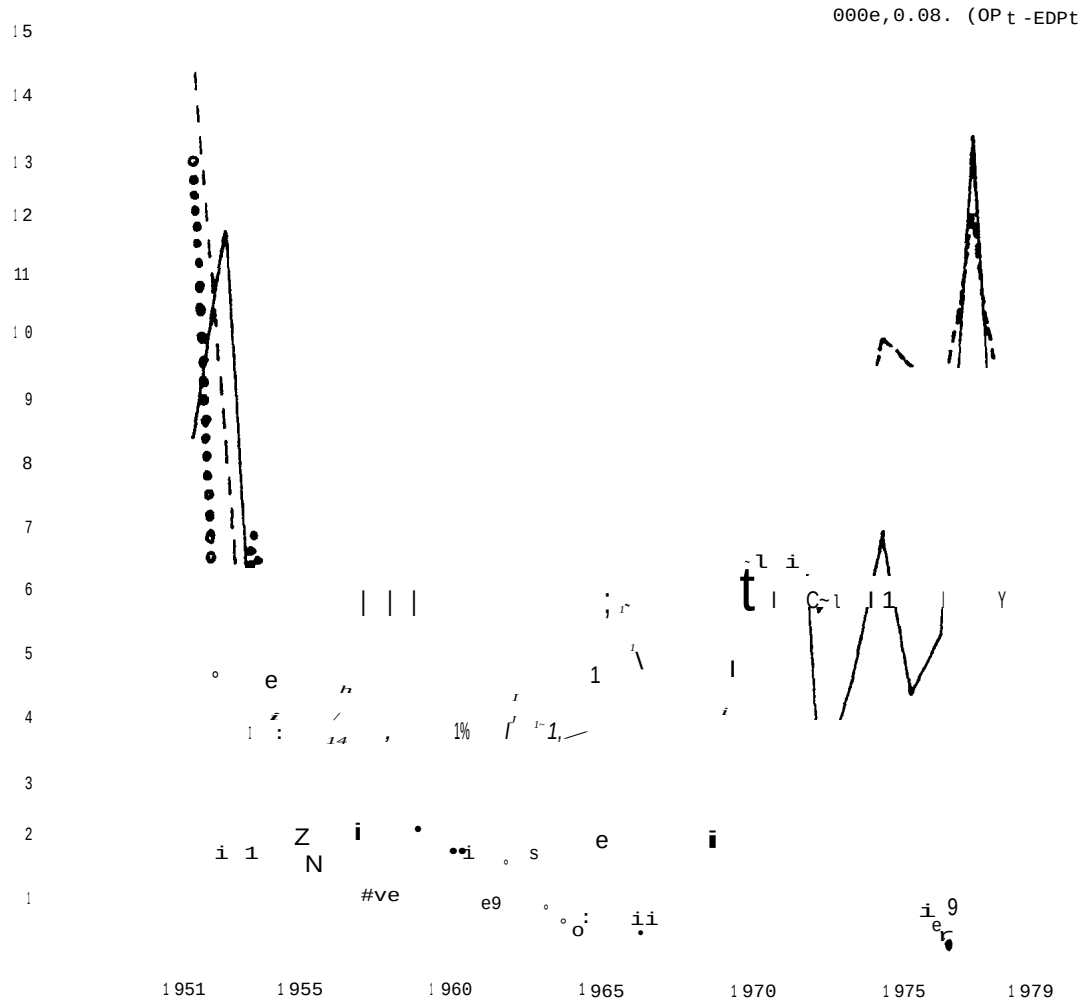


Figure 4.1. Vp_a, DP_t and (DP_t-EDPA), 1951-1979.

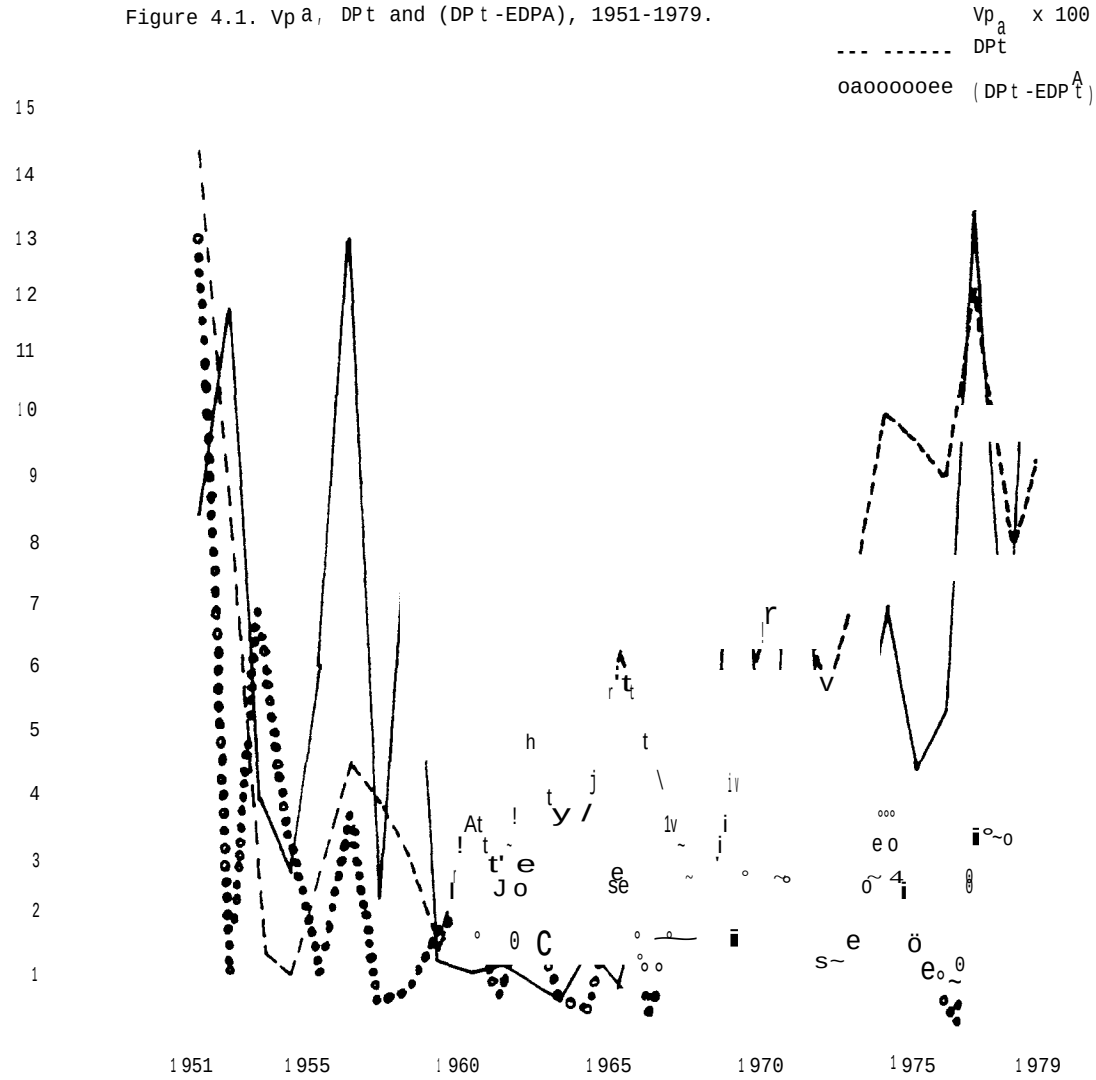


Figure 4.2. Vpd, DPt and (DPt-EDPA), 1951-1979.

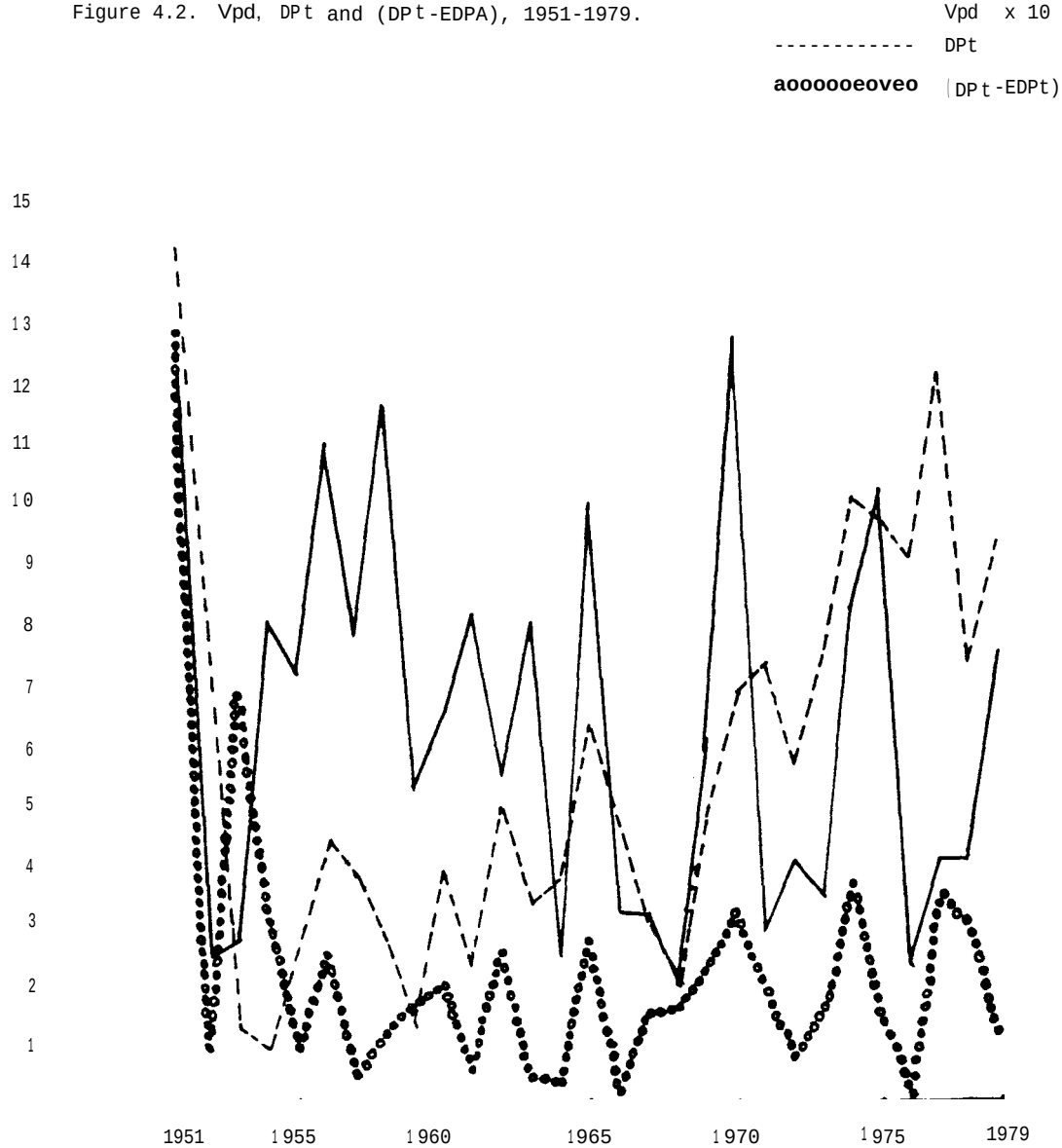
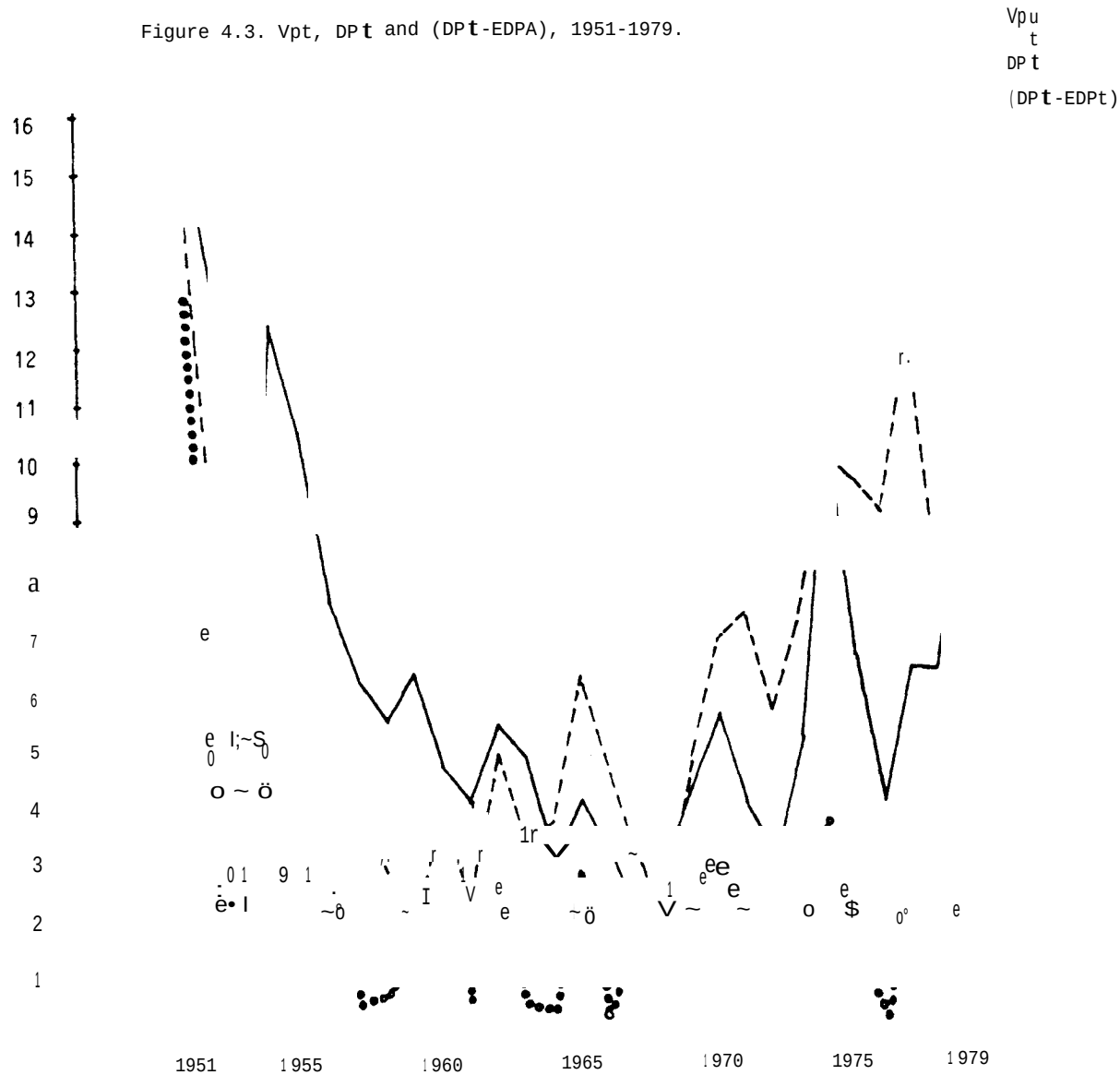


Figure 4.3. Vpt, DPt and (DPt-EDPA), 1951-1979.



We now turn to the regressions of Vp_t on different measures of inflation, for the sample period 1951-1979. We have used the three variance measures Vp^a_t, Vp^d_t and Vp^u_t as the dependent variables in the regressions. These have been regressed on DP^A_t, EDP^A_t and $(DP_t - EDP^A_t)$, and EDP^E_t and $(DP_t - EDP^E_t)$, respectively. All in all, that makes 9 equations. In addition, we have checked for first-order serial correlation in the errors, and in some cases the correlation coefficient between the residuals was significant. Running the regressions with both error processes, OLS and AR(1), we have 18 equations. The results are presented in Table 4.3. The nine equations presented in Table 4.3 **have been chosen according to the appropriate error process.** Following Engle (1974), this is done by accepting the hypothesis of a first-order autoregressive process if e is greater than 0.6 and statistically significant at the 5 % significance level. This is a rule of thumb for choosing between the OLS process and the AR(1) process. For the regressions with Vp^d_t and Vp^u_t the AR(1) process is rejected but for the regressions with Vp^a_t the AR(1) process is accepted.

That leaves us with nine equations for which we can test the overall significance using F-tests on R^2. In five cases the regression equations are significant at the 5 % level of significance: in equations (1), (5), (7), (8) and (9) of the table. In equation (1), Vp^a_t is regressed on DP_t and the t-value for the latter is 2.74. In the latter four equations all regressions with Vp^u_t as the dependent variable show overall significance. When Vp^u_t is regressed on DP^2_t and expected and unexpected squared inflation, under extrapolative expectations, respectively, the equations are significant at the 1 % level. Both expected and unexpected inflation are significant at the 1 % level.

When adaptive expectations are assumed, as in equation (8) in the table, the overall fit is significant at the 5 % level. However, in this case, unexpected inflation is significant only at the marginal significance level of about 20 % and also show a wrong negative sign.

Table 4.3 Regressions of Vpt, Vpt and Vpt on actual, expected and unexpected inflation. R^2 is the multiple correlation coefficient adjusted for degrees of freedom, F is the F-statistic, p is the estimated first-order correlation coefficient for the residuals and D-W is the Durbin-Watson statistic. t-values are in parentheses. The critical values of the F- and t-distributions at the 5 % leve] are F(2,26) = 3.38 and t(26) = 2.056.

Equation no.	Dependent variable	Independent variables						R2	F(2.26)	p	D-W
		konstant	DP^2	EDP_t^2	$(DP_t - EDP_t)^2$	EDP_E^2	$(DP_t - EDP_E)^2$				
1	Vpt	.00038 (4.063)	.04122 (2.741)					.189	7.511	-	2.104
2	vpt	.00040 (3.454)		.04597 (1.721)	.02115 (.832)			.048	1.706	-	2.302
3	v a	.00040 (3.499)				04145 (1.735)	.02695 (.847)	.053	1.780	-	2.338
4	Upt	.00568 (6.937)	.13621 (1.045)					.003	1.092	-	1.926
5	vpt	00714 (8.434)		-.40447 (-2.057)	28501 (1.525)			.157	3.612	-	2.095
6	Vpt	.00668 (7.745)				-.25265 (-1.394)	.42553 (1.763)	.108	2.690	-	2.134
7	v u	.00328 (1.938)	.05962 (3.380)					.400	19.66	679 (4.9)	2.056
8	vpt	.01264 (3.025)		-.85481 (-3.126)	-.25557 (-1.471)			.293	6.812	.911 (13.2)	2.000
9	v u	.00443 (4.712)				.37389 (2.388)	74432 (4.110)	.470	13.406	.617 (2.49)	1.976

In Table 4.3 we can also see that the t-values for expected *inflation* in general are higher than for unexpected inflation, hence giving support to the non-neutral hypotheses put forward in Chapter 3. The constants all have the right positive signs and are always significant at the 5 °•. level.

The best fits are found in equations (7) and (9), with R^2 *being* 0.40 and 0.36 respectively, when Vp_t^u is used as the variability measure and when extrapolative expectations are assumed. Vp_t^u is the unweighted variability measure, where <u>all</u> the commodities in the CPI are used, and hence give a measure of the total variance. So does Vp_t^a, but the variance within the six aggregate commodity groups is then ignored. Finally, the constant-quality commodity measure, Vp_t^d, is very poorly explained here. Therefore, it seems as if Vp_t^u is the measure we should prefer. Vp_t^u is significantly related to both expected and unexpected inflation, with the correct expected positive signs on the parameters, and the overall fit is highly *significant.*

4-4 nter<u>nationa</u>l Evidencc_~_A Comparison

The results found here are similar to those found by Fischer (1981,1982) for USA and West Germany, (equations (1) to (5) in Table 4.1), except that Fischer l;btained a rather odd negative *constant* in the regression equations . It should be noted that Fischer used the actually observed *inflationary* expectations of the Michigan Survey Research Center. As here, Fischer found actual, expected and unexpected *inflation* to be positively and significantly related to the variance of relative price changes.

The findings for Sweden confirm earlier evidence for USA, Argentina, Holland and Mexico, for the relationship between the variability of relative-price changes and the actual rate of *inflation.*

The evidence here, that both expected and unexpected inflation are significantly related to Vp_t, contradicts the findings by Blejer (1981) for Argentina and Blejer and Leiderman (1982) for Mexico. They found unexpected inflation significant, but not expected inflation.

Though the findings here are fairly strong, when compared to earlier foreign evidence, and in general support the hypotheses put forward, the relatively low multiple correlation coefficients indicate that the underlying model could be improved. Therefore, in the next chapter we shall analyse the determination of relative price variability in a more sophisticated model.

5 A MODEL OF RELATIVE PRICES AND RELATIVE-PRICE VARIABILITY IN AN OPEN ECONOMY

5.1 Introduction

The reduced form regressions of the previous chapter are hard to interpret. In the present chapter, we shall therefore try to give the model more structure. This shall be carried out by constructing a model, based on the previous theoretical review in Chapters 2 and 3, in which price variability is determined.

We are interested in the possible non-neutrality that night exist from the influence of expected inflation on the variability of relative price changes. In order to test that hypothesis, we construct a neutral model, in the spirit of Chapter 2. It is then possible to test whether the addition of non-neutrality to the model significantly affects the variability of relative prices

Before developing the model, however, we shall provide a short review of previous theoretical models, in which the relationship between inflation and relative-price variability has been explicitly analysed.

5.2 Earlier Theoretical Models

As could be seen in Chapters 2 and 3, the variability of relative prices can be analysed within different frameworks. One framework is provided by the Lucas model in Chapter 2, where price variability is not affected by the expected rate of inflation. In other models, such as those of Tobin (1972), Sheshinsky and Weiss (1977) or Okun (1981), relative price variability is directly linked to the expected rate of inflation.

Explicit treatment of the variability of relative prices in theoretical models can be found in Parks (1978), Cukierman (1979), Cukierman and Wachtel (1979,1982), Fischer (1981a,1981b,1982) and in Blejer and Leiderman (1982). In Chapter 2 we have already discussed the development of the Lucas model by Cukierman and Wachtel. Here we

shall focus our attention on the models in Parks (1978) and Blejer and Leiderman (1982). The model in Cukierman and Wachtel (1979,1982) is stochastic, while the models of Parks and Blejer and Leiderman are deterministic. The model of Blejer and Leiderman is an extension of Parks' model to an open economy.

In Parks' model, supply and demand functions are defined for each market i and the economy consists of n such markets. The supply function on market i is defined as

$$(5.1)\quad \log q_{it} = a_i + \theta_i \log (p_{it}/EP_t) + \gamma_i t$$

where p_{it} is the price of commodity i at time t and EP_t is the expected price level, t is a time trend and log is the natural logarithm. We could call (5.1) a deterministic Lucas supply function. Parks rationalises it as a supply function developed from a Cobb-Douglas production technology, where all n commodities are used as inputs. An alternative, and more realistic, rationalisation for this type of supply function is given in the next section.

Parks also defines demand functions

$$(5.2)\quad \log q_{it} = \eta_i \log p_{it} + \pi_i \log y_t$$

where y_t is the money income, $-q_i=p_i$ ensures homogeneity of degree zero in income and prices and all cross-price effects are ignored. Equating supply and demand and solving for pit, this model determines $Vp_t = Lw_{it}(Dp_{it} - DP_t)$ as a function of $(DP_t - EDP_t)$, $(Dy_t - DP_t)$ and some cross-terms. Hence, it conforms well with the Lucas model discussed in Chapter 2.

Within a similar framework, Blejer and Leiderman (1982) analyse relative price variability for an open economy. They decompose Vp_t for traded and non-traded goods and assumes that $EDP_t = \theta EDP_{Tt} + (1-S)EDP_{NTt}$ (where T and NT refer to traded and non-traded goods, and $0<\theta<1$) is the rationally expected rate of inflation. Vp_t in this model then also depends on deviations between DP_{Tt} and DP_{NTt}

Parks' and Blejer and Leiderman's models are estimated by OLS regressions and the results were presented to the reader in Table 4.1. We now turn to the development of a similar model for an open economy.

5.3 The Model

The model here will be in the spirit of the model in Parks (1978). We shall derive supply and demand functions for a set of markets and determine Vp t in the model. We start with the supply side.

Firstly, we assume that a representative firm operates under a Cobb-Douglas technology with constant returns to scale, using labour, raw materials and capital as inputs. The capital stock is assumed fixed and the production function is defined by

(5.3) q = lambkl-a-b

where k, a, b, and c are constants, 1 is the quantity of labour, m is the quantity of raw materials, k is the capital stock and q is the quantity of output.

Since we assume the elasticity of substitution to be one, and use both labour and raw materials in the production function, this formulation might, at firmt sight, appear somewhat unrealistic. Since a CES-function would have been inconvenient for the empirical analysis later on, we shall use the Cobb-Douglas as an approximation. Another simple alternative to the Cobb-Douglas would have been a production function with raw materials proportional to output 1) . However, it can be argued that substitution between labour and raw materials actually take place and can even be substantial. If raw material prices rise, it is likely that one tries to economise on raw materials, e.g. by changing technical constructions, the composition and tolerances of different products, trying to waste less, etc. In that process, raw materials will typically be substituted with labour. In addition, since aggregate data is used in the empirical analysis, substitution will take place between firms, and, for firms producing more than one output, between products.

The profit function for the representative firm can be veritten as

$$(5.4)\quad a = pq - (wl + p^m m + p^k k),$$

where w is the wage rate, p_m the price of raw materials and where p^k may be thought of as a quasi-rent on capital.

The **firm takes all** prices, output price and input prices, as given. However, assume that the labour market can be characterised by the following simple supply and demand functions, which are, for the sake of convenience, assumed to be linear

$$(5.5)\quad ls = 11 + 12(w/EP)$$

and

$$(5.6)\quad ld = 13 + 14(w/EP),$$

where 1^s is labour supply, 1^d is labour demand, 11, 1Z, 13, and 14 are parameters, and EP is the expected price level. (5.5) and (5.6) states that 1 and 1 depends on the expected real wage rate, where the general price level is not perfectly known.

This kind of labour market model is chosen, since, as we shall see, it gives the required results: a neutral model, insofar that only unexpected inflation affects real variables. We can interpret the expected real wage (w/EP) in the following way: At each point in time the employees know their nominal wage w with certainty, but lack complete information on the general price level. Indexing time with t, EP_t is the price level which the agents anticipate at time t. This expectation is assumed to be formed at some earlier date, presumably at time t-t. Hence, EP_t is based on information before time t. This desription of the labour market is accurate in situations where nominal wage conditions at time t are contracted at time t-i, which is a common procedure in practice.

The labour market clearing wage then is

$$(5.7)\quad w = \left(\frac{13}{2} - \frac{11}{4}\right) EP.$$

Let (13-11)/(12-14)=A. Since both w and EP are assumed to be positive, A is positive.

The labour market supply function assumes that labour supply depends on real wages before taxes. If we introduce a linear tax rate in the supply function, the latter changes to

$$^{s} = 11 + 12(w(1-t)/EP)$$

and the nominal wage in equilibrium to

$$(5.7')\quad w = \left(\frac{1}{2}\,\frac{11-11}{4}\,\frac{t}{2}\right) EP$$

Letting $(13-11)/(12-14-12t)=A'$ we see that A'>A if t>O. Furthermore, if t increases over time, A' will not be a constant but will increase over time. However, labour market studies 3) general reveal low supply elasticities and hence 1 2 t will be small . In addition, if wage subsidies are introduced into the demand function, the equilibrium wage changes to

$$(5.7'')\quad w = \left(\frac{1}{2} - \frac{13}{14} - \frac{11}{2}t - \frac{1}{4}s\right) EP$$

where s is the fraction of the wage rate which is subsidised. Letting $(13-11)/(12-14+14s-12t)=A''$, we see that the difference between A and A " depends on the size of (14s-12t). If the latter is zero, A=A '' . In this model, we ignore taxes and subsidies, assuming that (1 4 s-1 2 t) is small, and we adhere to the simple relationship (5.7).

Given labour market equilibrium, the profit function of our representative firm changes to

(5.4') $a = pq - (A\ EP\ l + p_m\ m + p_k\ k)$.

The cost function[4] for the firm is

(5.8) $e(EP, p_m, q, k) = \min (A\ EP\ 1 + p_m\ m + p_k\ k)$

subject to $1^a\ m^b\ k^{1-a-b} = q$. The notation e should not be confused with the exponential function.

Solving the problem (5.8) we obtain a cost function

$$(5.9)\quad e(EP, p_m, q, k) = G\ EP^{\frac{a}{a+b}}\ p_M^{\frac{b}{a+b}}\ q^{\frac{1}{a+b}}$$

where G is a constant, given by

$$G = k^{\frac{1-a-b}{a+b}}\ \left(\left(\frac{b}{a+b}\right)^{\frac{b}{a+b}} + \left(\frac{b}{a}\right)^{-\frac{a}{a+b}}\right) A^{\frac{a}{a+b}},$$

The profit maximisation problem of the representative firm is

$$(5.10)\quad \max_q\ p\ q - G\ e(.)\ q^{\frac{1}{a+b}}$$

The first-order condition is

$$aab\ e(.)\ q^{\frac{1-a-b}{a+b}} = 0$$

which can be solved for q to give the equilibrium supply function for the representative firm:

$$(5.12)\quad q = \left(p \frac{(a+b)}{Ge(.)}\right)^{\frac{a+b}{1-a-b}}$$

Taking logs of the supply function, it can be expressed in log-linear form as

$$(5.13)\quad \log q = 8 + a \log (p/EP) + 0 \log (p/p_m),$$

where 8, a, and 0 are constants, given by

$$(5.14)\quad e = laabb\,(\log (a+b))\sim\ a = 1-a\_b \text{ and } S = 1_{-a-b}$$

The parameters in the supply function are positive, i.e. supply reacts positively to increases in output price and negatively to increases in input prices.

With EP defined according to (4.7) or (4.8), and **introducing the index** i for the particular market and t for a certain time period, we complete the supply side of the model with the following supply functions:

$$(5.15)\quad \log qsu = 8_i + a_i \log (pi_t/EP_t) + Si \log (pi_t/pm_t)$$

It remains to specify the demand side of the model. Here we will introduce an influence from the rest of the world: the demand for Swedish goods from abroad. The demand functions are specified as

(5.16) $\log q_{it} = ;i + rli \log (pit/pt) + ui \log (yt/Pt) +$

$ei \log (pit/PWt) + yi \log (yf/PWt)$

where y_t^d is domestic money income, y_t^f is foreign money income, P_t is the domestic price level and PW_t is the foreign price level. For simplicity, all cross-price effects are ignored. The demand functions are homogenous of degree zero in income and prices. The expected signs of the parameters are q,<0, M,>0, e_i<0 and ~,>0. Hence, quantity demanded depends on domestic and foreign real income and on relative prices, the domestic relative price and the domestic commodity price relative to the foreign price level, all expressed in the domestic currency.

This system of supply and demand functions typically embodies the neutrality property, since both supply and demand functions are homogenous of degree zero in nominal variables. Multiplying all variables measured in the monetary unit with some scalar A>0 would leave the system in equilibrium with all quantities unaffected.

Equating supply and demand, we can solve for the equilibrium price on market i at time t, p it, . Using Dp it= log p_{it} -log p it-1 , we can solve for the relative change of the price of commodity i at time t.

(5.17) Dpit Qi (-aiEDPt+ SiDpmt -(qi+pi)DPt + uiDyd

- eiDPWt + 0i(Dyt-DPWt))

where $g_i = (\alpha_i + \beta_i - \varepsilon_i - \eta_i)$.

The solution for the change in relative-prices can be obtained by subtracting with DP_t on both sides of (5.17) as:

$$(5.18)\quad Dp_{it} - DP_t = \frac{1}{g_i}\Big(-a_i(DP_t - EDP_t) + p_i(Dp_{at} - DP_t) + N_i(Dy_d - DP_t) + e_i(DP_t - EDP_t) + (DY_f - DPW_t)\Big).$$

We can also solve for the rate of inflation, defined by $DP_t = \sum_i w_i Dp_{it}$ as:

$$(5.19)\quad DP_t = \frac{1}{k}\Big(\sum_i \frac{w_i}{g_i} EDP_t + \sum_i \frac{w_i}{g_i} Dp_{at} + \sum_i w_i \frac{f_i}{g_i} Dy_t^d - \sum_i w_i \frac{e_i}{g_i} DPW_t + \sum_i w_i \frac{\tilde{i}}{g_i} (DY_t^f - M)_t\Big),$$

where

$$k = 1 + \sum_i w_i g_i$$

(5.18) and (5.19) forms a recursive system in the sense that (5.18) contains only the independent variables EDP_t, Dp_{mt}, Dy_t, DPW_t and $(Dy_t^f - DPW_t)$ and the endogenous variable in (5.19), DP_t. Inserting the right-hand side of (5.19) on the right-hand side of (5.18), we get the solution for the change in relative-price on commodity i at time t as:

$$(5.20)\quad Dpit-DPt = \left(\frac{a_i}{g_1} - \frac{k_i}{k_l} L_{wi} \frac{a_i}{g_1} \right) EDPt +$$

$$\left(\frac{\sim i}{g_i} - \frac{k_i}{k} L_{w_i} \frac{\theta_i}{g_i} \right) Dpmt +$$

$$\left(\frac{\mu_i}{g_i} - \frac{k_i}{k} w_i \frac{\mu_i}{g_i} \right) Dyt^d -$$

$$\left(\frac{e_i}{g} - \frac{k_i}{k_l} L_{w_i} \frac{E_i}{g} \right) DPWt +$$

$$\frac{\sim i}{gi} \frac{k-}{k} r\, w_i \frac{}{gi} \left(Dy_t - DPW_t \right)$$

where k,=(n,+N,+g,)/g,.

According to (5.18), relative-price changes depend on unexpected inflation, $(DP_t - EDP_t)$, relative-price changes on raw materials, $(Dp_{mt} - DP_t)$, changes in domestic real income, $(Dy_t^d - DP_t)$, the deviation from the purchasfng power parity, $(DPt - DPWt)$, and changes in foreign real income, $(Dy_t - DPW_t)$.

Hence, once again it is evident that changes in relative-prices only depend on real variables except for the unexpected rate of inflation. The model can therefore, in our terms be Galled a neutral one. However, note that it allows for the domestic price level to deviate from the foreign price level, ex p~essed in the domestic currency. Hence, the model is not super-neutral, since the law of one price is not imposed.

From the previous analysis of the signs of the parameters in the supply and demand functions, it follows that $g_i>0$. The effects on the change in relative prices from a change in any of the independent variables are ambiguous. For example, the effect of a change in $(DP_t - DPW_t)$, the deviation from the purchasing power parity, is

$$(5.21)\quad \frac{8(Dp_{it}-DP_t)}{a(DP_t-DPW_t)} \quad \frac{1}{g_i}\left(C_i - a_i\,\frac{DDP_t}{a(DP_t-DPW_t)}\right.$$

$$d_i\,\frac{gDP_t}{a(DP_t-DPW_t)} - v_i\,\frac{9DP_t}{a(DP_t-DPW_t)}$$

$$\left.\sim_i\,\frac{DDP_t}{a(DP_t-DPW_t)}\right).$$

If the change of the deviation from the purchasing power parity comes from a change in DP_t, the right-hand side of (5.21) reduces to

$$\frac{(\varepsilon_i-\alpha_i-\beta_i-\mu_i-\psi_i)}{g_i}$$

and if it comes from a change in DPW_t, the right-hand side of (5.21) is

$$\frac{1}{g_i}\left(E, - (a_i\,\Delta_i + u_i + O_i)\right)\left(1\ w_i\ \frac{E1}{g_i} + L\ W_{..}\ \frac{\sim 1}{-}\right).$$

The signs of these partial derivatives are ambiguous and depend on the supply and demand parameters on the different markets.

The variance of relative-price changes in the model can now also be determined.
We use the variability measure (4.3), $Vp_t = L\ w_i\,(Dp_{it} - DP_t)^2$, where the w_i's are assumed to be constant over time. (5.18) inserted in (4.3) gives the variance of relative-price changes in the model as

$$
\begin{aligned}
(5.22)\ V_{pt} = {} & B_1 (DP_t - EDP_t)^2 + B_2 (Dpm_t - DP_t)^2 + B_3 (DY_t - DP_t)^2 + \\
& B_4 (DP_t - DPW_t)^2 + B_5 (DY_f - DPW_t)^2 + B_6 (DP_t - EDP_t)(DP_{mt} - DP_t) + \\
& B_7 (DP_t - EDP_t)(Dy_t - DP_t) + B_8 (DP_t - EDP_t)(DP_t - DPW_t) + \\
& B_9 (DP_t - EDP_t)(Dy_t - DPW_t) + B_{10} (Dpm_t - DP_t)(DY_d - DP_t) + \\
& B_{11} (DPm_t - DP_t)(DP_t - DPW_t) + B_{12} (DPm_t - DP_t)(Dy_t - DPW_t) + \\
& B_{13} (DY_t - DP_t)(DP_t - DPW_t) + B_{14} (Dy_t - DP_t)(DY_f - DPW_t) + \\
& B_{15} (DP_t - DPW_t)(DY_f - DPW_t),
\end{aligned}
$$

where the B-coefficients and their expected signs are given by

$$
(5.23)\ B_1 = \sum w_i \frac{a_i^2}{g_i} > 0,\quad B_2 = \sum w_i \frac{\delta_i^2}{g_i} > 0,\quad B_3 = \sum w_i \frac{\mu_i^2}{g_i} > 0,
$$

$$
B_4 = \sum w_i \frac{\gamma_i^2}{g_i} > 0,\quad B_5 = \sum w_i \frac{\delta_i^2}{g_i} > 0,\quad B_6 = 2\sum w_i \frac{-\alpha_i \gamma_i}{g_i} < 0,
$$

$$
B_7 = 2\sum w_i \frac{-a_i \gamma_i}{g_i} < 0,\quad B_8 = 2\sum w_i \frac{-\gamma_i}{g_i} < 0,
$$

$$
B_9 = 2\sum w_i \frac{\gamma_i}{g_i} < 0,\quad B_{10} = 2\sum w_i \frac{\delta_i}{g_i} > 0,
$$

$$
B_{11} = 2\sum w_i \frac{\pi_i \gamma_i}{g_i^2} < 0,\quad B_{12} = 2\sum w_i \frac{\delta_i}{g_i^2} > 0,
$$

$$
B_{13} = 2\sum w_i \frac{\delta_i}{g_i^2} < 0,\quad B_{14} = 2\sum w_i \frac{\mu_i \gamma_i}{g_i^2} > 0 \text{ and}
$$

$$
B_{15} = 2\sum w_i \frac{\epsilon_i \psi_i}{g_i^2} < 0.
$$

The model developed here differs from previous models in the following ways. Compared to the Lucas model in Chapter 2, the model here is deterministic. It is more general than Lucas' model in that it allows different supply and demand parameters between markets and gives an explicit role to foreign demand and for raw material prices. The open economy model is an natural extension in an empirical study for Sweden. The role input prices, like oil prices, have been emphasised by others[6], and it is likely that they have had sonve influence on relative-price variability. The present model is, however, in one respect more restrictive than the Lucas model, since inflationary expectations are restricted to be equal between inarkets.

Compared to the models in Parks (1978) and in Blejer and Leiderman (1982), the present model is a generalisation, since it considers the effects of raw material prices and, compared to Parks, the effects of foreign demand.

The possible non-neutral effects from the exaected rate of inflation, discussed in Chapter 3, will be taken up in the next sections, when we formulate the hypotheses to be tested.

5.4 Estimation of the Model

This section begins with a brief discussion of the data which are available for estimation. Then we analyse the econometric methods which will be used and specify the hypotheses to be tested. Finally, we discuss the results which are expected on the basis of our model.

5.4.1 The Data

A full specification of the data sources are given in Appendix 2. Here we shall briefly discuss the problems which arise when our model is faced with the data and the necessary adjustments that these problems imply.

The data required are given by the equatfons (5.18) and (5.22). We need data on DP_t, Dpm_t, Dy_t, DPW_t, Dy, and Vp_t. As in the previous chapter consideration is given to these different measures of Vp_t. Vp_t^a, Vp_t^d, and Vp_t^u. All these measures are computed from the price

series in the Swedish CPI. Here our first problem arises. In the theoretical model, supply and demand prices were supposed to be the same. However, in practice, the supplier delivers goods to a wholesaler, who in turn delivers to a retailer. In addition, there are turnover taxes which further add to the suppliers' price. In some cases, prices are subsidised, so that consumer prices can be lower than producer prices. I have not found any practical solution to this problem.

The effect of the difference between supply and demand prices can be evaluated. We introduce the percentage markup Å it, Å it >-1, so that the supply price is p it , and the demand price (1+x it)p it. This changes the solution for relative-price changes to

$$(5.24)\quad Dpit-DPt = \frac{(-ai(DPt-EDPt)}{gi} + pi(DPmt-DPt) + Ni(Dyt-DPt) + ei(DP_t-DPWt) + Oi(Dyt-DPWt) + (ni+ei)\,Dit)$$

The term $1/g_i\,(n+c_i)DÅ_{it}$ is added to (5.18). Thus, estimating (5.18) instead of (5.24) amounts to deleting the term above from the estimation. This estimation gives biased estimates of the parameters, since (5.18) is a misspecification. For instance, the estimate of $(-a_i/g_i)$, the coefficient for $(DP_t - EDP_t)$, will instead be equal to

$$\frac{-ai}{g_i} + \left(\frac{li+ei}{g_i}\right)\frac{cov((DPt-EDPt),DAit)}{var((DPt-EDPt))}$$

where the last term is the bias. Hence, if the independent variables are uncorrelated with DA it in the sample, we still obtain unbiased estimates of the parameters in the model.

As in the previous chapter, DP_t has been measured as the annual change in CPI and Dy_d f as the annual change in GNP in the Swedish National Accounts. Dyt, changes in foreign money income, has been measured as annual changes in GNP for 12 OECD-countries , those countries which

are the most important trade partners for Sweden. In the measurement of Dy^f_{kt}, exchange rates changes have been taken account of, so that each GNP-change has been adjusted by the appropriate change in the exchange rates.

Each country's GNP-change has been weighted by itf share of imports of these 12 countries' total imports from Sweden. Dy_t can be written as

$$(5.25)\quad Dy^f = \sum_k \frac{M_{it}}{\sum_j} Dykt \qquad k=1,....12$$

where M_{kt} is the value of exports to country k at time t and Dy^f_{kt} is the change in GNP in country k at time t.

DPW_t has been constructed in a similar way. In this case each country's consumer price index has been weighted to give

$$(5.26)\quad DPW_t = \sum_k \frac{M_{kt}}{\sum_j M_{jt}} DPW_{kt} \qquad k=1,...,12$$

where DPW kt is the change in CPI of country k at time t.

This leaves us with the input-price variable, Dp_{mt}, changes in raw material prices. Dp_{mt} has been collected from the National Accounts as the implicit price index on raw materials.

In the empirical estimation we will also include a constant term. This is consistent with the inclusion of a time trend in the production function, i.e. (5.3) is replaced by

$$(5.3')\quad 4 = e^{61t}\ la\ mb\ k1\text{-}a\text{-}b$$

and (5.13) by

(5.13') $\log g = A + a \log (P/EP) + S \log (p/p_m) + b\ t$

where b=b' c, and c is a constant. $e^{b't}$ is usually included because of labour-saving technical progress. Therefore, the inclusion of this term should take care of some of the long-run effects in the supply function.

This completes the discussion of the data and we now go on to specify the empirical model and the econometric methods.

5.4.2 Hyootheses and Econometric MOdels

The basic models to be tested are given by (5.18) and (5.22). Ordinary least squares seems to be the efficient estimation method in these cases, since both (5.18) and (5.22) are linear in the parameters.

When a time trend is included in the production functions and the supply functions are replaced by (5.13'), we obtain the additional equations

(5.27) $Dpit\text{-}DPt = {}_{gi}{}^{(-DLi(DPt-EDPt)} + 0i(DPmt-DPt) +$

$N_i(Dyt-DPt) + e_i(DP_t-DPWt) + \sim i(Dy\ t-DPWt) - bi)$

and

(5.28) $Vpt = K + B0 + B16(DPt-EDPt) + B17(DPmt-DPt) +$

$B18(DYt-DPt) + B^{19}(DPt-DPWt) + B2U(Dyf-DPWt)$,

where K is the right-hand side of (5.22) and the additional parameters and their expected signs are

$$B_{0} = E_{wi} \frac{\delta_i^2}{g_i^2} > 0, \quad B_{16} = 2 E_{wi} \frac{\delta_i \alpha_i}{g_i^2} > 0,$$

$$B_{17} = 2 E_{wi} \frac{\gamma_i}{g_i} < 0, \quad B_{18} = 2 E_{wi} \frac{\gamma_i}{g_i} < 0,$$

$$B_{19} = 2 E_{wi} \frac{-\delta_i \varepsilon_i}{g_i^2} > 0 \text{ and } B_{20} = 2 E_{wi} \frac{-\delta_i \psi_i}{g_i^2} < 0.$$

The equations (5.18), (5.22), (5.27) and (5.28), with stochastic terms added to them, form our regression equations. These equations are <u>neutral</u> in the sense discussed at length in Chapter 2.

To test if the expected rate of inflation has a significant <u>non-neutral</u> effect on relative-price changes, EDP_t is added to (5.18) and (5.27). EDP_t is measured as before, according to adaptive or extrapolative expectations, respectively. We then obtain a set of equations (5.18'), (5.22'), (5.27') and (5.28') for the non-neutral hypothesis: (5.18) changes to

$$(5.18') \quad Dp_{it} - DP_t = \frac{1}{g_i} \left(-a_i (DP_t - EDP_t) + p_i (Dp_{mt} - DP_t) + \right.$$
$$\left. \gamma_i (Dy^d - DP_t) + e_i (DP_t - DPW_t) + *_i (DY_f - DPW_t) \right) +$$
$$E_i EDP_t$$

and (5.27) changes to

$$(5.27')\quad Dpit-DPt = \frac{}{9i}\,(-a_i(DP_t-EDPt) + 9\,(Dp^{mt}-DPt) +$$

$$u_i(Dy^t-DP_t) + e_i(DPt-DPWt) + \$i(Dy\,t-DPWt)$$

$$-6_i) + EiEDPt$$

A Priori, we know nothing about the sign of $_i$. For some goods it may be negative and for others positive. According to the discussion in Chapter 3, we know that an increased rate of expected inflation would increase relative price variability. However, for a certain time period some relative prices would decrease while others would increase, due to differences in price adjustment costs, and there is no method which enables us to discriminate between these different goods. Developing Vp_t for (5.18') and (5.27'), we obtain

$$(5.22')\quad Vpt = K + B_{22}EDP2 + B_{23}EDPt(DPt-EDPt) +$$

$$B_{24}EDPt(Dp_{mt}-DPt) + B_{25}EDPt(Dyt-DPt) +$$

$$B_{26}EDPt(DPt-DPWt) + B_{27}EDPt(Dyt-DPWt),$$

where K is the right-hand side of (5.22) and the additional parameters and their expected signs are

$$B_{22} = £wi\,\frac{E_i}{2}\,>0,\quad B23=2£wi\,\frac{-aiEi}{2}\,\gtrsim 0,$$

$$B24 = 2\,£\,w_i\,\frac{SiEi}{2}\,\gtrless 0,\quad B25 = 2\,1\,wi\,\frac{oiEi}{2}\,>0,$$

$$B26 = 2\,£\,wi\,\frac{eiki}{2}\,\gtrless 0 \text{ and } B27 = 2\,£\,wi\,\frac{OiEi}{2}\,\gtrsim 0.$$

The only unambiguous sign is for e_{22}, which is positive, while the cross-term parameters have no determinate signs. Developing Vp_t for (5.27') will not be done here, since the nutuber of parameters then would be as many as our nurober of observations.

To estimate the models given by (5.18), (5.22), (5.27), (5.28), (5.22') and (5.27'), a stochastic structure has to be imposed. The models are linear in **the parameters, so ordinary least** squares would seem to be appropriate. A stochastic disturbance term u_t is added to (5.18), the equation for relative-price changes without an intercept. This can be rationalised on the grounds that shocks to the supply and demand functions are permanent, so that these shocks **are2random walks.** Then u_t is white noise with $E(u_t)=0$ and $E(u_t)=o$, where o is positive and finite. A stochastic disturbance, v_t, is also added to the right-hand side of (5.19). It then appears that this disturbance show up on both sides of (5.18). Hence, OLS is not appropriate for (5.18), since measurement errors in DP_t would give rise to biased estimates. Therefore, a regression of DP_t on the independent variables in (5.19) was roade, and the predicted values of DP were used on the left-hand side of (5.18) in the estimations 8) . Using t this procedure, OLS can be applied to (5.18), (5.18'), (5.27) and (5.27').

With these assumptions, Vp_t changes to

$$Vp_t = E\ wit(DPit-DPt)2 + i\ wit\ u\ it \qquad i=1,\ldots.\ n$$

The error term in (5.22) is then a sum of squared normally distributed random variables and hence must be chi-square distributed. However, from the Central Limit Theorem, we know that the distribution of the sum of n independent, 9identically distributed random variables is asymptotically normal Hence, as n the error term E w i u it approaches the shape of the normal density with positive and finite mean and variance.

Hence, OLS is an appropriate estimation method for the equations (5.22), (5.22') and (5.28) if n is large. However, note that the expectation of the error term is positive and not zero. The effect of the error term being positive can be seen in considering the following simple regression model. Suppose E(u t)=a'>0. Then we can write the

regression model as

$$y_t = a + 0x_t + u_t + (a' - a') = (a + a') + yx_t + (u_t - a')$$

$$= \alpha^* + \beta x_t + u_t^*$$

where

$$u_t^* = (u_t - a')$$

and where

$$E(u_t^*) = E(u_t - a') = a' - a' = 0$$

Hence, the effect of an error term with a positive mean implies a change in the intercept. In our case, an intercept should be included in the estimation, *which* should be positive, to account for the expected positive mean of the residuals. Consequently, B_0 is added to (5.22) and (5.22').

However, the large-sample properties of the error terms cast some doubts on the use of highly aggregated data and this might explain the better fit obtained for the disaggregated data in Vp_t^u in the previous chapter. The presence of a chi-squared distributed error may actually explain the negative intercepts in Fischer (1981,1982), who used 12 commodity groups and hence could expect small-sample bias. Since n varies between 212 and 335 in Vp_t^u, but is only 6 for the aggregated Vp_t^a and 44 for the constant-quality commodity set in Vp_t^d, it seems appropriate to apply OLS on the disaggregated data.

The estimations will proceed in two steps. First, we estimate equation (5.22) and (5.22') by OLS. To see if the time trend in the production functions improves the fit, we also estimate (5.28). Secondly, we estimate (5.18), (5.18'), (5.27) and (5.27') with (Dp_{it} -DP_t) as the dependent variables, equation by equation. Since the same independent variables appear on the right-hand sides of these price equations, OLS is an efficient estimation method.

In addition to the neutrality hypothesis, we also test whether relative raw material prices, (Dp_{mt} -DP_t), or the influence from foreign variables, (DP_t -DPW_t) and (Dy_t^f -DPW_t), significantly affect

relative-price changes and the variability of relative price changes. The likelihood ratio test is then applied, with the risk of some small sample bias.

The likelihood ratio test says that twice the difference between the logarithmic likelihood value for the model with n free parameters and the corresponding value for the more restricted model with n-k free parameters is asymptotically chi-square distributed with k degrees of freedom under the null hypothesis of the more restricted model. In addition to the likeliho;ö ratio test, we also apply the F-test on the sum of squared residuals

5.4.3 Some Econometric Problems

The regression equations given by (5.22) and (5.27) give rise to some econometric problems. As seen in (5.22) we could expect some of the independent variables to be highly correlated. It is even more apparent in (5.28), where, e.g., both unexpected inflation and squared unexpected inflation are included as independent variables. Therefore we expect the multicollinearity problem to arise here.

Since there is no perfect collinearity between the independent variables it is possible to obtain the least squares estimates of the parameters. However, the interpretation of the single parameters will prove difficult, in the presence of multicollinearity, since the *ceteris Paribus* interpretation of the parameters is no longer valid. In general, the presence of multicollinearity tends to produce large estimated variables of the regression coefficients, while the overall significance of the regression is not affected. Of course, the presence of multicollinearity might induce the researcher to drop some truly significant variables and hence impose a misspecified model with biased estimates.

In our problem, however, we are not primarily interested in the value of single parameters. The significance of the following variables are tested:

(1) raw material prices,
(2) foreign variables and
(3) expected inflation.

In the first case, five variables are excluded while in the second case seven variables are dropped from the model (5.22). Hence, if the correlation between the omitted and the remaining variables are low, the multicollinearity problem does not give rise to any problems in our hypothesis tests. In fact, this is likely to be the case here, since what is excluded here, is one variable, e.g. relative raw material prices, along with some cross-term variables which include raw material prices. This is particularly obvious when we use the model (5.28), which includes a constant term, since then the model includes certain variables and the square of them and among these correlation is high.

The treatment of serial correlation is carried out in the same way as in the previous chapter. We test for first-order autocorrelation and reject the hypothesis of no autocorrelation if g>0.6 and is statistically significant at the 5 % level of significance. In that case AR(1) is a better choice than the OLS error process, even if the true error process is of higher order.

With these preliminary qualifications we now turn to the estimations and the empirical results.

5.5 The Emoirical Results

In this section we present the main results of the regression analysis and the tests of the hypotheses. The regression equations are given by (5.18), (5.22), (5.27) and (5.28). In the test for non-neutrality we include EDP_t and get the additional equations (5.18'), (5.22') and (5.27').

5.5.1 Relative-Price.Variabilit

First we consider the regressions with Vp_t^u as the dependent variable, based on (5.22) and (5.28). The test will be a 'ofint test, since we also test the hypotheses on the formation of expectations, as given by (4.7), extrapolative expectations, and (4.8), adaptive a expeectationu. Since we also have three different measures of Vp_t : Vp_t, Vp_t and Vp_t, the nutuber of possible regression equations is quite large.

The regression results ars here presented for the use of Vp_t^u, the unweighted variability measure, and EDP_t^E, expected inflation with extrapolative expectations. It should be noted that the main results did not change when Vp_t^a and Vp_t^d were used or when adaptive expectations were assumed. However, the overall fit of the equations was better, as in Chapter 4, when Vp_t^u was used as the dependent variable and when extrapolative expectations were assumed.

Table 5.1 presents the results from the regression with (5.22). Likelihood ratio tests are carried out for the overall significance of the model and for the hypotheses, put forward above.

Hence, the likelihood ratio test is applied to the model (5.22) and the restricted hypothesis that all the 15 parameters equal zero. The test is made by taking twice the difference between the log of the likelihood 2 function of the model (5.22), and of Vp_t^u constant. The resulting X (15)=39.5 is compared to the critical value of 30.58 at the 1 °•. level of significance. Hence, the model (5.22) is not rejected by the data.

An alternative test to the likelihood ratio test is the F-test on R^2. The F-ratio is 14.27 and the critical value at the 1 % significance level is 3.82. Hence, the hypothesis that all parameters in (5.22), except the constant, is zero, is rejected by our data.

As can be seen in Table 5.1, there are few coefficients that are significant at the 5 t level of significance (with a critical value for a two-sided test of the t-distribution = 2.145) according to the t-values given in the parentheses. The model is by itself not rejected by the likelihood ratio test. The large estimated standard errors of the estimated coefficients might be dus to multicollinearity, i.e. to the relativsly high torrelation between the independent variables.

Table 5.1. Regression equation based on (5.22). Dependent variable is Vp_t. The expected sign of each coefficient is is given. t-values are reported in parentheses. The equation is corrected for first-order autocorrelation with g = .91.

Independent variables	Expected sign of coefficient	Coefficient estimates
Constant	$B_0 > 0$	.00541 (4.98)
$(DP_t - EDP_t)^2$	$B_1 > 0$	1.440 (1.97)
$(DP_{mt} - DP_t)^2$	$B_2 > 0$	1.310 (2.40)
$(DY^d - DP_t)^2$	$B_3 > 0$	-.750 (-1.38)
$(DP_t - DPW_t)^2$	$B_4 > 0$	-5.369 (-2.49)
$(DY_t - DPW_t)^2$	$B_5 > 0$	.627 (1.71)
$(DP_t - EDP_t)(DP_{mt} - DP_t)$	$B_6 < 0$	-1.884 (-1.13)
$(DP_t - EDP_t)(DY^d - DP_t)$	$B_7 < 0$	4.018 (2.98)
$(DP_t - EDP_t)(DP_t - DPW_t)$	$B_8 < 0$	5.115 (2.49)
$(DP_t - EDP_t)(DY_t - DPW_t)$	$B_9 < 0$	-5.147 (-3.22)
$(DP_{mt} - DP_t)(DY^d - DP_t)$	$B_{10} > 0$	.790 (.93)
$(DP_{mt} - DP_t)(DP_t - DPW_t)$	$B_{11} < 0$	5.206 (1.90)
$(DP_{mt} - DP_t)(DY_t - DPW_t)$	$B_{12} > 0$	.559 (.79)
$(DY^d - DP_t)(DP_t - DPW_t)$	$B_{13} < 0$	1606 (.65)
$(DY^d - DP_t)(DY_t - DPW_t)$	$B_{14} > 0$	-.526 (-.68)
$(DP_t - DPW_t)(DY_t - DPW_t)$	$B_{15} < 0$	2.144 (1.27)

Log of likelihood function = 152.53

Standard error of the regression = .00181903

$\bar{R}^2 = 0.877$

We now turn to the tests of our hypotheses. The further hypothesis is that expected inflation also affects relative price variability. In addition, we also test the significance of relative raw material prices and the foreign variables. Note that the tests here are made as it (5.22') could be treated as a maintained hypothesis. That presents no problems, since if H 0 :(5.22) and H1:(5.22'), H 0 is rejected by our data. Again, we apply the likelihood ratio test and the results are presented in Table 5.5. As can be seen, all the restricted hypotheses are rejected, i.e., expected inflation, relative raw material prices and the foreign variables are all significant at the 1 : level of significance of the X^2-distribution. In Tables 5.2 and 5.3 we present the regressions where raw material prices and the foreign variables have been dropped, respectively, while Table 5.4 gives the results when EDP^E_t has been added to the model. Again, a limited number of variables are significant in the regressions. Note however, that in the regression with EDP_t added to the model, both unexpected and expected inflation is **significant** at the 5 : level of the t-distribution.

The regression results are presented in Table 5.6. The introduction of a time trend in the production function significantly improves the fit. The **likelihood ratio statistic is** $_X$ =74.30, which is larger than the critical value of 14.45 at the 2.5 % significance level. Both relative raw material prices and the foreign variables improve the fit of the model, which is shown by the likelihood ratio tests in Table 5.7. Hence, if we accept the model (5.28), with a constant in the supply function, as a maintained hypothesis, we must reject the hypothesis that neither relative raw material nor the foreign variables do not affect relative-price variability. The application of F-tests gives similar results at the 5 % level of the F-distribution.

Table 5.2. Regression equation based on (5.22') but with raw material prices excluded. The dependent variable is Vpt. The expected signs of each coefficient are given. t-values are reported in parentheses. The equation is corrected for first-order autocorrelation with g = .86.

Independent variables	Expected sign of coefficient	Estimated coefficients
Constant		00211 (.69)
$(Dp^t - EDP\ t)^2$	B1 > 0	1.722 (3.34)
$(Dy - DPt)^2$	B3 > 0	-.134 (-.22)
$(DP\ t - DPWt^2$	B4 > 0	1.139 (.44)
$(Dyt\ DPWt)^2$	B5 > 0	-.274 (-.90)
(DP t EDPt (Dy a-DPt)	B_7 < 0	-2.665 (-1.68)
$(DP^t - ED\ t)(DPt\ DPWt)$	B 8 < 0	-1.358 (-.55)
(DPt-EDt)(Dyf DPWt)	B9 < 0	1.079 (.90)
(DY'-DPt)(DPt-DPWt)	B13 < 0	.190 (.07)
$(Dy^d - DP\ t)(Dy\ f - DPWt)$	B io > 0	.974 (1.39)
(DPt-DPW t)(DYt-DPW t)	B15 < 0	.085 (.07)
EDP^2t	B22 > 0	1.149 (1.94)
EDPt (DPtEDPt)	8 23 > 0	2.522 (2.87)
EDPt (Dyt-DP t)	B25> 0	-.287 (-.257)
EDPt (DPtDPwt)	B26> 0	-.257 (-.16)
EDP t(Dyt-DPW t)	B27 ~ 0	-.248 (-.41)

Log of likelihood function = 147.34

Standard error of the regression = .0021943

$\bar{R}^2 = 0.454$

Table 5.3. Regression equation based on (5.22') with the foreign variables excluded. Dependent variable is Vpt. The expected signs of each coefficient are given. t-values are reported in parentheses. The equation is corrected for first-order autocorrelation with p = .94.

Independent variables	Expected sign of coefficient	Estimated coefficient
nt		00336 (1.02)
(DPt-EDP t)^2	B1 > 0	1.650 (5.75)
(Dpmt DP t)^2	B2 > 0	-.271 (-1.49)
(Dyd-DP t)^2	B3 > 0	.141 (.49)
(Dpt-EDP t)(DPmt DPt)	B6 < 0	-.868 (-1.87)
(DPt-EDPt)(DYt-DPt)	B7 < 0	-1.591 (-4.17)
(DPm£DPt)(Dytd-DPt)	B10 > 0	-1.575 (-2.32)
EDP2	B22 > 0	.671 (3.55)
EDP t(DPtEDPt)	B23> 0	2.479 (5.32)
EDP t(DpmtDPt)	B 24< 0 >	1.450 (4.76)
EDPt (DYdd-DP t)	B25-:7 0	.287 (.84)

Log of likelihood function = 153.62

Standard error of the regression = .00148255

R 2= 0.745

Table 5.4. Regression equation based on (5.22'). Dependent variable is Vpt. The expected signs of each coefficient are given. t-values are reported in parentheses. The equation is corrected for first-order autocorrelation with p = .99.

Independent variables	Expected sign of coefficient	Estimated coefficient
Constant		0051q (.83)
(DPt EDPt) 2	$B_1 > 0$	2.692 (5.482)
(DPrit DPt) 2	$B_2 > 0$	.070 (.21)
(DYa-DPt)	$B_3 > 0$	-.161 (-.26)
(DPt DPWt) 2	$B_4 > 0$	.116 (.06)
(DY f-DPW t)	$B_5 > 0$	-.365 (-1.84)
(DPt EDPt) (D Pmt DP t)	$B_6 < 0$	-1.068 (-1.189)
(DPtEDPt)(DydDP,)	$B_7 < 0$	-3.072 (-2.23)
(DPtEDPt)(DPt DPWt)	$B_8 < 0$	-3.437 (-1.51)
(DPtEDPt)(Dyt-DPW t)	$B_9 < 0$	.358 (.19)
(UPrnt DPt)(DYt DPt	$B_{10} > 0$	-1.388 (-1.089)
(D Pmt DPt)(DPt DPWt).	$B_{11} < 0$.	7.922 (1.92)
(DPmt DPt)(DYf-DPWt)	$B_{12} > 0$	-.646 (-.65)
(Dya -DPt (DP t - DPWt	$B_{13} < 0$	1.690 (.76)
(DY t DPt (DY t-DPW t)	$B_{14} > 0$	.097 (.15)
(DP t DPW)(Dyt DPW t	$B_{15} < 0$	1.588 (1.45)
(EDP t) 2	$B_{22} > 0$	.233 (.45)
EDP t(DP-EDP t)	$B_{23} > 0$	3.236 (5.39)
EDP t(Dpnt DP t)	$B_{24} > 0$	2.146 (5.00)
EDP t(D t-DP t)	$B_{25} > 0$	-.572 (-.58)
EDP t (DP tDPWt)	$B_{26} \sim 0$	-2.136 (-2.10)
EDP t (DYf-DPWt)	$B_{27} s 0$	.781 (1.93)

of likelibood function = 179.97

Standard error of the regression = .00092954

$\bar{R}^2 = 0.974$

.....

Table 5.5. L;kelihood ratio tests. The tests are made at the 2.5 % significance level.

These are the log likelihood values of the different models:

.....

(5.22)	152.53
(5.22')	179.97
(5.22') excl. Dpmt	147.34
(5.22') excl. the foreign variables	153.62

(i) Test of Dp_{mt}

2 x (179.97-147.34) = 65.26

=> raw material prices accepted

$X^2(6) = 14.45$

(ii) Test of foreign variables.

2 x (179.97-153.62) = 52.70

=> foreign variables accepted

$X^2(11) = 21.92$

(iii) Test of EDP t

2 x (179.97-152.53) = 54.88

=> expected inflation accepted

$X^2(6) = 14.45$

Table . 5.6. 'Regression. equation .based on (5.28). Dependent variable is Vpt The expected sign of each coefficient is given. t-values are rePorted in parentheses. The equation is corrected for first-order autocorrelation with g = .95.

Independent variables	Expected sign of coefficient	Estimated coefficient
Constant	B ' p > p	(1.628)
(DPt -EDP t)	8 1 6 > 0	. 145 (1.991)
(Dp mt DP t	8 17 <0	. 150 (2.729)
(D t-DP t)	a18< 0	-.126 (-.872)
(DPt -DPW t)	B 1 9 > 0	-.010 (-.066)
(Dy t DPW t)	B 20 < 0	.036 (1.175
(DPtEDP t)2	a 1 > 0	1.354 (4.080)
(Dpmt Dp t)2	B 2 > 0	1.045 (2.621)
(DY d _DP t)2	B 3 > 0	1.032 (.589)
(DPtDPW t) 2	B 4 > 0	-2.633 (-1.351)
(DytDPW t)2	B 5 > 0	.032 (.109)
(DPt EDPt)(Dpmt DPt)	B6 < 0	-1.676 (-1.311)
(DP tEDPt)(DYd-DPt)	B 7 < 0	-.286 (-.139)
(DPtEDP t)(DPtDPW t)	B 8 < 0	2.175 (1.060)
(Dpt -EDP t)(Dyt-DPW t)	B 9 < 0	-3.462 (-1.567)
(DPmt DP t) (D t-DP t)	B 1 0 > 0	-4.732 (-2.161)
(DPmt DPt) (OPtDPWt	B 11 < 0	2.647 (.846)
(DPmt DF t) (DY tDPWt)	8 12 > 0	1.340 (1.871)
(DY d-DPt)(DPt DPWt)	B 13 < 0	-.077 (-.018)
(DY d-DP t)(Dyt-DPWt)	B 14 >0	-.473 (-.484)
(DPt DPWt)(Dpt DPWt)	B 15 < 0	2.163 (2.361)

Log of likelihood function = 175.54

Standard error of the regression = .0018326

R2 = .874

.....

Table 5.7. Likelihood ratio tests. The tests are made at the 2.5 % significance level.

These are the log likelihood values of the different models:

.....

(5.22)	138.39
(5.28)	175.54
(5.28) excl. Dpmt	145.95
(5.28) excl. foreign variables	151.67

(i) Test of trend term in production functions.

2 x (175.54-138.39) = 74.30

=> trend term is accepted

$\chi^2(6)$ = 14.45

(ii) Test of Dpmt-

2 x (175.54-145.95) = 59.18

=> raw material prices are accepted

$\chi^2(6)$ = 14.45

(iii) Test of the foreign variables.

2 x (175.54-151.67) = 47.74

=> the foreign variables are accepted

$\chi^2(11)$ = 21.92

.....

In conclusion, the empirical analysis of the models of relative-price variability, given by (5.22) and (5.28), provide support for the model. The neutral model is clearly a misspecification, since the expected rate of inflation significantly affects Vp_t^u. In addition, according to our data, the further development of the model in Parks (1978), through the inclusion of relative raw material prices and some foreign variables, significantly improves the model.

The effect on Vp_t of an increase in any of the independent variables cannot be seen directly from the estimated coefficients. In fact, if we take the partial derivatives of Vp_t with respect to any of the independent variables in (5.22'), these partial derivatives are not unambiguous but involve inner derivatives, such as

$$B\ 15\ DPW_t \qquad 9\ DPW_t \qquad 8(Dyt\text{-}DPWt)$$

which depend on whether it is Dy_t^f or DPW_t which changes. However, we can compute the additional effect on Vp_t from including the non-neutral property through EDP_t. This can be done by taking the partial derivative of the difference between (5.22') and (5.22), with respect to EDP_t. Let

$$A\ Vpt = B22EDP2 + B23EDPt(DPt\text{-}EDPt) + B24EDPt(Dpmt\text{-}DPt) +$$

$$B25\ EDPt(Dyt\text{-}DPt) + B26EDPt(DPt\text{-}DPWt) + B27EDPt(Dyt\text{-}DPWt).$$

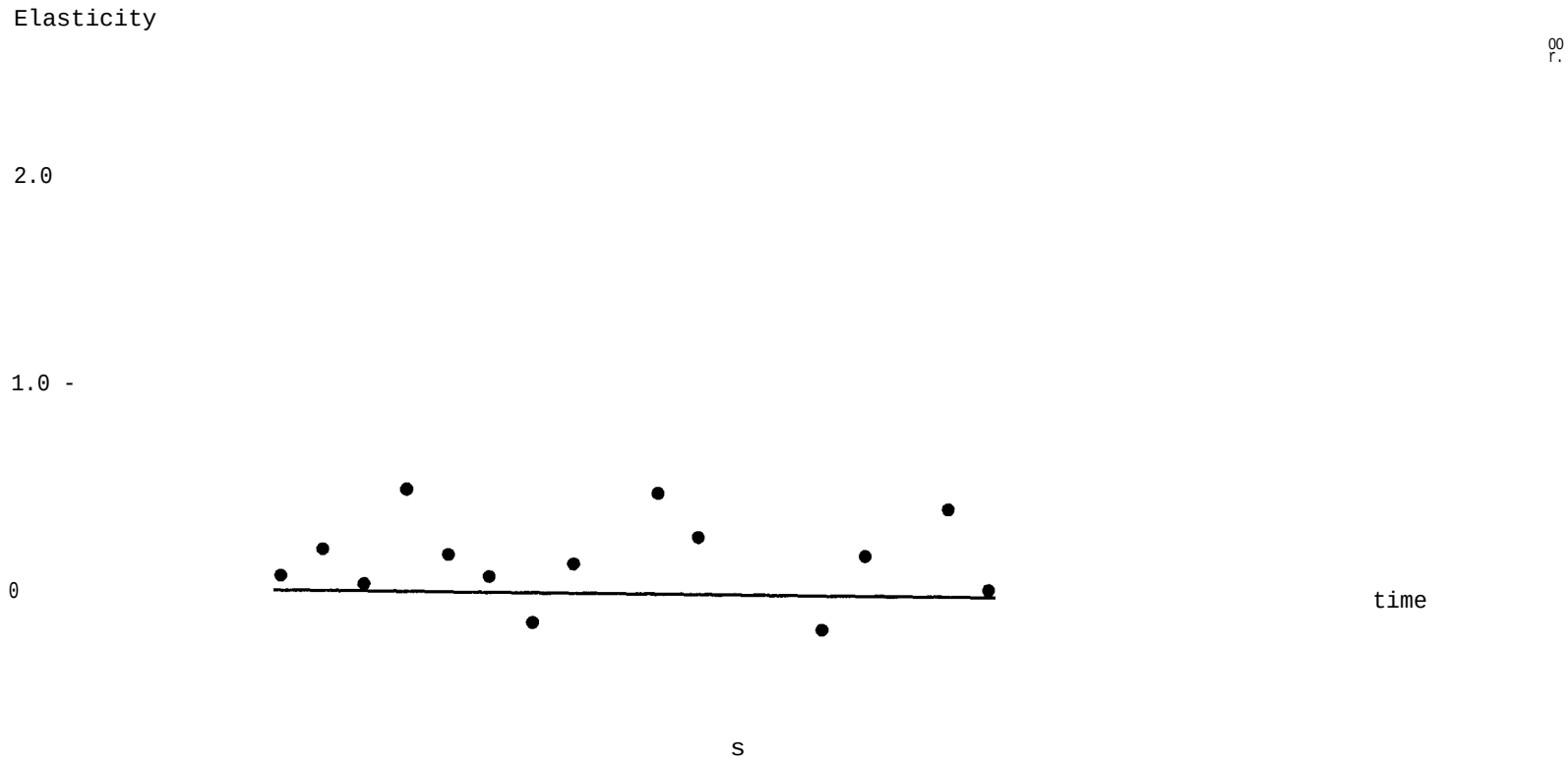
The elasticity of Vp_t with respect to EDP_t can then be computed as

$$(5.26)\quad \frac{\partial Vp_t}{\partial EDP_t} = \frac{EDP}{Vp_t}\,(B_{22}EDP_t + B_{23}(DP_t - EDP_t) + B_{24}(Dpm_t - DP_t) + B_{25}(Dy_t - DP_t) + B_{26}(DP_t - DPW_t) + B_{27}(Dy_t - DPW_t))$$

which shows the sensitivity over time of the variability of relative-price changes to changes in the expected rate of inflation. This measure of sensitivity is shown for the sample period in Figure 5.1. As can be seen, the sensitivity of Vp_t to changes in the expected rate of inflation varies considerably over time. Particularly in the seventies, the increased expected rate of inflation has increased the variability of relative-price changes. Moreover, the variability of this sensitivity has also increased. A possible interpretation of this result could be in terms of adjustment costs. If the timing of pricing decisions of firms is independent, then an increase in the variability of price adjustment costs would imply this finding. The development during the sample period, with sales via supermarkets and via mail-order catalogues, indicates that the variability of the costs of price adjustments might have increased. Whether that actually has been the case is, of course, an empirical question.

The empirical evidence found in testing the model for the variability of relative-price changes gives strong support for the hypotheses put forward. The non-neutral effects from changes in the expected rate of inflation on this variability is statistically significant and the variability has become more sensitive to such changes during the seventies. The model used here has explicitly considered an open economy and has incorporated the effects of changes in relative raw material prices. Both the foreign variables and, in particular, raw material prices, have significantly affected the variability of relative-price changes. The latter findings indicate that previous empirical models in this field have been misspecified, which particularly could be suspected in the case of raw material prices.

Figure 5.1. The elasticity of Vp_u w.r.t. EDP_t, 1951-1979.



5.5.2 Relative-price Chanaes

As noted before, the large number of independent variables in our earlier regression equations probably introduced multicollinearity. A possible solution to this problem is to use the same basic models as before, but to examine instead the effects on relative-price changes. The same basic hypotheses can then be tested in an alternative way, Le., the basic neutral model is formulated for relative-price changes on different commodities and a test is made of the hypothesis of non-neutral effects from the expected rate of inflation on relative-price changes.

The basic neutral models now are given by (5.18) and (5.27) and the non-neutral models by (5.18') and (5.27'). (5.18) and (5.18') refer to the short-run supply functions and (5.27) and (5.27') to the long-run supply functions.

For the purpose of these estimations, we use the 44 constant-quality commodities. They are listed in Appendix 4. The procedure is then to apply OLS on each equation separately, on the assumption that the equations are independent. This makes it possible to examine which commodities are significantly affected by the expected rate of inflation, through inspection of the estimated t-values. The same analysis is made for changes in raw material prices and for the foreign variables. Note here that DP t on the left-hand sides of the equations is the prediction from the regression based on (5.19).

A constant is now added to the model (5.27), since we, in the regressions with Vp_t^u as the dependent variable, found that the included constant, in (5.28), was significant. Note that this constant stems from the time trend in the production function of the firm.

The results for the E model (5.27'), i.e. the 44 relative-price equations including EDP t as an independent variable, are presented in Table 5.9. As before, the error process has been chosen according to the rule in Engle (1974). Only in one case, in equation 11, was AR(1) chosen.

Note that the relative-price changes do not sum to zero in this case, since we study a sub-group of constant-quality commodities.

As seen in Table 5.9, only 9 of the 44 equations were accepted by the F-tests at the 5 % level on the null hypothesis of all coefficients being zero. Another 4 equations are accepted at slightly higher significance levels. In general, these regression results seem to be rather poor. For most of the equations, excluded variables account for the variance in relative-price changes. In previous empirical work with price equations, it is usually the nominal prices which have been used as the dependent variables. As some experiments have shown, also in this model it turns out that nominal price changes are better explained. These results have a **correspondence** in **the testing of** demand systems, where it is n rmally much easier to explain quantities consumed than budget shares

Applying t-tests to the estimated coefficients at the 5 % level, we find that the constant is significant in 2 equations, unexpected inflation in 9 equations, changes in relative raw material prices in 3 equations, changes in domestic real income in 2 equations, deviations from PPP in 3 equation, changes in foreign real income in 2 equations and expected inflation in 6 equations.

In general, the supply variables seem to be more important for relative-price changes than the demand variables. In 20 **cases, the supply variables are significant, whereas** the demand variables are only significant in 7 cases.

According to the analysis in Chapter 3 we would expect EDP_t to affect customer goods, but not auction goods. EDP_t significantly affects relative-price changes in equations 14, 16, 17, 20, 22, and 23. The commodities are Salt, Pants, Socks, Childrens boots, Table and Peg chairs, respectively. Except for Salt, these goods could be characterised as customer goods and thus the findings in this respect are consistent with Okun's theory of different price responses for diversified types of markets.

Table 5.9. Relative-price change equations, 1951-1979. Dependent variables are (Dpit -DPt), but where DPt on the left-hand side of each equation has been predicted from regressions based on (5.19). R2 is the multiple correlation coefficient adjusted for degrees of freedom. The critical value of the F-distribution at the 5 9 level is F(6,22) = 2.55. t-values are in parentheses. The critical value of the t-distribution at the 5 8 level for a two-tailed test is t(22) = 2.074.

Commodity no.	independent variabler Constant	(DPt-EDPt)	(Dpmt DPt)	(Dyt-DPt)	(DPt-DPWt)	(Dy t-DPWt)	EDPt	R2	F(6,22)	Error process
1	-.009 (-1.80)	-.400 (-1.07)	-.891 (-3.00)	1.049 (1.64)	-.085 (-.OS)	.299 (.84)	.620 (1.33)	.213	2.260	OLS
2	-.044 (-.85)	.881 (2.24)	-.564 (-1.92)	.659 (1.01)	-1.125 (-1.14)	.179 (.68)	.351 (.71)	.260	2.636	OLS
3	.008 (.21)	-.011 (-.04)	-.404 (-1.72)	.194 (.39)	-.701 (-.92)	.164 (.62)	.001 (.00)	-.067	.706	OLS
4	-.046 (-.85)	.698 (1.64)	-.386 (-1.15)	-.109 (-.15)	-1.896 (-1.73)	.263 (.69)	.720 (1.33)	.156	1.861	OLS
5	-.014 (-.16)	.751 (1.08)	.304 (.55)	.174 (.15)	1.763 (.99)	.117 (.19)	-.350 (-.40)	-.097	.588	OLS
6	.011 (.18)	.117 (.24)	-.227 (-.60)	-.367 (-.45)	-.511 (-.42)	.344 (.80)	-.350 (-.06)	-.186	.269	OLS
7	-.017 (-.33)	**-.322** (-.83)	**-.054** (-.17)	**.387** (.59)	**-.848** (-.85)	.283 (.81)	.383 (.77)	-.104	.562	OLS
8	-.080 (-1.19)	1.014 (1.92)	-.017 (-.04)	2.179 (2.44)	3.758 (2.76)	-.060 (-.13)	.325 (.48)	.225	2.357	OLS
9	.146 (.84)	-.531 (-.39)	1.198 (1.11)	-1.101 (-.48)	-2.256 (-.65)	-.388 (-.32)	-1.069 (-.62)	-.077	.667	OLS
10	.140 (.52)	-.451 (-.22)	-.188 (-.11)	-2.222 (-.63)	-4.348 (-.81)	.716 (.38)	-1.080 (-.40)	-.218	.165	OLS
11	-.207 (-1.70)	1.084 (1.09)	-1.928 (-2.45)	-.146 (-.09)	-5.135 (-1.69)	3.800 (3.39)	1.206 (1.07)	.291	2.385	AR1
12	.002 (.02)	-.423 (-.66)	.159 (.31)	-.964 (-.88)	-.568 (-.34)	.290 (.50)	.206 (.25)	-.105	.556	OLS
13	.112 (1.01)	-1.220 (-1.41)	-.034 (-.05)	-1.584 (-1.08)	-1.283 (-.57)	.245 (.32)	-.869 (-.78)	-.121	.496	OLS
14	-.060 (-1.48)	.606 (1.92)	-.268 (-1.07)	-.068 (-.13)	-.796 (-.98)	.140 (.49)	1.150 (2.86)	.259	2.634	OLS
15	-.027 (-1.27)	.315 (1.90y	-.070 (-.53)	.575 (2.05)	.428 (1.00)	-.011 (-.07)	-.214 (-1.01)	.269	2.718	OLS
16	-.065 (-2.78)	.877 (4.82)	.028 (.20)	.414 (1.34)	-.693 (-1.48)	-.042 (-.26)	1.056 (4.55)	.648	9.604	OLS
17	-.069 (-2.56)	.442 (2.09)	-.180 (-1.07)	.366 (1.02)	-.549 (-1.01)	.090 (.48)	.673 (2.50)	.210	2.239	OLS
18	.017 (.38)	.654 (1.89)	.289 (1.05)	-.098 (-.17)	.015 (.02)	.001 (.01)	-.348 (-.79)	.050	1.248	OLS
19	-.025 (-.70)	.777 (2.74)	.176 (.78)	.672 (1.40)	-.430 (-.59)	-.231 (-.91)	.308 (.85)	.384	3.909	OLS
20	-.050 (-1.13)	1.424 (4.14)	.295 (1.08)	.609 (1.05)	-.163 (-.18)	-.208 (-.68)	.927 (2.11)	.436	4.602	OLS

Table 5.9 continued

Commodity no.	Independent variables Constant	(DPt-EDPE)	(D_{pmt}-DPt)	(Dy d-DPt)	(DPt-DPWt)	(Dy t-DPWt)	EDP E	R^2	F(6,22)	Error process
21	-.017 (-.46)	.995 (3.41)	.011 (.05)	.431 (.87)	-.637 (-.85)	-.057 (-.22y	.523 (1.40)	.369	3.733	OLS
22	-.047 (-1.41)	.156 (.60)	-.088 (-.43)	-.220 (-.50)	-.637 (-.94)	.223 (.95)	.717 (2.14)	.077	1.388	OLS
23	-.011 (-.38)	.083 (.35)	-.333 (-1.78)	-.236 (-.59)	-.975 (1.61)	.159 (.75)	.645 (2.14)	.157	1.871	OLS
24	.051 (1.21)	-.238 (-.71)	-.065 (-.25)	-.906 (-1.61)	-.512 (-.60)	-.290 (-.97)	-.199 (-.47)	-.062	.729	OLS
25	.028 (.25)	-1.180 (-1.35)	-.010 (-.01)	-.595 (-.40)	-2.500 (-1.11)	.285 (.36)	.626 (.56)	-.062	.728	OLS
26	-.013 (-.21)	-.120 (-.26)	-.251 (-.69)	-.301 (-.39)	1.117 (.94)	-.011 (-.03)	.160 (.27)	.010	1.045	OLS
27	-.014 (-.35)	-.537 (-1.77)	-.310 (-1.29)	-.376 (-.73)	-1.110 (-1.42)	.162 (.59)	.016 (.04)	-.060	.738	OLS
28	-.029 (-.49)	.133 (.28)	-.124 (-.33)	.527 (.66)	.824 (.68)	-.079 (-.19)	.039 (.06)	-.204	.210	OLS
29	-.015 (-.40)	.476 (1.60)	-.083 (-.35)	.408 (.81)	1.029 (1.34)	-.257 (-.96)	.512 (1.35)	.047	1.232	OLS
30	-.025 (-.68)	.794 (2.76)	.299 (1.31)	.457 (.94)	1.558 (2.11)	-.316 (-1.23)	.592 (1.61)	.160	1.889	OLS
31	-.024 (-.43)	.524 (1.18)	.139 (.40)	.566 (.75)	.712 (.62)	-.102 (-.26)	-.026 (-.05)	-.161	.354	OLS
32	-.073 (-1.20)	.042 (.09)	-.622 (-1.66)	.954 (1.19)	-.668 (-.55)	.329 (.77)	1.161 (1.92)	-.002	.991	OLS
33	-.036 (-.60)	.569 (1.22)	.364 (.98)	-.149 (-.19)	.343 (.29)	-.361 (-.86)	.754 (1.27)	-.010	.955	OLS
34	-.012 (-.21)	1.211 (2.71)	.100 (.28)	.144 (.19)	.207 (.18)	-.265 (-.66)	.038 (.07)	.158	1.875	OLS
35	.067 (1.25)	-.748 (-1.80)	.261 (.79)	-1.276 (-1.81)	-.801 (-.75)	-.403 (-1.08)	-.364 (-.68)	.055	1.271	OLS
36	.026 (.53)	-.546 (-1.39)	.743 (2.39)	-.348 (-.52)	2.344 (2.32)	-.730 (-2.08)	-.231 (-.46)	.252	2.573	OLS
37	.037 (.70)	165 (.39)	225 (.68)	.244 (.35)	.747 (.69)	-.168 (-.44)	.003 (.01)	-.235	.112	OLS
38	.010 (.27)	408 (1.44)	.085 (.38)	.489 (1.02)	.585 (.80)	.078 (.31)	.037 (.10)	-.108	.547	OLS
39	-.013 (-.23)	1136 (.30)	.417 (1.15)	1.050 (1.36)	1.037 (.88)	-.533 (-1.30)	.487 (.83)	.008	1.040	OLS
40	.044 (.97)	.461 (1.30)	.304 (1.08)	.243 (.41)	.708 (.78)	-.248 (-.78)	-.302 (-.67)	-.077	.667	OLS
41	-.020 (-.43)	.173 (.46)	.064 (.22)	.874 (1.38)	.914 (.95)	-.054 (-.16)	.113 (.24)	-.151	.388	OLS
42	-.082 (-.90)	.294 (.41)	.010 (.02)	1.433 (1.18)	1.155 (.62)	-.011 (-.02)	.730 (.79)	-.189	.258	OLS
43	010 (.29)	-.350 (-1.35)	.119 (-.58)	.364 (.83)	1.017 (1.53)	-.169 (-.73)	-.209 (-.63)	.096	1.497	OLS
44	.025 (1.14)	-1.026 (5.97)	.091 (.67)	.126 (.43)	.613 (1.38)	-.037 (-.24)	-.344 (-1.57)	.656	9.905	OLS

The demand variables are significant in equations 8, 11, 15, 30, and 36. The commodities are Salted herrings, Apples, Gentleman's suits, Coffee-cups, and Razor blades, respectively. Salted herrings, Apples and Razor blades are relatively homogenous commodities and hence, for these, demand should influence prices even in the short run.

The experted rate of inflation is significant E for 6 of the 44 commodities. To test the overall significance of EDP_t the likelihood ratio test can be applied to minus tuvice the sum of the difference between the log likelihood values of the 44 commodities, which is X - distributed with 44 degrees of freedom; χ (44)= 86.2 against the critical value at the 1 °e level of approximately 68.8. Therefore, the restricted model (5.27) is rejected by our data.

To sum up the empirieal evidence, the hypothesised models have not been rejected by our data. There are sonve differences when the models are applied to relative-price change variability and to relative-price changes. In the former case, the exclusion of the foreign variables, $(DP_t - DPW_t)$ and $(Dy_t - DPW_t)$, was rejected by our data. In the latter case, however, the foreign variables were insignificant in 40 of the 44 price equations. Whereas changes in relative raw material prices were significant for relative-price change variability, as shown in the previous section, it was only significant in 3 of the 44 relative-price change equations. These are the major differences between the two cases. Both relative-price change variability and relative-price changes are significantly affected by unexpected and experted inflation and by changes in relative raw material prices. It appears as if the specification of the regression equations are important for the regression results. However, the relatively poor results in the regressions with relative-price changes did not change the main results of the hypothesis tests.

The inclusion of relative raw material prices in the model is a major improvement. In earlier models of relative-price change variability, raw material prices have not been included, which by our data is interpreted as a misspecification. They play a major role in the explanation of relative-price change variability and of relative-price changes.

Furthermore, the experted rate of inflation exerts a strong non-neutral influence here. This is in line with earlier results of Fischer (1981a,1982) for the United States and West Germany, but in contradiction with the findings by Blejer and Leiderman (1982) for Mexico.

Some qualifications to our results require to be made, the first of which is of a theoretical nature. The basic neutral model which has been used here is very simple. It assumes competitive markets and embodies a very simple characterisation of the labour market. In addition, it is a static model and involves no dynamic relationships. Nevertheless, it fits our data quite well. Although it is preferrable to keep things as simple as possible, it is my belief that a dynamic model would have been an improvement.

In addition, the non-neutral element of the influence of experted inflation on relative-price changes have been added to our neutral model ad hor. It would have been better to explicitly introduce those non-neutral elements, e.g. by an explicit modeling of price adjustment costs. In our case there was no simple way in which this could have been done.

The second qualification is of an empirical nature. Since the multiple correlation coefficients are below unity, there remains some unexplained variance in relative-price change variability and in relative-price changes. For some commodities our models fit quite well, but for others quite badly. The improvement of the model of course should take place at the theoretical level, but more complicated models could have serious empirical consequenses. For instance, the model (5.28) could have been made more complicated at the theoretical level, but would then have been impossible to estimate in the statistical sense, since the nurober of parameters would have exceeded the available number of observations.

A third important qualification concerns the causality between the variables in the model. In the empirical estimations the independent variables were considered to be exogenous. This assumption is justified at the theoretical level. For instance, it is assumed that the input prices are taken as given by the representative competitive firm.

In the models here, as well as in other models, the expected rate of inflation has been included as an independent variable in the regression equations. The rate of inflation could be considered exogenous to the firm, but in general it is an endogenous variable, determined by other economic variables. From the analysis in Chapter 3, it is also clear that the causality between Vp_t and DP_t is far from obvious. Feedback from Vp_t to DP_t is possible and hence the exogeneity assumption would be violated.

The question of dynamics and causality will therefore be dealt with in the next chapter.

6 RELATIVE-PRICE VARIABILITY AND INFLATION IN A MACROECONOMETRIC MODEL: TESTS OF CAUSALITY

6.1 Introduction

The question of the causality between relative-price change variability and inflation was raised earlier, e.g. by Vining and Elwertowski (1976). In Chapter 2, following Cukierman (1979) and Cukierman and Wachtel (1979), it was made clear that in the Lucas model, the variance of relative-price changes and the variance of the general price level, both moved in the same direction over time, because of changes in the variance of demand shocks. Likewise, in the Scandinavian model of wage and price formation, the variability of labour productivity caused the variability of relative-price changes and the rate of inflation to move in the same direction. In cases like these the question of causality is ambiguous, since both Vp_t and DP_t are endogenous variables.

In this chapter we shall use a vector autoregression (VAR) to study the dynamic response in certain variables to shocks in different variables. We shall also apply the Wiener-Granger notion of causality to test the causal order between Vp_t and DP_t. The model is set up on the presumption that the model in the previous chapter can be treated as a maintained hypothesis.

Vector autoregressions have been proposed as an alternative to large-scale macroeconometric models by Sims (1980) and Litterman (1980,1982). Fischer (1982) used a VAR to study the behaviour of Vp_t. Ashley (1981) used the Wiener-Granger causality con ept in a bivariate model to test the causal order between Vp_t and DP_t

According to Sims' critique of conventional macroeconometric models, these are -based on arbitrary identifying restrictions. Exogenous variables are defined on a priori grounds and because of the complex structural relationships involved in economic models, statistical inference based on these models is.hazardous.

Sims' alternative is to fit a VAR, where all variables are endogenous, in order to avoid the arbitrary identifying restrictions. In a VAR, each variable is regressed on all variables lagged. Hence, lagged variables are considered exogenous.

The economist's problem then mainly reduces to the choice of the relevant variables to include in the model. However, as will be seen in the following, there are problems with how to interpret the empirical results, and with how to relate them to "structural" interpretations. In fact, further restrictions will have to be imposed to make sensible interpretations possible

The motives for using a VAR here are twofold. In the first place, we introduce dynamics in the model, and we shall analyse the dynamic response in the variabler of the system to shocks in the different variables. Secondly, the dynamics of the model permit a test of the causality between Vp_t and DP_t.

In the next section we give the chosen variables for the five-variabie VAR, and the VAR itself is described in section 6.3. In 6.4 the causality test method is given and 6.5 gives the empirical results and conclusions.

6.2 Selection of Variabler

It is easily understood that the number of variabler to include in the VAR must be limited. The number of degrees of freedom in the system quickly decreases with the number of variabler and lags.

Consider our model (5.25). The number of independent variables is 20 plus a constant. If we restrict the number of lags to 3, we end up with 61 independent variables in each equation. This must be considered to be too many, when we have only 29 annual observations on each variable. Hence, we must restrict the number of variabler or the number of lags in the system. Since we have annual data, a three year lag is considered appropriate and hence the number of variabler cannot be more than 9, which would leave us with 1 degree of freedom in each equation, provided we include a constant.

If we drop the cross-terms in (5.25) we are left with 6 variables: Vpu_t, $(DP_t - EDP_t)$, $(Dp_{mt} - DP_t)$, $(Dyd_t - DP_t)$, $(DP_t - DPW_t)$ and $(Dyf_t - DPW_t)$. For convenience, we drop the u superscript for the unweighted variance, Vp_t^u. Adding EDP_t to the model we have 7 variables. Even with 7 variables, however, we are left with only 7 degrees of freedom in each equation.

Hence, we will use some proxies for the above variables. We include Vp_t and DP_t as defined above. In addition, we include DPW_t, the relative change in import prices, DW_t, the relative change in unit labour costs and DU_t, the relative change in unemployment. DPW_t includes some raw material prices and hence is to some extent used as a proxy for changes in raw material prices. In the model (5.25) we see that increases in DPW_t should increase Vp_t. DW_t **is a natural proxy for** EDP_t**, considering** the equilibrium wage rate in (5.7). Finally, DU_t, the change in the unemployment rate is used as a proxy for changes in domestic and foreign real income. That is, it is assumed that there is an inverse relationship between changes in domestic and foreign income and DU_t. Therefore, an increase in DU_t is expected to affect Vp_t in a direction opposite to Dy_t and Dy_t. Finally, we include a constant in each equation, to account for time trends in the variabler.

The data used are annual data from 1951 to 1979 for the Swedish economy 4) . All data sources are specified in Appendix 2. The use of annual data presents some problems in a VAR. We leave that discussion for section 6.5.

6.3 The Vector Autoregressive **Model**

In the VAR, there are n endogenous variables, defined by the nx1 vector y_t. The VAR is defined by

$$(6.1)\quad B(L)y_t = u_t,$$

where B(L) is an nxn matrix of polynomials in the backward-shift operator L and u_t is an nx1 vector of random variables, serially uncorrelated with finite and constant variance and zero mean. Hence, the right-hand sides of the equations in the system contain exactly the same variables, i.e. succesive lags of the n endogenous variables. For ease of exposition, we ignore deterministic components, such as

constants or time trends.

To estimate B(L) one must limit the lag length in the polynomials. If m is the lag length and d the nutuber of deterministic coefficients, there are n(nm+d) coefficients to be estimated.

In our case, n=5, m=3 and d=1, so the nutuber of parameters to be estimated are 80, 16 in each equation.

Since all equations have the same explanatory variables, OLS equation by equation is efficient. No restrictions are imposed on the lag pattern; each of the five variables in the system is predicted as a linear combination of past values of all five variables in the system.

The difficulties with the VAR do not lie in the estimation, but rather in the interpretation. It is very difficult to make any sense of the estimated coefficients in the regression equations. The coefficients on succesive lags tend to oscillate and there are complicated feedbacks across the equations.

Therefore, the analysis is concentrated on the dynamic response in the system to typical random shocks in the variables. A typical random shock is a positive residual of the size of one standard deviation unit of each equation in the system.

The dynamic responses are characterised by the moving average representation

$$(6.2)\quad y_t = \sum_{s=0} A_s u_{t-s}$$

where u_t is a nxt vector of random disturbances, assumed to be serially uncorrelated, i.e. generated by a white noise process, and A_s is the matrix of coefficients in the moving average representation.

At this point, the first problem of interpretation arises. The covariance matrix of the residuals, $\Omega = E u_t u'_t$, is in general not diagonal and therefore the residuals are non-orthogonal. But if the residuals are non-orthogonal, it is hard to interpret the dynamic responses in the system. For instance, it is then impossible to know whether the dynamic responses to a shock in the DP_t-equation is the

result of an autonomous change in DP_t or is the effect from a shock in the Vp_t-equation on DP_t. **Hence,** the residuals of the system are best orthogonalised.

The orthogonalisation has been achieved here through the Choleski factorisation method, which amounts to finding a triangular matrix S, such that Q=SS' and $u_t = Sv_t$, where v_t is a vector of orthogonal innovations. The factorisation will depend on how the variables are ordered in Q. In general, the procedure is to remove the covariances between the residuals in a particular order, where the variable highest in order is allowed to affect all other variables contemporaneously. The Choleski factorisation is similar to regressiog the error of the variable highest in order on the errors of all other variables and using the errors from this regression as the orthogonal innovations for the variable ranked first in the decomposition. The errors of the variable ranked as the second variable then are regressed on the errors of the remaining variables, and so on. In this way the covariances among the errors are removed and contemporaneous correlation is imposed in a particular order.

The moving average representation with orthogonal innovations is

$$(6.3) \quad yt = \underset{s=0}{C} As \; Sv_{t-s} .$$

It there is considerable correlation between contemporaneous residuals, then the particular ordering of the factorisation might be important. If contemporaneous correlation is high between some variables, the results can be checked by altering the ordering in the factorisation between these variables.

In addition to the dynamic responses to standard deviation unit shocks, we shall analyse the historical decomposition of the time series into a prediction of each variable and the components of the accumulated effects of past and current shocks. The historical decomposition is based upon the following partitioning of the moving average representation:

$$(6.4)\quad y_{T+j} = \sum_{s=0}^{j-1} A_s v_{T+j-s} + \sum A_s v_{T+j-s}$$

Period T is the base period, period T+1 the first period of historical decomposition and period T+j is in our case equal to the last period of the sample. The first sum in (6.4) is that part of y_{T+j} which is due to shocks in periods T+1 to T+j and the second sum is the forecast of y_{T+j}, based on the information available at time T.

The historical decompositions thus **partition the difference between the actual series and the** forecast, between the variablerin the model. This partition is determined by the components of the vector v_{T+j-s} of orthogonal innovations. Therefore, the forecast augmented by the innovations in all the variablergives the actual value of the variable.

In addition to describing the system's response to different kinds of shocks we shall also make a decomposition of the variance of forecast errors. We give the model a one-period shock of the size of one standard deviation unit. The k-step ahead forecast error is

$$(6.5)\quad \sum_{s=0}^{k} A_s v_{t-s} .$$

The variance of **the k-step ahead forecast error** is

$$(6.6)\quad s^2(i,k) = \sum_{j=1}^{n} \sum_{s=1}^{k} a_{ij}(s)^2 s^2 ,$$

where there are n variables in the system. $s^2 = s^2(j,1)$ is the variance of the jth innovation, and the $a_{ij}(s)$ are the coefficients on the sth lag of the jth innovation in the moving average representation of the equation for variable i.

The decomposition of the variance of forecast errors allows for an analysis of the influence on variable i of shocks in all the variables. It also gives some information on the possible exogeneity of variables. If forecast error variance in a variable is explained, to a dominating extent, by own-innovations, it is evidence for that variable being exogenous. Note, however, that the decomposition of variance is dependent on the particular ordering in the factorisation of 4. If a variable is ordered high in the orthogonalisation, it is likely that its own-innovations would take a larger share in the decomposition of variance of forecast errors. This will particularly be the case if the contemporaneous correlation is high.

6.4 Causality Test in a Vector Autorearession

In the decomposition of variance of forecast errors, exogeneity of a variable is equivalent to that variable's own-innovations accounting for 100 % of its forecast errors. In systems of economic variables, this is not likely to occur frequently. Therefore, we need an explicit test of exogeneity.

In this section we shall adopt the Wiener-Granger causali y concept and the application of it to a vector autoregression . A formal description is given in Hsiao (1982) and the following causality definitions draw on his work.

The exposition will be more clear if we use our specific model. Hence, let y_t={ m_t, Vp_t, DP_t, DW_t, DU_t} be a vector stochastic process. Let I_t =y_t be the relevant information set accumulated since time t-1 and let It ={y_s !s<t } .

Define I_t-DP_t as the set of elements in I_t without the element DP_t. I t -DP t is defined analogously to I_t -DP_t. We drop the time subscript and denote by c(VplI) the root of mean square error of the minimum root of mean square linear prediction error of Vp, given information set I. Hence, o(VplI) is the performance of predicting Vp given past y. Likewise, o(VplI-DP) is the performance of predicting Vp given past y, but without DP in the information set. The generalised Wiener-Granger causality concepts can now be defined:

1. Direct Causality. If o(VplI) < o(VpI I-DP) and o(VPIVP, DP) < o(VPIVP), o(VPII-DPW) < o(VPII-DPW-DP), o(Vpll-DPW-DW) < o(Vpj I-DPW-DW-DP) an o(VplVp, DP) < o(VplVp) then we say that DP causes Vp directly, relative to I, denoted by DP=>Vp.

The direct causality means that DP only causes Vp when current Vp is better predicted by usinq past DP, no matter what information set is used.

2. Direct Feedback. If DP=>Vp and Vp=>DP, *then* there is direct feedback, denoted by DP<=>Vp.

3. No Causality. DP does not cause Vp when either (i) o(VplI) _ o(VpI I-DP-DPW-DW-DU) or (ii) o(VpjI) = o(VPII-DP), o(DPWI I) _ o(DPWII-DP), o(DWII) = o(DWII-DP), o(DUII) = o(DUI I-DP).

Condition (i) implies that the best prediction of Vp makes use of past values of Vp only. Condition (ii) implies that past values of Vp, DPW, DW and DU are sufficient for predictioq current Vp, DPW, DW and DU.

As pointed out in Chapter 3, it might be that a third variable is causinq both Vp and DP to move in the same direction, but in a bivariate analysis it may be that DP=>Vp. The case where a third variable is drivinq both DP and Vp is called spurious causality.

4. Svurious Causality. Assume that DPW=>DP,Vp. *Then,* when condition (ii) of No Causality holds, but o(VplI) = c(VplI-DP) < o(VpI I-DPW) <o(VpI I-DP-DPW) and o(DPII) < o(DPII-DPW), o(DPIDP, DPW) <o(DPIDP), then spurious causality from DP to Vp occurs.

Finally, there is also the possibility of indirect causality. For *instance,* DPW may cause DP and DP in turn cause Vp. But, as in the case of spurious causality, there is no direct causality from DP to Vp.

5. Indirect Causality. If o(VplI) = o(Vpj I-DP) < o(VplI-DPW) < c(VpI I-DP-DPW) and o(DPWII) < o(DPWII-DP), o(DPWIDPW, DP) < o(DPWIDPW), then we say that DP causes Vp indirectly, denoted by DP Vp.

This completes the definitions of causality to be applied here. In addition, we must consider the possibility of instantaneous causality, i.e. that current Vp is caused by current values of some other variables in the system.

This problem will here be treated in the context of contemporaneous correlation. By changing the order of the orthogonalisation of innovations, it is possible to examine the importance of contemporaneous correlation. By changing the order of the variables in the orthogonalisation, one allows for different contemporaneous effects between the variabler. We small pay more attention to this problem when we apply the causality definitions to our model in 6.5.5.

Having defined the VAR and the different causality concepts, we now turn to the empirical estimation and the results.

6.5 Empirical Results

The estimation of the VAR and the causality tests produces a large number of results. We small only show a small number of there in the text. Further results are given in Appendix 4.

Recall again that the estimated VAR includes five variables: DPW, Vp, DP, DW, and DU. We use annual data for the period 1951-79 and a three-year lag. In addition, we include a constant in each equation to allow for time trends in the variabler.

6.5.1 Estimation of the VAR

As described in section 6.3 we apply ordinary least squares to each equation separately in the system. The output from the regressions is presented in Appendix 4.

The estimated coefficients are not so interesting, since they tend to oscillate and this makes interpretation difficult. However, blockwise F-tests on the variables in the system makes sense. The F-statistics and the marginal significance levels are given in Appendix 4. As can be seen, the F-statistics are in general low. In the equation for DU there is no single variable significant below the 19% significance

level. In the other equations only Vp and DPW are significant at the 5% level. In the Vp-equation, lagged Vp is significant at the 3% level and DPW at the 11% level.

Since we use annual data, it is more likely that the contemporaneous torrelation between the residuals is high. The torrelation matrix is given below.

Table 6.1. Correlation matrix of contemporaneous residuals.

	DPW	Vp	DP	DW	DU
DPW	1.000	.726	.768	.621	.156
Vp	.726	1.000	.493	.236	.018
DP	.768	.493	1.000	.698	.064
DW	.621	.236	.698	1.000	.390
DU	.156	-.018	.064	.390	1.000

As can be seen in Table 6.1, DPW is highly correlated with Vp, DP and DW; Vp is correlated with DP; DP is correlated with DW and DW is correlated with DU. The torrelation coefficient between Vp and DU is negative, which is what we would expect, since DU is used as a proxy for Dy and Dy . Vp moves procyclically, which confirms the time series pattern of figures 4.1 - 4.3 in Chapter 4. The torrelation between DP and DU is positive, which probably reflects the stagflationary development during the 70s.

Since there are significant torrelations between the residuals in the system, the ordering of the variables in the orthogonalisation will probably be important. We shall return to that problem in subsection 6.5.3.

6.52 D namic Responsen to Unit Shocks

The dynamic responses to standard deviation unit Shocks, characterised by the moving average representation (6.3) are presented in Figures 6.1 - 6.5. These responses will now depend on the ordering in which variables are orthogonalised. The responsen presented here are based on t:he ordering: DPW, Vp, DP, DW and DU. This amounts to assuming that foreign price changes are exogenous. Shocks in DPW immediately affect all other variables, while Shocks in DU do not affect the other variables contemporaneously. The effects of other orderings of the variables we leave for the next subsection, where we analyse the decomposition of the variance of forecast errors.

There are basically two ways to present the dynamic responses. First, we could give the responsen in one variable to Shocks in all variables. Secondly, we could take the responsen in all variables to a shock in one variable. In the first case there is no problem of scaling, but in the second case the dynamic responses are scaled by the standard deviations of each regression equation. Therefore, the first period response, in the variable ordered first, to an own-innovation, is unity. The first way of presenting the responses gives answers to the question: what chocks (variables) are most important for variable i? The second gives answers to: which variable is mostly influenced by a shock in variable i? The first way of giving the responses is presented in Figures 6.1 - 6.5 and the second way, with standard deviation scaling, is given in Figures 1 - 5 of Appendix 4.

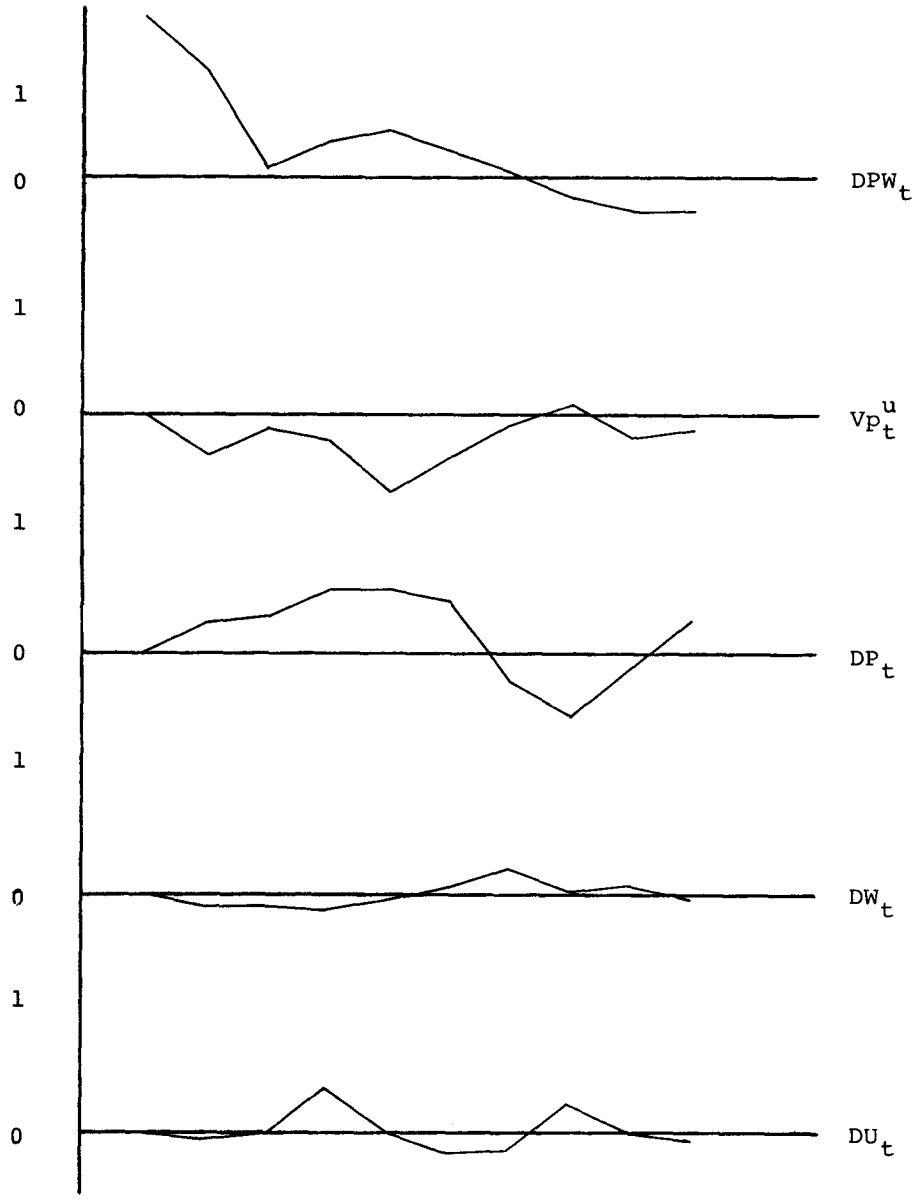


Figure 6.1. Dynamic responses in DPW_t to shocks in DPW_t, Vp_t^u, DP_t, DW_t and DU_t, 10 periods ahead. Vertical unit is .0300.

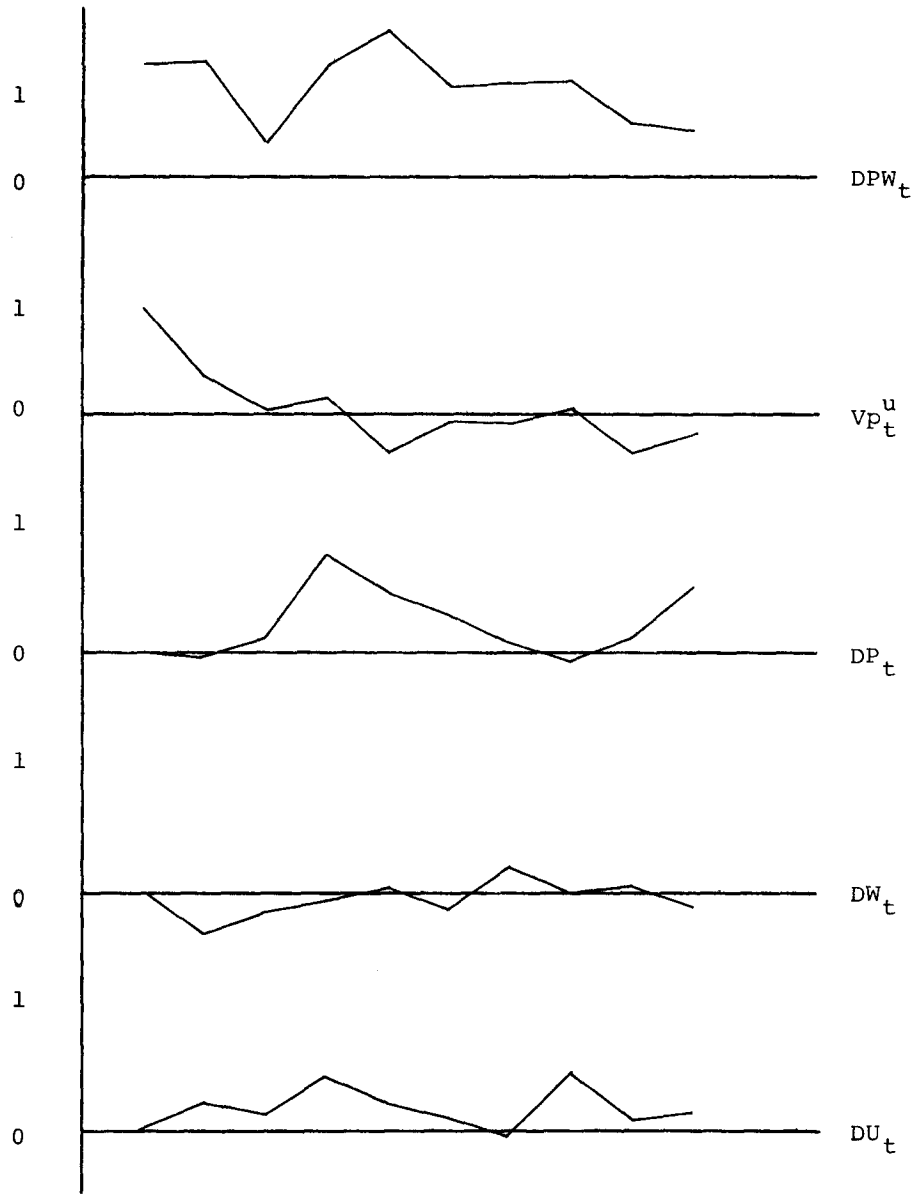


Figure 6.2. Dynamic responses in Vp_t^u to shocks in DPW_t, Vp_t^u, DP_t, DW_t and DU_t, 10 periods ahead. Vertical unit is .0005.

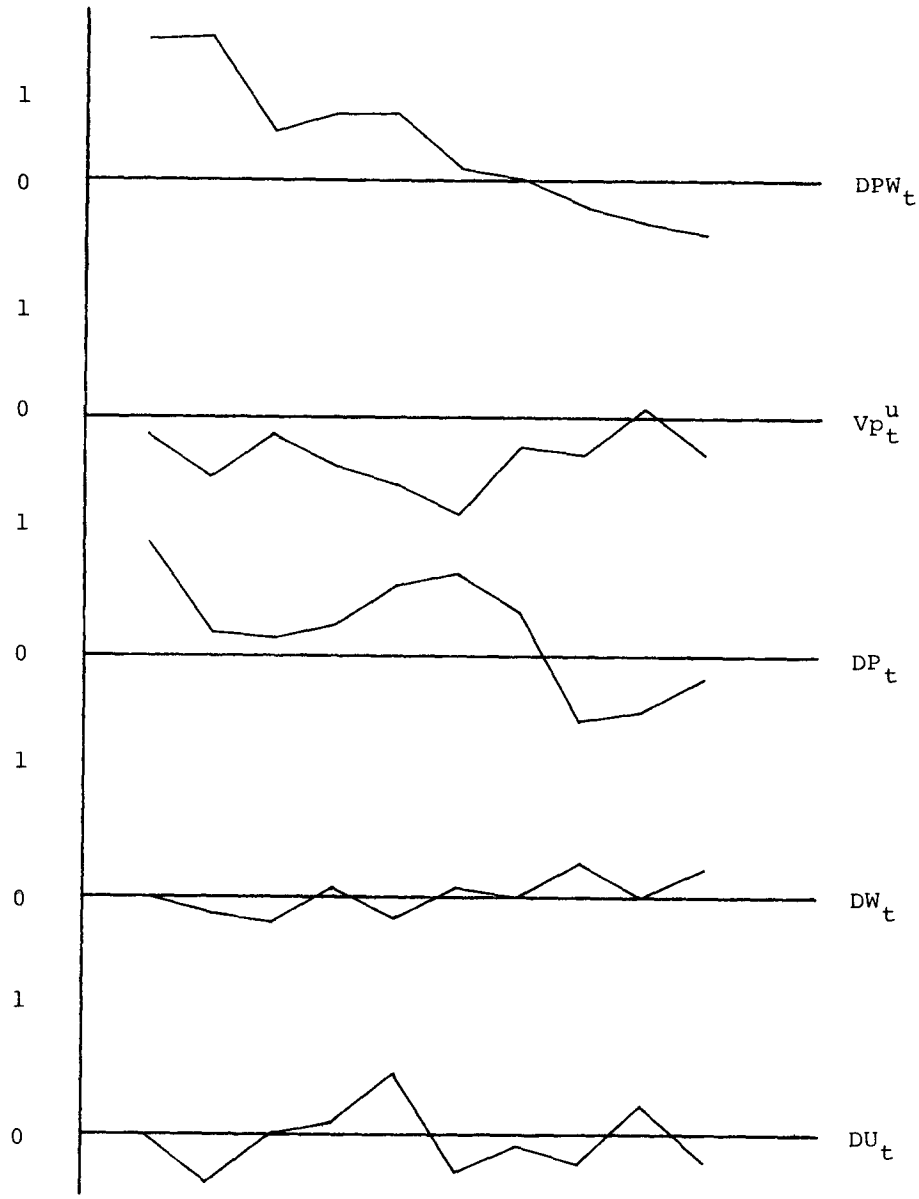


Figure 6.3. Dynamic responses in DP_t to shocks in DPW_t, Vp_t^u, DP_t, DW_t and DU_t, 10 periods ahead. Vertical unit is .0100.

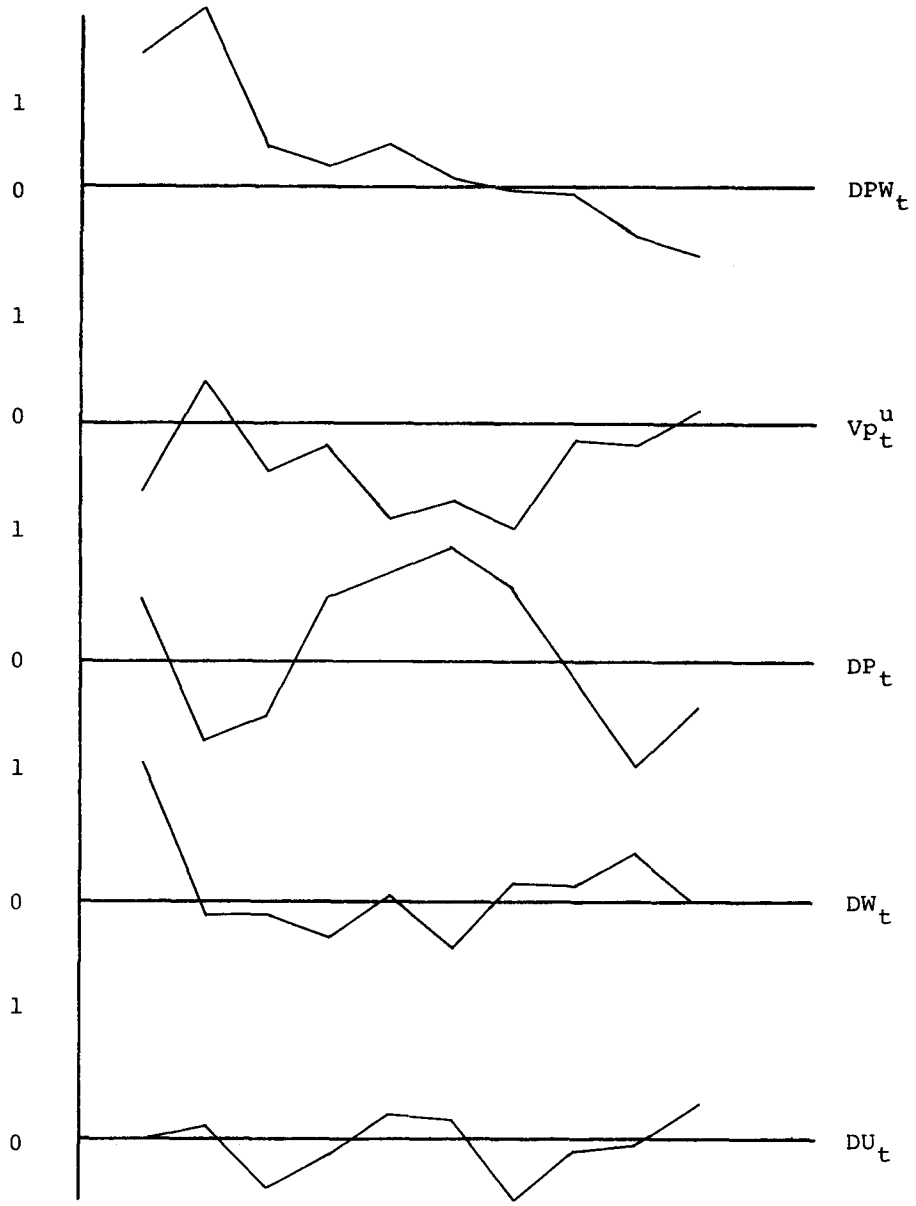


Figure 6.4. Dynamic responses in DW_t to shocks in DPW_t, VP_t^u, DP_t, DW_t and DU_t, 10 periods ahead. Vertical unit is .0100.

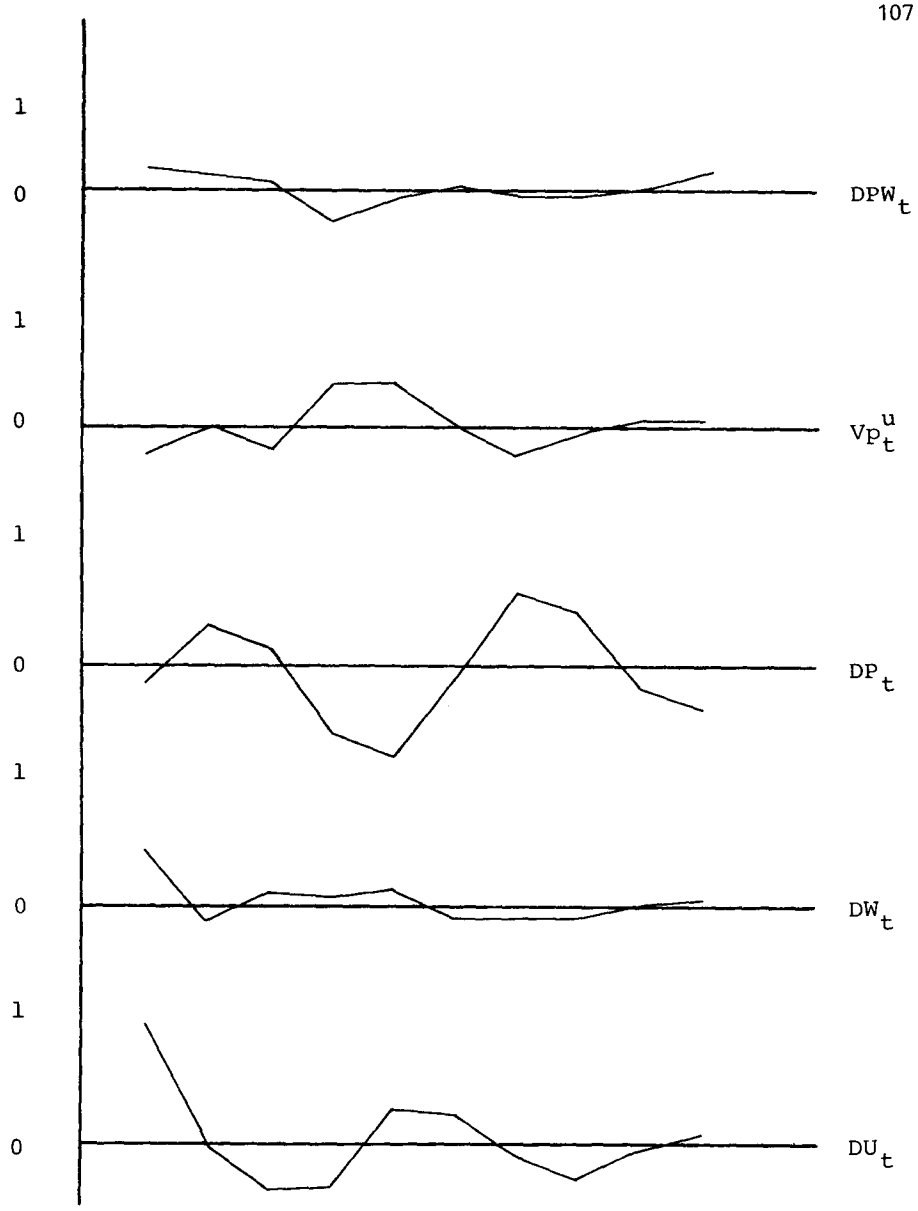


Figure 6.5. Dynamic responses in DU_t to shocks in DPW_t, Vp_t^u, DP_t, DW_t and DU_t, 10 periods ahead. Vertical unit is .1000.

Figure 6.2 shows the dynamit responses in Vp to shocks in all the variables. Relative price change variability is most heavily influenced by shocks in DPW and DP. The effects of own-innovations are quickly damped, but shocks in DPW and DP show a pronounced cyclical and slowly damped pattern. Skocks in DPW, DP and DU all increase Vp, while a wage change innovation tend to decrease Vp. These responses are consistent with the model in the previous chapter, where changes in the equilibrium wage rate were linearly related to the expected rate of inflation and where the actual and the expected rate of inflation affected vp in opposite directions. Somewhat surprisingly, the effects of a chock in unemployment is that price variability increases. In Chapter 4 we saw a procyclical pattern in Vp, which is not confirmed by the responses to a chock in DU. As the regressions with relative-price change equations in Chapter 5 showed, the supply variables seemed to be more important than the demand variables and it is presumably that phenomenon which is reflected here, through the countercyclical effects from DU-innovations on Vp. Notice, however, the procyclical time pattern of Figure 5 in Appendix 4. The initial effect is that Vp increases, but after that Vp behaves procyclically with DU. Hence, the initial effects on prices, and wages, from a skock in DU tend to be small, but to rise after a while and then level off slowly.

In figure 6.3 we illustrate the effects on DP of shocks in all the variables. A chock in Vp tends to decrease DP, while a chock in foreign prices has a positive influence on DP. The rate of inflation is sensitive to innovations in foreign prices and to own-innovations.

Figure 6.3 and 6.4 show that wage changes are sensitive to inflation-innovations, while inflation is not so sensitive to wage-innovations. This is apparent in figures 3 and 4 of Appendix 4, where the effects of wage shocks are small compared to inflation-innovations. In Figure 4 there is evidence that in the cyclical pattern following a wage-change chock, wages tend to lag prices by one year. However, this is not the case for inflation-shocks, where wage inflation and price inflation show a very similar cyclical pattern. This result is consistent with the simple labour market model in the previous chapter, where the equilibrium wage rate was linearly related to the expected price level.

Figure 6.5 shows that changes in unemployment is very sensitive to a inflation-shock. This could be seen as a contradiction to the neutral models, in which nominal variables would have a small and quickly damped effect on real variables. In addition, changes in unemployment are sensitive to a price variability innovation. The first-step effect is a decrease in unemployment, but a peak is reached after 4 years. A possible interpretation of this phenomenon is that increases in relative-price change variability imply structural changes in the economy and that the latter take considerable time and implies a transitory increase in unemployment. However, it is probably the case that it takes not only temporary changes in price variability to induce such structural changes, but sustained changes in price variability.

In Figures 1 - 5 of Appendix 4 we have drawn the dynamit responses in all the variabler to a shock in one of them. In Figure 1 we see the responses to a shock in DM The innovation in DPW can be seen as a supply shock, e.g., as a shock in oil prices. The effects are that all the other variables increase. There is a strong and slowly damped effect on price variability, inflation and wage changes. Unemployment increases for the first three periods, but then decreases. The stronger effects on wages and inflation can be seen as an effect of the accommodating Swedish policy, strongly oriented towards full employment.

An innovation in Vp decreases both price and wage inflation. This finding is contradictory to the theory of asymmetric price adjustments, with downward stickiness in prices in markets with excess supplies. This theory implies that increased relative price variability increases wage and price inflation.

The effects of an inflation-innovation can be seen in Figure 3 of Appendix 4. It increases Vp with a sharp peak the fourth year. It also tends to feed itself, with a decline only after 8 years. The initial effect on wages is an increase followed by an immediate decrease and a peak after 5 years. The effects of wage-innovations are much more damped, as can be seen in Figure 4 of the same appendix.

For some dynamit responses the cycles are very pronounced and slowly dampe6. In Table 6.2 we provide the forecast standard errors k steps ahead

Table 6.2. Forecast standard errors k years ahead. Forecast standard errors are the positive square root of (6.6).

	k	
DPW	1	.0405
	2	.0505
	3	.0516
	5	.0632
	10	.0716
	25	.0812
Vp	1	.0013
	2	.0017
	3	.0018
	5	.0026
	10	.0032
	25	.00.36
DP	1	.0151
	2	.0203
	3	.0209
	5	.0250
	10	.0302
	25	.0393
DW	1	.0179
	2	.0245
	3	.0258
	5	.0292
	10	.0364
	25	.0452
DU	1	.1166
	2	.1232
	3	.1318
	5	.1797
	10	.2075
	25	.2139

For a stationary process, the forecast standard error tends to some upper bound. The forecast standard errors level off most quickly for Vp and DU, but, especially for DP and DW, the responses are very slowly damped. Again, there is some evidence for the employment--oriented accommodating Swedish policy, but it could also be seen as evidence for slow adjustment in prices and quick quantity adjustment, as argued by Gordon (1981) or Okun (1981). Notice here also the discussion in Wicksell (1936) and his discussion of the dichotomy and

the different equilibrium concepts used for the monetary and the real part of the economy (see also the reference in Chapter 1). According to Wicksell, the equilibrating fortes in the real part of the economy are very strong, so that the the initial equilibrium will be restored quickly in response to a temporary shock. On the contrary, the equilibrating fortes in the nominal part of the economy are weak, in the sense that the initial equilibrium will not be restored (is *indifferent" in Wicksell's words) unless the initial disturbance is removed. Something of this can be read from the forecast standard errors in Table 6.2 and from the dynamit responses in the figurer above. The dynamit responses to different shocks are more damped for the two real variabler Vp and DU, while the nominal variables, DPW, DP and DW show a more prolonged cyclical pattern. But, contrary to Wicksell's idea of a dichotomy, nominal variables in this system exert a strong influence on real variables.

6.5.3 Decomaosition of Variance of Forecast Errors

The decomposition of forecast error variance is given in Table 6.3. The variance of the error, as given by (6.6), is decomposed among the components of v, the vector of orthogonal innovations. The variance of the forecast errors does not depend upon the factorisation of 4, but the decomposition does. In Table 6.3, the decomposition is based on the orthogonalisation in the order: DPW, Vp, DP, DW and DU, as indicated in the table.

Table 6.3 gives the percentages of the total variance of k-step ahead forecast errors, due to innovations in the different variables. Since only DPW is allowed to affect all the other variables contemporaneously, it accounts for 100 : of its forecast error variance in the first period. An exogenous variable would account for most of its own variance by own-innovations. Therefore, a Preliminary informal check for exogeneity can be achieved by looking at the diagonal cells in Table 6.3.

Table 6.3.. Decomposition of variance of k-step ahead forecast ..... errors. The innovations arg orthogonalised in the indicated order. Variance ..k....Shock in:'.....

in:		DPW	Vp	DP	DW	DU
DPW	1	100.0	0	0	0	0
	2	93.13	4.41	2.07	.31	.09
	3	89.36	**4.83**	**5.11**	**.61**	**.09**
	5	**65.21**	**14.40**	16.08	.91	3.41
	10	54.92	14.73	23.76	1.95	4.64
Vp	1	52.69	47.31	0	0	0
	2	62.65	31.27	.03	4.31	1.74
	3	62.44	29.80	.51	5.14	2.11
	5	63.75	15.29	14.07	2.39	4.50
	10	65.86	11.83	14.12	2.45	5.74
DP	1	58.92	.86	40.22	0	0
	2	66.31	6.47	23.34	.35	3.53
	3	66.20	6.56	22.58	1.33	3.33
	5	56.18	12.26	23.05	1.52	6.99
	10	43.00	18.44	28.28	2.73	7.55
DW	1	38.56	9.72	9.18	42.55	0
	2	57.44	7.33	12.10	22.76	.36
	3	53.63	9.02	13.83	20.74	2.79
	5	43.56	14.85	21.25	17.31	3.04
	10	32.21	18.94	30.24	13.83	4.78
DU	1	**2.43**	**3.63**	**1.32**	**16.94**	**75.67**
	2	**3.05**	**3.25**	**9.63**	**16.32**	67.75
	3	2.81	4.84	9.94	15.04	67.36
	5	4.16	11.01	32.75	8.89	43.19
	10	3.71	9.81	42.75	7.54	36.19

After 5 years DPW-innovations account for the largest part of the variance in all variables except DU. As much as 15 and 24% of the variance in DPW after 10 years is explained by innovations in Vp and DP, respectively. Strictly speaking, DPW is not exogenous either.

The variance in Vp is largely due to innovations in DPW, Vp and DP, which account for 64, 15 and 14°%e of the 5-year ahead variance, respectively. Notice, however, that DP-innovations are not so important for the variance in Vp on a short-term basis.

The variance of inflation is dominated by innovations in DN, Vp and DP, which account for 56, 12 and 23 °-o. respectively. Hence, feedback from Vp to DP is possible on a long-term basis, though it by no means dominates the forecast error variance in DP.

Wage and unemployment-innovations are not very important for the other variables, but after 3 years wage-innovations account for 15 ö of the variance in DU.

Wage-innovations are not important for inflation, but inflation-innovations account for 30 e of the variance in DW after 10 years. This casts some doubts on the assumption of wages being exogenous, commonly made in empirical work with price equations. Note in particular here, that these findings are consistent with the Scandinavian model for an open economy, as analysed in Chapter 3. In that model, both wages and prices are dominated by prices in the world market and the equilibrium rate of inflation in that model only deviates from price changes in the exposed sector through differences in productivities between the exposed and the sheltered sectors. As can be seen in Table 6.3, the forecast error variances in both DP and DW are dominated by shocks in DPW, both in the short and in the long run.

The results in Table 6.3 are based on the particular ordering in the Choleski factorisation of 4. Since contemporaneous torrelation between the residuals is relatively large, the results may be due to this particular choice. In Table 6 of Appendix 4 we give the results for the alternative ordering, where Vp have been put last in order. There are sonve changes in the figurer, but the main results remain.

The main results, then, are that innovations in DPW are important for all the variabler except DU. Innovations in price variability are important, particularly for the variance in wage and price inflation. Inflation-innovations are important for all variables, but explain the variance in Vp and DU with a considerable lag. Though contemporaneous torrelation between some of the variables is considerable, the change of the ordering of Vp and DP in the orthogonalisation of the residuals does not change the main results of the responses in the system.

6.5.4 Historical Decomaosition

The historical decompositions, based on the partitioning (6.4) of the moving average representation, are given in Figures 6-10 in Appendix 4. Figures 7 and 8 show the decomposition of Vp and DP.

The historical decompositions can be used to analyse major shocks during specific time periods. Here we shall concentrate on the events in the 70s. There were two major supply shocks, in 1974 and 1979, the two oil-price shocks. These are partly reflected in DM In addition, there were two devalutations of the Swedish currency in 1977, one of 10 and one of 6%, which should be reflected in DM

In Figure 7, the historical decomposition of Vp is plotted. The projection of Vp is denoted by * and this projection plus the cumulative components of the innovations in each of the variables since time T (T=1969) are given. In 1974, the year of the first oil-price shock, the base prediction of Vp is .007 with the cumulative impact of innovations in DPW since 1970 being .003. The impact from innovations in other variables is much smaller that year. The effects during the second oil-price shock in 1979 are much smaller.

Similarly, in 1977 the impact of innovations in DPW is dominating, adding .003 to the predicted .006, which is evidence of the impact of the Swedish currency depreciation on Vp.

The effects on inflation can be seen in Figure 8. These effects are quite similar to those in Figure 7. Import price-innovations give large effects on inflation in 1974 and 1977, but much smaller effects in 1979

Inflation-innovations have not been very important for price variability in the early 1970s, but since 1975 they have. In 1975 and 1976, DP-innovations increase Vp and in 1977-1979 there is a large negative impact.

The same pattern goes for the impact of Vp-innovations on the rate of inflation. Since 1974, price variability-innovations have a large positive effect on inflation. From 1976 to 1979, innovations in Vp add about .02 to DP each year. Relative-price variability shocks hence have been a potential source of inflationary impulses in the Swedish

economy in the late 70s.

To conclude, innovations in import prices have had a large influence on both price variability and inflation during the 70s in the Swedish economy. Innovations in inflation have had a large impact on price variability in the late 70s, but innovations in price variability have also influenced inflation during the same time period. The effects from the two oil-price shocks and from the Swedish currency depreciations in 1977 can clearly be seen from the effects of changes in import prices on both inflation and on the variability of relative-price changes.

6.5.5 Causality Tests

In the causality tests we apply the definitions in section 6.4, i.e., we shall compare the forecasting performance of different models. The method for comparing models is the one described and applied by Ashley, Granger and Schmalensee (1980) and Ashley (1981), in which post-sample forecast errors of different models are compared in the following way.

Let o(DPII) be the one-step ahead post-sample root of mean square forecast errors made by the five-variable VAR above. Then, let o(DPII-Vp) be the forecast errors made by a four-variable VAR, with Vp deleted from the first model. Define

$$(6.7)\quad Dif_t = o_t(DPJI\text{-}Vp) - o_t(DPI\ I)$$

and

$$(6.8)\quad Sum_t = o_t(DPjI\text{-}Vp) + o_t(DPI\ I).$$

Then, consider the regression equation

$$(6.9)\quad Dif_t = \sim_0 + S_1 (Sum_t - Sum) + ut,$$

where Sum is the sample mean of Sum_t over the postsample period and u_t is a disturbance term with the usual properties. Then, as shown in Ashley, Granger and Schmalensee (1980), p_0 is the difference in mean forecast error between the two models and $\sim_1$ is proportional to the

difference in forecast error variance.

The test of direct causality Vp=>DP then implies testing of the hypothesis that S_0 andjor B_1 is greater than zero. Provided S_0 and 0 1 are positive this can be done by a F-test on the null hypothesis that both coefficients are zero.

Since we have annual data and only 29 observations, the test is likely to be weak. We have undertaken the post-sample forecasting for the period 1971-1979, and 0sed the Kalman filter for updating **the parameters of the models** . This gives only 7 degrees of freedom for comparing the forecasting performance of the models. In addition, since we use annual data, the test will be inconclusive, since contemporaneous correlation between some of the variables is high and significant. Hence, even if, say, we find evidence of no causality from Vp to DP, there may still be direct causality, provided it all occurs within a year. On the other hand, if we find evidence of direct causality from Vp to DP, this would cast sonve doubts on the regressions made in the previous chapter.

Another problem is that the residuals in the system in general are not white. The Box-Pierre statistic does not reject whiteness of the residuals in the Vp- and DPW-equations. The B-P statistic is

$$Q=n \sum_{k=1}^{m} e_k^2$$

where B 2 k is the kth lag autocorrelation of the residuals. Q10is asymptotically chi-squared distributed with m degrees of freedom The significance levels are .97, .92 and .75 for the Vp-, DPW-, and DP-equations, respectively, while the DW-equation and the DU-equation are significant at the .41 and .43 levels, respectively. Hence, the white-noise assumption is accepted for the Vp-equation, which is reassuring for the regressions in the previous chapter, but rasts sonve doubts on the VARs here.

Turning to our results, then, we find no evidence of Direct Causality, neither DP=>Vp nor Vp=>DP. In the bivariate test of direct causality from DP to Vp, the coefficient p , i.e. the urean of the difference between u(Vp/Vp) and o(VPI Vp,DP) is significant at the 8% significance level. Since condition (ii) of No Causality is confirmed,

there is a possibility of Spurious Causality. We tested that possibility by assuming that DPW caused both DP and Vp. We found that c(VPII-DP) < o(VpI I-DN), o(VplI-DPW) < o(VplI-DN-DP) and o(DPII) < o(DPII-DN), but that o(DPIDP, DPW) > o(DPIDP). Because of the last inequality, the hypothesis of Spurious Causality from DP to Vp is rejected by our data. The regression equations, based on (6.9), for the test of Direct Causality, both for DP=>Vp and Vp=>DP, are given in Appendix 5. Since the direct causality from DP to Vp is rejected when we compare the information sets I and I-DP, we do not show the **tests for all combinations of information sets.** The bivariate case is also shown in the tables, because similar tests have been done earlier for these information sets

We should not place ooo much emphasis on these results, since they are based on a weak data basis, both far the predictions and for the causality tests. In conclusion, the causality tests show that there are no direct causalities, neither DP=>Vp nor Vp=>DP, revealed by our data. Since the data could be considered insufficient for a causality test, and since there are **significant contemporaneous torrelation between some of** the variables in the model, this test is inconclusive. Our results can be compared to these of Ashley (1981). He made a causality test, based on a bivariate model with monthly data on DP and the standard deviation of relative-price changes. He found DP=>Vp but not the reverse. We found similar evidence here for the bivariate model, but not for the multivariate five-variable VAR.

There is no evidence, neither here nor in Ashley (1981), of direct feedback from Vp to DP: this gives support to the specification of the regression equations in the previous chapter.

7 SUMMARY AND CONCLUSIONS

Economic theory has for a long time focused on the relationship between nominal and real variables. Models in which the economy dichotomises into a nominal and a real part, independent of each other, have had a great influence on economic thought. Closely related to the dichotomy is the concept of neutrality, which says that an economic system comprised by a set of functions relating endogenous and exogenous variables, is neutral, if these functions are homogenous of degree zero in all nominal variables. Multiplying all nominal variables with some proportionality factor will leave the system in equilibrium, with all real variables unaffected.

The dichotomy and the neutrality property was questioned early, i.a. by Keynes in the thirties. In Keynes's world, changes in the money supply would affect real variables, since, via changes in interest rates, investment and real income would be affected. Such effects are inconsistent with the natural rate hypothesis, according to which agents' decisions depend on relative prices only.

The controversy about the Phillips curve in the sixties and seventies can be seen as a continuation of the debate about the relationship between nominal and real variables. Keynesian orthodoxy and the stable negatively sloping Phillips curve was questioned and the natural rate Phillips curve appeared as the neoclassical challenge to this orthodoxy. Friedman's and Phelps's and Lucas's theories of the Phillips curve were based on the presumption that agents have incomplete information. In the former framework, workers temporarily misperceive real wage rates and in the Lucas model they confuse absolute with relative prices. The incomplete information approach implies a relationship between nominal and real variables, to the extent that unanticipated changes in the money supply or in unanticipated inflation affects relative prices and real output.

In the present study, we have empirically analysed the relationship between nominal and real variables, specifically the relationship between inflation and changes in relative prices. This relationship has come into focus in recent macroeconomic theory, particularly in

the Lucas model of the Phillips curve. In Chapter 2 we showed how the variance of relative prices and the variance of the general price level were correlated over time in the Lucas model, through the mutual dependence on the variance of exogenous demand shocks. This result is due to the incomplete information of agents, who are assumed to know the prices in their own inarkets but have no certain knowledge about the general price level.

The illusion-based model of Lucas has been called a neutral model. However, as has been shown in Chapter 3, not only unexpected inflation has an impact on relative prices, but fullt' expected inflation can influence the course of relative prices. If firas face price adjustment costs and these costs differ between firas, then an increased rate of inflation will increase the variability of relative-price changes. This type of theory has nothing to do with incomplete information and implies a direct causality from fullt' expected inflation to the variability of relative-price changes.

The question of causality between these two variables was further analysed in Chapter 3, when we described other theories which embodied a relationship between expected inflation and the variability of relative-price changes. Theories of asymmetric price adjustments, which postulate that prices are sticky downwards in some sectors or industries in the economy, imply a reverse causal order, since relative excess supplies and excess demands produce an inflationary bias, due to the failure of prices to decrease, or to rise sufficiently, in markets with excess supplies. Closely related to this model are theories which distinguish between markets with different characteristics, e.9. with respect to differences in contract structure. In that kind of model, different exogenous shocks, which could emanate both from the supply and the demand siden, produce a positive relationship between inflation and relative-price variability, due to differences in price adjustments. Markets with implicit contracts are characterised by gradual price adjustment while prices on auction-like markets adjust quickly. Finally, it is shown that in the Scandinavian model of wage and price formation in an open economy, a positive relationship between inflation and the variability of relative-price changes is generated by relative productivity changes between traded and nontraded goods sectors.

The review of the theories of the relationship between inflation and relative prices in different models reveals that this relationship is not very stable, since the exogenous fornes differ from model to model. Despite this fatt, in Chanter 4, we analysed empirically the relationship between the variance of relative-price changes and the expected and unexpected rate of inflation. Regressions were made for annual Swedish data of tonsumer prices for the period 1951-1979. The aim of this empirical analysis was to compare the results for Sweden with earlier findings for other countries. The expected rate of inflation is assumed to be formed in two alternative ways: adaptive and extrapolative expectations. The results for Sweden tonform well with earlier studies, though the effects from expected inflation appears somewhat stronger. The results suggest that a 1 % increase in the rate of expected inflation, increases the standard deviation of relative-price changes by approximately 0.4 %. The effect from unexpected inflation was stronger, with a corresponding figure of 0.7

The simple regression studies in chapter 4 revealed that in many countries there was a positive significant relationship between inflation and the variability of relative-price changes. However, these regressions were made without economic structure and hence can be viewed as misspecifications. Therefore, in Chanter 5 we build an equilibrium model of an open economy, which consists of many markets, each of which clears in each time period. The strategy was to build a model in which neutrality is maintained. To be able to distinguish between the different theories put forward in chapters 2 and 3, the effects of incomplete information was embodied in the model. This was done by assuming a labour market in equilibrium, in which the equilibrium wage rate depended on the expected price level. The rationalisation is that supply and demand decisions are based on complete information about nominal wage rates but incomplete information about the general price level, i.e. incomplete information about the real wage rate. This situation arises if wage tontratts for period t are fixed in period t-i.

The open economy characteristics of the model appear on the demand side, since demand depends on the foreign price level and on the foreign level of real income. An extension in comparison with earlier models in the same area is that raw materials are included in the technology of firms and hence the supply functions also include raw

material prices. Compared to the Lucas model, this model is also more general in that it allows for different supply and demand parameters between markets. However, the assumption on inflationary expectations is more restrictive, since they are assumed to be equal across markets.

The multi-market equilibrium model is solved for changes in relative prices and for the variance in relative-price changes. Changes in relative prices in equilibrium depend on unexpected inflation, changes in relative raw material prices, changes in domestic and foreign real income and on the deviation from the purchasing power parity.

This model was then tested in regression equations. The expected rate of inflation was added to the model and it was then possible to test whether it was significantly related to changes in relative prices and to the variability of relative-price changes. In addition, we tested whether the extensions made here, i.e. the inclusion of raw material prices and open economy considerations were significant. The analysis was carried out for Swedish consumer prices while the data for raw material prices and domestic and foreign income was taken from the national accounts statistics. Annual data for the period 1951-1919 was used.

In likelihood ratio tests and F-tests, we showed that the hypothesis that the effects from expected inflation, changes in relative raw material prices and changes in the foreign variables are zero, was rejected at low significance levels.

The tests were made in two alternative ways. Firstly, for the equilibrium variance of relative-price changes and, secondly, for relative-price changes on a set o£ constant-quality commodities. The latter tests have not been made before and the results found here reinforces the previous results for relative-price variability.

The tests implied that previous models have been misspecified, particularly since relative raw material prices were shown to be important for the variability of relative prices.

The model in Chapter 5 was essentially a static model in which it was assumed that it was inflation which affected changes in relative prices. Differences in price adjustment costs between firas justified that assumption. However, as pointed out in Chapters 2 and 3, the true exogenous forces may be others. Therefore, in Chapter 6 use was made of a dynamic time-series model, a vector autoregression, in which all variables were treated as endogenous, and in which causality could be tested. The decision regarding which variables to include in the model should be based on proper economic theory, although the nurober of variables and the nurober of lags in the model must be restricted, since otherwise the nurober of degrees of freedom would soon be exhausted. We included the variability of relative-price changes, the rate of inflation, changes in import prices, the rate of wage inflation and changes in the unemployment rate in the model and we used a three year lag. The dynamic responses to different kinds of shocks were studied and the system showed a slowly damped dynamic pattern.

The variability of relative-price changes was particularly sensitive to shocks in inflation and import prices. Shocks in the variability of relative-price changes was shown to reduce both wage and price inflation. The latter results are contradictory to the theories which assume asymmetric price adjustments and downward stickiness in prices. In the analysis of historical shocks it was shown that import price shocks were important for both inflation and the variability of relative-price changes, and, in particular, the two oil-price shocks were clearly visible.

The fornval causality tests, based on the Wiener-Granger causality concepts, were somewhat inconclusive, which was probably due to the relatively poor data basis. However, no direct feedback from price variability to inflation was found, thus giving support to the econometric specifications in Chapter 5. There was weak support for direct causality from inflation to relative-price variability in the test based on the bivariate model, but in general there was no direct causality from inflation to relative-price variability.

In conclusion, the present study has shown that there is a significant relationship between **inflation and the variability of relative-price changes.** This relationship does not only hold for unexpected inflation based on agents' incomplete information, but also a fully expected

inflation is significantly related to relative prices and relative-price variability. Weak support was also found for the hypothesis that causality goes from inflation to relative-price variability, but also that supply shocks may be the exogenous disturbance. We have not analysed the welfare implications of relative-price variability, but the empirical results suggest that inflation may have substantial effects on the allocative efficiency of the price system and on the distribution of income.

NOTES

Chapter 1

1) On the distinction between neutral and dichotomised models and for some examples of these features in classical macromodels, see Niehans (1978) or Sargent (1979).

2) see wicksell (1936), ch. 3.

3) See Lange (1942), Becker and Baumol (1952), Patinkin (1965), Archibald and Lipsey (1958), and Mauer (1966). For a survey, see Hansen (1966) or Niehans (1978).

4) See Sargent (1979), p. 103-105.

5) See Niehans (1978), p. 30, 67 and 206.

6) See Keynes (1930), p. 85 aa.

7) For an illuminating summary on NRH, see Azariadis (1982). For works in the Friedman/Phelps direction, see Phelps (1970) and for surveys on the REH, see Barro and *Fischer* (1976), Schiller (1978), Buiter (1980) and Begg (1982). For a critical analysis of the foundations of the new classical macroeconomics, see Hahn (1982).

8) In Samuelson's words some advocates of the dichotomised economy are labelled "jackasses":

"Mine is the great advantage of having been a jackass. From ?. January 1932 until an indeterminate date in 1937, I was a classical monetary theorist. I do not have to look for the tracks of the jackass embalmed in old journals and monographs. I merely have to lie down on the couch and recall in tranquillity, upon that inward eye which is the bliss of solitude, what it was that I believed between the ages of 17 and 22. This puts me in the same advantageous position that Pio Nono enjoyed at the time when the infallibility of the Pope was being enunciated. He could say, incontrovertibly, "Before I was Pope, I believed he was infallible. Now that I am Pope, I can <u>feel</u> it."

Samuelson (1968), p. 1.

9) For these attempts and the econometric debate, see Lucas (1973), Sargent (1976), Barro (1977,1978), Barro and Rush (1980), Wallis (1980), Mishkin (1982), and Pesaran (1982).

10) I.a., see Sargent (1976) and Barro (1977,1978).

11) See his Treatise on Money, ch. 8, where Keynes discusses index number problems and the classical dichotomy.

Chapter 2

1) The observation was made much earlier, by Fisher (1926).

2) An illustration of this development is given in Robert Gordon (1976,1977) or in Okun (1981), ch. VI.

3) The references are Phelps (1967), Friedman (1967,1968), Lucas and Rapping (1969), Phelps et.al. (1970), Lucas (1972,1973,1975), and Lucas and Prescott (1974).

4) This is described by Friedman in his classic 1968 article:

"But it describes only the initial effects. Because selling prices of products typically respond to an unanticipated rise in nominal demand faster than prices of factors of production, real wages received have gone down - though real wages anticipated by employees went up, since employess implicitly evaluated the wages offered at the earlier price level. Indeed, the simultaneous fall ex post in real wages to employers and rise ex ante to employees is what enabled employment to increase. But the decline ex post in real wages will soon come to affect anticipations. Employees will start to reckon on rising prices on the things they buy and to demand higher nominal wages for the future. 'Market' unemployment is below the natural leoel. There is an excess demand for labor so real wages will tend to rise toward their initial leoel."

Friedman (1968), p. 10.

5) Note that I have not included the lagged output term Ay_{t-1} in Lucas' model, which gives a *solution" to the persistence problem.

6) For a derivation of this projection, see Sargent (1979), chapter X.

7) See Sargent (1979), ch. XIII for details.

8) The result is due to Cukierman (1979).

9) See Cukierman and Wachtel (1979). They use a fixed-weight price index (or price level) where the weights are assumed to be small on each market.

10) The solution for the expected general price level in equilibrium is obtained by substituting (2.8) into the fixed-weight formula for the general price level.

Chapter 3

1) For surveys on these relationships, see Fischer (1981b) and Cukierman (1983).

2) See Tobin and Brainard (1963), Tobin (1969), Tobin and Buiter (1976) or Niehans (1978).

3) A general macroeconomic reference is Okun (1981). See also Tobin (1982). The literature is closely associated with models with imperfect and costly information and with the formation of implicit contracts. See Akerlof (1970), Salop (1973,1978), D.F. Gordon (1974), Williamson, Wachter, and Harris (1975), Azariadis (1975), Baily (1978), and Stiglitz (1979) for studies in the labour market and Phelps and Winter (1970) and Salop and Stiglitz (1977) for the product market. The effects of multiperiod contracts in the labour market with rational expectations has been studied by Fischer (1977) and Taylor (1980).

4) The analysis is based on Sheshinsky and Weiss (1977).

5) It is easily understood that a continuously changed price with positive adjustment costs would lead to bankruptcy, since adjustment costs would be infinite.

6) This result is conditional on the frequency of price changes remaining unaltered. Intuitively one would think that an increased inflation rate would increase the frequency of price changes. However, as Sheshinsky and Weiss have shown, the effect on the frequency of price changes in this case is ambiguous.

7) This conclusion was reached by Sheshinsky and Weiss (1977) p. 301:

'According to the analysis, with a constant rate of inflation, prices will increase on the average at the rate of inflation. More importantly, if the timing of firas' price adjustments is independent, then we would observe a variance across products or firas which increases with the rate of inflation. This implies that informational costs exist even with a steady aggregate rate of inflation."

8) On these empirical evidence, see Cagan (1974), Coutts, Godley and Nordhaus (1978) and Robert Gordon (1975,1981).

9) See the references in n. 4 above.

10) A typical pricing rule in an environment with low and predictable inflation would be normal cost pricing at historical costs.

11) Macromodels with sectorally sticky prices have also been developed be Schultz (1959) and Tobin (1972).

12) Again, note the quotation from Friedman (1975) on p. 7 above, where the oil price shock is assumed to be wholly accomodated by relative price changes.

13) In Deaton (1975) the estimated own-price elasticities of demand ranged from -0.39 to -0.11 for "Other fuels" and from -0.74 to -0.51 for "Ruvning costs of motor vehicles", depending on the form of the demand functions.

14) Bordo (1980) finds a similar relationship due to differences in the length of contracts. Differences in contract length may be caused by differences in risk or in risk aversion; see Arrow (1971).

15) For an exposition of the model, see Edgren, Faxen and Odhner (1969,1973) and Aukrust (1970,1977). For a discussion, see Lundberg (1972) and Paunio and Halttunen (1976).

16) Again, variables are expressed in IMs.

17) See the quotation in the Introduction from the Treatise.

Chapter 4

1) See Mills (1927).

2) Cf., compare with the discussion in Vining and Elwertowski (1976) about the "instability of the general price level". Parks (1978) interprets this as unanticipated inflation.

3) On the first relationship, (i), see Blejer (1981) and on (iv), see Okun (1971), Gordon (1971), Logue and Willett (1976), Jaffee and Kleiman (1977), Foster (1978), Blejer (1979), Engle (1980), and Fischer (1981a,b). Blejer (1981) found a positive significant relationship between the variance of relative price changes and the variance of the rate of inflation, hence accepting the hypothesis (i). The general finding for the hypothesis (iv) is the same, i.e. a positive significant relationship between the inflation rate and its variability, though there are exceptions (see Engle (1980)).

4) See Theil (1967), p. 155.

5) The coefficient of variation is defined as $V_t = Vp_t^{1/2} / DP_t$

6) See Schultz (1959) or Okun (1975,1981).

7) See equation (14) in Table 4.1.

8) These are Food; Alcohol and tobacco; Housing, fuel and light; Clothing and footware; Furniture and household equipment; and Miscellaneous.

9) See Fisher and Shell (1972) or Muellbauer (1975), for the treatment of taste and quality changes in cost-of-living index numbers.

10) b is a maximum likelihood estimate, which is computed in the TSP statistical package. The estimation method is described in Beach and MacKinnon (1978).

11) Note, however, the discussion of the stochastic disturbance terms in the next chapter, in which we show that the error terms are hon-normal for highly aggregated data, hence suggesting that OLS is inappropriate for Vp_t^a.

Chapter 5

1) Though simple, it implies a supply function which is hon-linear in parameters and hence less attractive for estimation purposes.

2) The labour supply and demand functions could also have been formulated in log-linear form, which would not have been of importance for the argument. The equilibrium wage rate in (5.7) would then have changed to $w=e^A EP$. In addition, the labour demand function could have been changed to $1 = 13+14\ w$, which again would not have altered the argument. A rationalisation for the formulation in (5.5) and (5.6) can be sought in a centralised wage bargaining process. Whatever specification is chosen, the resulting labour market equilibrium will be characterised by a simple linear relation between the wage rate and the expected price level, which is the result we are after.

3) See Cain and Watts (1973), Brown (1980) and Hansson and Stuart (1983). Hansson and Stuart compare several studies and compute a weighted median for women's and men's wage elasticity of approximately -0.10.

4) The analysis here essentially follows Varian (1978), ch. 1.

5) Superneutral in this sense is used by Kreinin and Officer (1978) and refers to the strong version of the monetary approach to the balance of payments, as expressed La. by Johnson (1976).

6) See, e.g., Bruno and Sachs (1982), de Menil and Westphal (1982), Giavazzi et.al. (1982), or Shigehara (1982).

7) These countries are Denmark, Norway, Finland, Holland, Belgium, France, Italy, Switzerland, West Germany, Great Britain, united States, and Japan. In 1979 these countries accounted for about 74 % of total Swedish exports.

8) The use of the regression equation based on (5.19) probably did not change the regression results substantially, since the residuals in the former regression equation were extremely small.

9) See Lindgren (1976), pp. 158-59 and 193-94.

10) The F-test for the overall significance of a regression equation is made by computing the F-ratio

$$\frac{(n-k)\ R^2}{(k-1)\ (1-R^2)}$$

which has a F(k-1,n-k) distribution under the null hypothesis that all the k regression coefficients, except the constant term, are zero.

11) See Deaton (1978).

Chapter 6

1) For a discussion of causality tests and the use and interpretation of vector autoregressions, see Zellner (1979), Schwert (1979) and Sims (1979). See also Sims (1977). For a general reference to time-series models, see Box and Jenkins (1976). For a discussion of time-series models as an alternative to large-scale econometric models, see Sims (1980) and for a comparison of the forecasting performance, see Nelson (1972), Fair (1979) and Litterman (1980).

2) Ashley's findings in the bivariate case, applied to monthly data for the United States, is that DP Granger causes VP, but not vice versa.

3) Sims' argument is that such restrictions imposed on a VAR, are more general in its nature, and less arbitrary than the traditional exogeneity assumptions in orthodox macroeconometric models.

4) It would have been preferable to use quarterly or monthly data in a vector autoregression. However, there is no consistent set of data, other than annual, for the variables included in our model. The Swedish national accounts only provide quarterly data for real national product, and there was no way in which we could obtain

quarterly data.

5) It should be noted that we study the causality between DP_t and Vp_t in two alternative ways. The first is the informal test, which is done by simply looking at the decomposition of the variance of forecast errors in the model, and inspecting the proportions of variance explained by own-innovations in the different variables. The second test is the formal test, based on the Wiener-Granger causality concepts.

6) These standard errors are based on the assumption that the estimated parameters equal the true parameters. Therefore, the true forecast error variances are larger than those in Table 6.2.

7) The latter effect may be due to the bad reflection of oil-prices in DPW_t. When we replaced DPW_t with Dp_{mt} the effects of innovations in Dp_{mt} in 1979 increased, both on VP_t^u and DP_t.

8) The effects of innovations in DW_t and DU_t on VP_t^u are generally small. In 1977 and 1978, however, there are increases in DW_t due to innovations in VP_t^u. Note also that inflation-innovations have been important for DW_t but the reverse have not been the case.

9) In general, the system of equations could be reestimated for each forecast, so that each set of forecasts is based on the information available at that time. The Kalman filter is a computationally cheap method for updating the estimates over a forecasting period. (On Kalman filters, see Phillip Cooper (1973)) Here it is assumed that the coefficient vector is not generally time varying, but follows a random walk. Let the system of equations to be estimated be $y_t = X_t y_t + u_t$, where the variance of u_t is denoted by n_t. Then, the coefficient vector is with $Var(v_t) = M_t$. The covariance matrix of S_{t-1} is denoted $S_t = S_{t-1} + v_t'$ S_{t-t}. Then, -;he updated coefficient vector is computed by $_t = N_{t-t} + S_t X'_t n_t (y_t - X_t d_{t,t-1})$ where $S_t = S_{t-1} + M_t$, where M_t is set to zero.

10) See Box and Pierce (1970).

REFERENCES

Aigner, D.J., (1971), Basic Econometrics, Prentice-Hall.

Akerlof, G.,(1970), "The Market for 'Lerrons': Qualitative Uncertainty and the Market Mechanism", Quarterly Journal of Economics, Vol. 84, pp. 488-500.

Archibald, G.C. and R.G. Lipsey,(1958), "Monetary and Value Theory: A Critique of Lange and Patinkin", Review of Economic Studies, Vol. 26, pp. 1-28.

Ashley, R-0981), "Inflation and the Distribution of Price Changes Across Markets: A Causal Analysis", Economic Inquiry, Vol. 19, pp. 650-60.

Ashley, R., C.W.J. Granger and R.L. Schmalensee,(1980), "Advertising and Aggregate Consumption: An Analysis of Causality", Econometrica, Vol. 48, pp. 1149-68.

Aukrust, 0.,(1970), "PRIM I: A Model of the Price and Income Distribution Mechanism of an Open Economy", Review of Income and Wealth, Vol. 16, pp. 51-79.

Aukrust, 0.,(1977), "Inflation in an Open Economy", in Krause, L.B. and W.S. Salant, eds., Worldwide inflation, Brookings Institution.

Azariadis, C.,(1975), "Implicit Contracts and Underemployment Equilibria", Journal of Political Economy, Vol. 83, pp. 1183-1202.

Azaridis, C.,(1981), "A Reexamination of Natural Rate Theory", American Economic Review, Vol. 71, pp. 946-60.

Baily, M.N.,(1978), "Stabilization Policy and Private Economic Behavior", Brookings Papers on Economic Activity, No. 1, pp. 11-50.

Balk, B.M.,(1978), "Inflation and Its Variability: Some Comments and the Dutch Case", Economic Letters, Vol. 1, pp. 357-60.

Barro, R.J.,(1976), "Rational Expectations and the Role of Monetary Policy", Journal of Monetary Economics, Vol. 2, pp. 1-33.

Barro, R.J.,(1977), "Unanticipated Money Growth and Unemployment in the United States", American Economic Review, Vol. 67, pp. 101-15.

Barro, R.J. and S. Fischer,(1976), "Recent Developments in Monetary Theory", Journal of Monetary Economics, Vol. 2, pp. 133-67.

Barro, R.J. and M. Rush,(1980), 'Unanticipated Money and Economic Activity", in S. Fischer, ed., Rational Expectations and Economic Policy, University of Chicago Press.

Beach, C.M., and J.G. MacKinnon,(1978), "A Maximum Likelihood Procedure for Regression with Autocorrelated Errors", Econometrica, Vol. 46, pp. 51-58.

Becker, G.S. and W.J. Baumol,(1952), "The Classical Monetary Theory: The Outcome of the Discussion", Economica, Vol. 19, pp. 355-76.

Begg, D.K.H.,(1982), The Rational Expectations Revolution in Macroeconomics, Philip Allan.

Blejer, M.I.,(1979), "Inflation Variability in Latin America: A Note on the Time Series Evidence", Economic Letters, Vol. 2, pp. 337-41.

Blejer, M.I.,(1981), "The Dispersion of Relative Commodity Prices Under Very Rapid Inflation", Journal of Development Economics, Vol. 9, pp. 347-56.

Blejer, M.I., and L. Leiderman,(1982), "Inflation and Relative-Price Variability in the Open Economy", European Economic Review, Vol. 18, pp. 387-402.

Bordo, M.D.,(1980), "The Effects of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts", Journal of Political Economy, Vol. 88, pp. 1088-1109.

Box, G.E.P. and G.M. Jenkins,(1976), Time Series Analysis: Forecasting and Control, Holden-Day.

Box, G.E.P. and D.A. Pierce,(1970), "Distribution of Residual Autocorrelations in Autoregressive-Integrated Moving Average Models", Journal of the American Statistical Association, Vol. 65, pp. 1509-26.

Brown, C.V.,(ed.),(1980), Taxation and Labour Supply, Oxford University Press.

Bruno, M., and J. Sachs,(1982), "Input Price Shocks and the Slowdown in Economic Growth: The Case of U.K. Manufacturing", Review of Economic Studies, Vol. 49, pp. 679-705.

Buiter, W.,(1980), "The Macroeconomics of Dr. Pangloss. A Critical Review of the New Classical Macroeconomics", Economic Journal, Vol. 90, pp. 34-50.

Cagan, P.,(1956), "The Monetary Dynamics of Hyper-Inflation", in M. Friedman, ed., Studies in the Quantity Theory of Money, University of Chicago Press.

Cagan, P.,(1974), "The Hydra-Headed Monster: The Problem of Inflation in the United States", American Enterprise Institute.

Cain, G. and H. Watts,(1973), "Towards a Summary and Synthesis of the Evidence", in Cain, G. and H. Watts,(eds.), Income Maintenance and Labor Supply, Academic Press.

Clements, K. and P. Nguyen,(1981), "Inflation and Relative Prices", Economic Letters, Vol. 7, pp. 131-37.

Cornell, B.,(1981), "Relative vs. Absolute Price Changes: An Empirical Study", Economic Inquiry, Vol. 19, pp. 506-14.

Coutts, K., W. Godley and W. Nordhaus,(1978), Industrial Pricing in the United Kingdom, Cambridge University Press.

Cukierman, A.,(1979), "The Relationship between Inflation and the General Price Level: A Suggested Interpretation", American Economic Review, Vol. 69, pp. 444-47.

Cukierman, A.,(1983), "Relative Price Variability and Inflation: A Survey and Further Results", in Brunner, K. and A.H. Meltzer, (eds.), VVariability in Emvlovment. Prices and Money, Carnegie-Rochester Conference on Public Policy, Vol. 19.

Cukierman, A. and P. Wachtel,(1979), "Differential Inflationary Expectations and the Variability of the Rate of Inflation: Theory and Evidence", American Economic Review, Vol. 69, pp. 595-609.

Cukierman, A. and P. Wachtel,(1982), "Relative Price Variability and Nonuniform Inflationary Expectations", Journal of Political Economy, Vol. 90, pp. 146-57.

Deaton, A.S.,(1975), Models and Projections of Demand in Post-War Britain, Chapman and Hall.

Deaton, A.S.,(1978), "Specification and Testing in Applied Demand Analysis", Economic Journal, Vol. 88, pp. 524-36.

Defris, L.V., and R.A. Williams,(1979), "The Formation of Consumer Inflationary Expectations in Australia", Economic Record, Vol. 55, pp. 136-48.

de Menil, G. and U. Westphal,(1982), "The Transmission of International Disturbances. A French-German Cliometric Analysis", Euronean Economic Review, Vol. 18, pp. 41-73.

DiPietro, W.R.,(1980), "The Effects of Changes in Relative Prices on Inflation and Unemployment", Nebraska Journal of Economics and Business, Vol. 19, pp. 41-51.

Edgren, G., K.O. Faxen and C.E. Odhner,(1969), "Wages, Growth and the Distribution of Income", Swedish Journal of Economics, Vol. 71, pp. 133-60.

Edgren, G., K.O. Faxen and C.E. Odhner,(1973), Waae Formation and th Economy, George Allen and Unwin.

Engle, R.F.,(1974), "Specification of the Disturbance for Efficient Estimation", Econometrica, Vol. 42, pp. 135-46.

Engle, R.F.,(1980), "Estimators of the Variance of U.S. Inflation Based Upon the ARCH Model", Working Paper, University of California, San Diego.

Fair, R.C.,(1979), "An Analysis of the Accuracy of Four Macroeconometric Models", Journal of Political Economy, Vol. 87, pp. 701-18.

Fischer, S.,(1977), "Long Term Contracts, Rational Expectations and the Optimum Money Supply Rule", Journal of Political Economy, Vol. 85, pp. 191-205.

Fischer, S.,(1981a), "Towards an Understanding of the Costs of Inflation: II", Carnegie-Rochester Conference Series on Public Policy 15, pp. 5-42. Supplement to Journal of Political Economy.

Fischer, S.,(1981b), 'Relative Shocks, Relative Price Variability and Inflation", Brookings Parvers on Economic Activity, No. ?., pp. 381-431.

Fischer, S.,(1982), **"Relative Price Variability and inflation** in the **United States** and Germany", Euronean Economic Review, Vol.

Fisher, 1.,(1911), The Purchasing Power of Money, MacMillan.

Fisher, 1.,(1926), "A Statistical Relation between Unemployment and Price Changes", International Labour Review, Vol. 13, pp. 785-92. Reprinted in Journal of Political Economy, Vol. 81, 1973, pp. 496-502.

Fisher, F.M. and K. Shell,(1972), The Economic Theory of Price Indices, Academic Press.

Foster, E.,(1978), "The Variability of Inflation", Review of Economics and Statistics, Vol. 60, pp. 346-50.

Friedman, M.,(1967), "Comment", in G.P. Shultz and R.Z. Aliber, (eds.), Guidelines, Informal Controls, and the Market Place, University of Chicago Press.

Friedman, M.,(1968), "The Role of Monetary Policy", American Economic Review, Vol. 58, pp. 1-17.

Friedman, M.,(1977), "Nobel Lecture: Inflation and Unemployment", Journal of Political Economy, Vol. 85, pp. 451-72.

Gale, D.,(1978), "The Core of a Monetary Economy without Trust", Journal of Economic Theory, Vol. 19, pp. 456-91.

Giavazzi, F., M. Odekon and C. Wyplosz,(1982), "Simulating an Shock with Sticky Prices", Euronean Economic Review, Vol. 18, pp. 33.

Glejser, H.,(1965), "Inflation, Productivity, and Relative Prices - A Statistical Study", Review of Economics and Statistics, Vol. 47, pp. 76-80.

Goodwin, R.M.,(1947), "Dynamical Coupling with Especial Reference to Markets Having Production Lags", Econometrica, vol. 25, pp. 181-204.

Gordon, D.F.,(1974), 'A Neo-Classical Theory of Keynesian Unemployment", Economic Inguiry, Vol. 12, pp. 442-59.

Gordon, R.J.,(1971), "Stegdy Anticipated Inflation: Mirage or Oasis?", Brookings Parvers on Economic Activity, No. 2, pp. 499-510.

Gordon, R.J.,(1975), "The Impact of Aggregate Demand on Prices", Brookings Parvers on Economic Activity, No. 3, pp. 613-62.

Gordon, R.J.,(1981), "Output Fluctuations and Gradual Price Adjustment", Journal of Economic Literature, Vol. 19, pp. 493-530.

Granger, C.W.J.,(1969), "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods", Econometrica, Vol. 37, pp. 424-38.

Hahn, F.H.,(1982), Money and Inflation, Basil Blackwell.

Hansen, B.,(1966), Lectures in Economic Theory - Part I: General Equilibrium Theory, Studentlitteratur.

Hansson, I. and C. Stuart,(1983), "Tax Revenues and the Marginal Cost of Public Funds", Mimeo., Department of Economics, University of Lund.

Hercovitz, Z_(1981), "Money and the Dispersion of Relative Prices", Journal of Political Economy, Vol. 89, pp. 328-56.

Hsiao, C_(1982), "Autoregressive Modeling and Causal Ordering of Economic Variables", Journal of Economic Dynamics and Control, Vol. 4, pp. 243-59.

Jacobs, R.L., and R.A. Jones,(1980), "Price Expectations in the United States: 1947-75", American Economic Review, Vol. 70, pp. 269-77.

Jaffee, D.M. and E. Kleiman,(1977), "The Welfare Implications of Uneven Inflation", in Lundberg, E., ed., Inflation Theory and Anti-Inflation Policy, MacMillan.

Johnson, H.G.,(1976), "The Monetary Theory of Balance-of-Payments Policies", in Frenkel, J. and H.G. Johnson,(eds.), The Monetary Approach to the Balance of Payments, University of Toronto Press.

Jonung, L.,(1983), "Which Model Du People Carry in Their Mind When They Forecast Inflation Rates?", Mimeo., The Swedish Institute for Economic Research, Stockholm.

Keynes, J.M.,(1930), A Treatise on Money, MacMillan.

Kreinin, M.E. and L.H. Officer,(1978), "The Monetary Approach to the Balance of Payments", Princeton Studies in International Finance, No. 43.

Lange, 0.,(1942), "Say's Law: A Restatement and Criticism", in 0. Lange, ed., Studies in Mathematical Economics and Econometrics, University of Chicago Press.

Leijonhufvud, A.,(1983), "What Would Keynes have Thought of Rational Expectations?", Paper to be presented at the Royal Economic Society's Centennial Celebrations, King's College, Cambridge, July 1983.

Lindgren, B.W.,(1976), Statistical Theory, Collier MacMillan.

Lipsey, R.G.,(1960), "The Relation between Unemployment and the Rate of Change of Money Wages in the United Kingdom 1862-1957: A Further Analysis", Economica, Vol. 27, pp. 1-31.

Litterman, R.B.,(1980), "A Bayesian Procedure for Forecasting with Vector Autoregressions", MIT Working Paper.

Litterman, R.B.,(1982), "A Use of Index Models in Macroeconomic Forecasting", Federal Reserve Bank of Minneapolis, Staff Report No. 78.

Logue, D.E. and T.D. Willett,(1976), "A Note on the Relation between the Rate and Variability of Inflation", Economica, Vol. 43, pp. 151-58.

Lucas, R.E.,(1972), "Expectations and the Neutrality of Money", Journal of Economic Theory, Vol. 4, pp. 10.3-24.

Lucas, R.E_ (1973), "Some International Evidence on Output-Inflation Tradeoffs", American Economic Review, Vol. 63, pp. 326-44.

Lucas, R.E.,(1975), "An Equilibrium Model of the Business Cycle", Journal of Po-litical Economy, Vol. 83, pp. 1113-44.

Lucas, R.E. and E.C. Prescott,(1974), "Equilibrium Search and Unemployment", Journal of Economic Theory, Vol. 7, pp. 188-209.

Lucas, R.E. and L.A. Rapping,(1969), "Real Wages, Employment, and Inflation", Journal of Political Economy, Vol. 77, pp. 721-51.

Lucas, R.E. and T.J. Sargent,(1978), "After Keynesian Macroeconomics", in After the Phillips Curve: Persistence of High Inflation and Unemployment, Federal Reserve Bank of Boston, Conference Series No. 19. Reprinted in Lucas, R.E. and T.J. Sargent, eds.,(1981), Rational Expectations and Econometric Practice, George Allen and Unwin.

Lundberg, E_(1972), "Productivity and Structural Change - A Policy Issue in Sweden", Economic Journal, Vol. 82, pp. 465-85.

Marquez, J. and D.R. Vining,(1982), "Inflation and Relative Price Behaviour: A Survey of the Literature", Discussion Paper No. 500, University of Pennsylvania.

Mauer, L.J.,(1966), "The Patinkin Controversy: A Review", Kyklos, Vol. 19, pp. 219-34.

Metzler, L.A.,(1941), "The Nature and Stability of Inventory Cycles", Review of Economics and Statistics, Vol. 23, pp. 113-2.9.

Mills, R.C.,(1927), The Behavior of Prices, National Bureau of Economic Research.

Mishkin, F.M.,(1982), "Does Aggregate Demand Policy Matter?", American Economic Review, Vol. 72, pp. 788-802.

Muellbauer, J.,(1975), "The Cost of Living and Taste and Quality Change", Journal of Economic Theory, Vol 10, pp. 269-83.

Muth, J.F.,(1961), "national Expectations and the Theory of Price Movements", Econometrica, Vol. 29, pp. 315-35.

Nelson, C.R.,(1972), "The Prediction Performance of the FRB--MIT-PENN Model of the U.S. Economy", American Economic Review, Vol. 62, pp. 902-17.

Niehans, J_(1978), The Theory of Money, Johns Hopkins University Press.

Okun, A.M.,(1971), "The Mirage of Steady Inflation", Brookings Papers on Economic Activity, No. 2, pp. 435-98.

Okun, A.M.,(1975), "Inflation: Its Mechanics and Welfare Costs", Brookings Papers on Economic Activity, No. 2, pp. 351-90.

Okun, A.M.,(1981), Prices and Quantities: A Macroeconomic Analysis, Basil Blackwell.

Parks, R.W.,(1978), "Inflation and Relative Price Variability", Journal of Political Economy, Vol. 86, pp. 79-95.

Patinkin, D_(1965), Mon~y_ Interest, and Prices, New York, 2nd ed.

Paunio, J.J. and H. Halttunen,(1976), "The Nordic Approach to Inflation: Interpretation and Comments", in Parkin, J.M. and G. Zis, eds., Inflation in the World Economy, Manchester University Press.

Pesaran, M.H.,(1982), "A Critique of the Proposed Tests of the Natural Rate-Rational Expectations Hypothesis", Economic Journal, Vol. 92, pp. 529-54.

Phelps, E.S.,(1967), "Phillips Curves, Expectations of Inflation and optimal Unemployment Over Time", Economica, Vol. 34, pp. 254-81.

Phelps, E.S. and S.G. Winter,(1970), "Optimal Price Policy under Atomistic Competitivn", in E.S. Phelps et. al., Macroeconomic Foundations of Employment and Inflation Theory, Norton.

Phillips, A.W.,(1958), "The Relationship between Unemployment and the Rate of Change of Money Wages in the U.K. 1861-1957", Economica, Vol. 25, pp. 283-99.

Phillips Cooper, J.,(1973), "Time Varying Regression Coefficients: A Mixed Estimation Approach and Operational Limitations of the General Markov Structure", Annals of Economic and Social Measurement, Vol. 2, pp. 525-30.

Salop, S_(1973), "Wage Differentials in a Dynamic Theory of the Firm", Journal of Economic Theory, Vol. 6, pp. 321-44.

Salop, S.,(1978), "Parables of Information Transmission", in A. Mitchell, ed., The Effect of Information on Consumer and Market Behavior, Chicago.

Salop, S. and J.E. Stiglitz,(1977), "Bargains and Ripoffs: A Model of Monopolistically Competitive Price Dispersion", Review of Economic Studies, Vol. 44, pp. 493-510.

Samuelson, P.A.,(1968), "What Classical and Neoclassical Monetary Theory Really Was", Canadian Journal of Economics, Vol. 1, pp. 1-15.

Sargent, T.J.,(1976), "The Observational Equivalence of Natural and Unnatural Rate Theories of Macroeconomics", Journal of Political Economy, Vol. 84, pp. 631-40.

Sargent, T.J.,(1979), Macroeconomic Theory, Academic Press.

Schiller, R.J_ (1978), "national Expectations and the Dynamic Structure of Macroeconomic Models", Journal of Monetary Economics, Vol. 4, pp. 1-44.

Schultz, G.P_ (1959), "Sectoral Shifts and Inflation", in Employment, Growth and Price Levels, (Rearings before the Joint Economic Committee, 86th Congress, 1st session, 25-28 May), pp. 4-10. Reprinted in Ball, R.J. and P. Doyle, eds., Inflation, Penguin Books, 1969.

Schwert, GY _ (1979), "Tests of Causality - The Message in the Innovations", in K. Brunner and A.H. Meltzer, (eds.), Three Aspetts of Policy and Policymakin: Knowledge, Data and Institutions, Carnegie-Rochester Conference Series on Public Policy, North-Holland.

Sheshinsky, E. and Y. Weiss,(1977), "Inflation and Costs of Price Adjustment", Review of Economic Studies, Vol. 44, pp.

Sheshinsky, E., A Tishler and Y. Weiss,(1980), "Inflation, Costs of Adjustment, and the Amplitude of Real Price Changes: An Empirical Analysis", Mimeo, Foerder Institute for Economic Research, Tel-Aviv University.

Shigehara, K_(1982), "Absorption of the Two Oil Shocks. The Japanese Case", European Economic Review, Vol. 18, pp. 249-61.

Sims, C.A.,(1977), "Exogeneity and Causal Ordering in Macroeconomic_ Models", in C.A. Sims, (ed.), New Methods in Business Cycle Research, Federal Reserve Bank of Minneapolis.

Sims, C.A.,(1919), "A Comment on the Papers by Zellner and Schwert", in K. Brunner and A.H. Meltzer, (eds.), Three Aspetts of Policy and Policymaking - Knowledge, Data and Institutions, Carnegie-Rochester Conference Series on Public Policy, North-Holland.

Sims, C.A.,(1980), "Macroeconomics and Reality", Econometrica, Vol. 48, pp. 1-48.

Stiglitz, J.E.,(1979), "Equilibrium in Product Markets with Imperfect Information", American Economic_Review, Papers and Proceedings, Vol. 69, pp. 339-45.

Taylor, J.B.,(1980), "Aggregate Dynamits and Staggered Contracts", Journal of Political Economy, Vol. 88, pp. 1-2.3.

Theil, H.,(1967), Economics and Information The , North-Holland.

Theil, H.,(1971), Principles of Econometrics, John Wiley & Sons.

Tobin, J.,(1972),"Inflation and Unemployment", American Economic Review, Vol. 62, pp. 1-18.

Tobin, J., ed.,(1982), Implicit Contracts and Macroeconomic Behaviour, Basil Blackwell.

Turnovsky, S.J.,(1969), "A Bayesian Approach to the Theory of Expectations, Journal of Economic Theory, Vol. 1, pp. 220-27.

Valentine, T.J.,(1977), "Price Expectations in Australia: An Alternative Analysis", Economic Record, Vol. 53, pp. 390-404.

Wallis, K.F.,(1980), "Econometric Implications of the Rational Expectations Hypothesis", Econometrica, Vol. 48, pp. 49-73.

Varian, H.R.,(1978), Microeconomic Analysis, Norton

Wicksell, K.,(1936), Interest and Prices, MacMillan and Co.

Voeller, J. and W. Eichhorn,(1976), TheorY of the Price Index, Lecture Notes in Economics and Mathematical Systems, ed. by M. Beckman and H.P. Kunzi, Vol. 140, Springer-Verlag, Berlin.

Williamson, O.E., M.L. Wachter and J.E. Harris,(1975), "Understanding the Employment Relation: The Analysis of Idiosyncratic Exchange", Bell Journal of Economics, Vol. 6, pp. 250-78.

Vining, D.R. and T.C. Elwertowski,(1976), "The Relationship between Relative Prices and the General Price Level", American Economic Review, Vol. 66, pp. 699-708.

Zellner, A_(1979), "Causality and Econometrics", in K. Brunner and A.H. Meltzer, (eds.), Three Asaects of Policy and Policymakina - KnowledQe. Data and Institutions, Carnegie-Rochester Conference Series on Public Policy, North-Holland.

APPENDICES

APPENDIX 1: NOTATIONS

The notations are listed in the order in which they appear in the text.

t = time

$y_t(z)$ = output in market z

y = relative-price parameter in Lucas' model

$p_t(z)$ = price in market z

E = mathematical expectation operator

P_t = general price level

$I_t(z)$ = information set in market z

x_t = demand shift parameter in Lucas' model

$s_t(z)$ = random variable in Lucas' model

$v_t(s)$ = random variable in Lucas' model

w_t = random variable in Lucas' model

$\bar{P}_t$ = mean of general price level in Lucas' model

$D2$ = logarithmic difference operator

o_x = variance of general demand shocks in Lucas' model

o_s^2 = variance of specific demand shocks in Lucas' model

o_2^2 = variance of the general price level in Lucas' model

r = variance of relative prices in Lucas' model

Dw = relative change in wages

Dp_T = relative change in prices on traded goods

Dp_N = relative change in prices on non-traded goods

Dg_T = relative change in productivity in traded goods sector

Dg_N = relative change in productivity in non-tradede goods sector

a_T = value-added share of the traded goods sector

a_N = value-added share of the non-traded goods sector

DP = rate of inflation

Vp = variance of relative-price changes

EDP = expected rate of inflation

i_t = nominal rate of interest

$V_t a$ = coefficient of variation of relative-price changes

Vp_t = variance of relative-price changes for a small number of ag3regate commodities

Vp_t = **variance of relative-price changes** for a set of constant-quality commodities

Vp_t^u = variance of relative-price changes for a large number of

commodities

$EDPE_t$ = expected rate of inflation according to extrapolative expectations

$EDPA_t$ = expected rate of inflation according to adaptive expectations

C = set of constant-quality commodities

log = natural logarithm

q_{it} = quantity of a commodity in market i at time t

q = output of a representative firm

1 = quantitiy of labour used in production of representative fira

m = quantitiy of raw materials used in production of representative firm

k = fixed capital stock of representative firm

ld_s = labour supply

1 = labour demand

rt = profit of representative firm

w = wage rate

p_m = price of raw materials

pk = quasi-rent on capital

ed= cost function of representative firm

y_t = domestic money income

y_t^f = foreign money income

DPW_t = relative change in foreign general price level

VAR = vector autoregression

B(L) = matrix of polynomials in the backward-shift operator L

y_t = vector of endogenous variables in VAR

u_t = vector of residuals in VAR

v_t = vector of orthogonal residuals in VAR

A_s = matrix of coefficients in moving average representation of a VAR

4 = covariance matrix of residuals in VAR

S2= triangular matrix used to orthogonalize the residuals in VAR

s = variance of forecast error

I = information set in VAR

DU = relative change in unemployment

Q = Box-Pierce statistic

pk = kth lag autocorrelation

APPENDIX 2: DATA SOURCES

DP: The annual rate of inflation has been measured by the Swedish Consumer Price Index. We have used the long-term index, in which the budget shares are adjusted at the end of the year. Source: Statistical Reports, Series P, National Central Bureau of Statistics, Stockholm.

Vp: Data for the variability of relative-price changes has been collected from the Swedish Consumer Price Index, on different aggregation levels (see the text). Source: See DP.

Dy^d: The change in domestic money income is measured by the change in Swedish GNP at market prices. ource: Statistical Reports, Series N, National Central Bureau of Statistics, Stockholm.

DPW: The change in foreign prices is measured as a weighted mean of consumer price indices in 12 countries. The countries are Denmark, Norway, Finland, Holland, Belgium, France, Italy, Switzerland, West Germany, Great Britain, United States and Japan. In 1979 these countries accounted for 70 of total Swedish imports. Sources: Statistical Reports, Series H, National Central Bureau of Statistics, Stockholm and United Nation: Monthly Bulletin of Statistics and Yearbook of National Accounts Statistics.

Dy^f: The change in foreign money income is a weighted mean of changes in gross national products at market prices in 12 countries. These countries are the same as above. Source: United Nations: Yearbook of National Accounts Statistics.

Dp_{mt}: The change in raw material prices is the implicit price index of the raw material component in the Swedish GNP (sum of value added). Source: Statistical Reports, Series N, Appendices, National Central Bureau of Statistics, Stockholm.

DW . The change in labour costs is the change in total labour costs (wage costs plus different kinds of taxes and social security fees) divided by the total number of hours worked. Source: See Dp_{mt}

DU: The change in the uneployment rate. For the period 1951-1979 data come from the registered unemployed at the National Labour Exchange Offices. For the period 1963-1979 data are from the Swedish Labour Force Survey (AKU). The latter series is constructed according to international standards. Since the AKU series is preferred here a regression of AKU on the other series for the period 1963-1979 was made and the AKU-series was then simulated backwards to 1951.

APPENDIX 3: LIST OF (APPROXIMATELY) CONSTANT-QUALITY COMMODITIES *FOR* RELATIVE-PRICE CHANGE EQUATIONS

1. Wheat-flour
2. Hulled oats
3. Rusks
4. Margarine
5. Eggs
6. Herrings
7. Codfish
8. Salted herrings
9. Potatoes
10. White cabbage
11. Apples
12. Oranges
13. French plums
14. Salt
15. Gentleman's suit
16. Pants
17. Socks
18. Woolen yarn
19. Dress materials, cotton
20. Boots for children
21. Half-soling with heeling
22. Table
23. Peg chairs
24. Armchairs
25. Bed
26. Light bulb
27. Electric iron
28. Sewing machine
29. China plates
30. Coffee-cups
31. Glasses
32. Hammer
33. Mattress
34. Toilet soap
35. Tooth paste
36. Razor blades
37. Hair-cutting
38. Washing with mangling
39. Newspaper, single copy
40. Weekly magazine, single copy
41. Cinema ticket
42. Sport competition ticket
43. Theatre ticket
44. Housing (rental apartments)

APPENDIX 4: EMPIRICAL RESULTS FROM VECTOR AUTOREGRESSION

EQUATION 1

DEPENDENT VARIABLE Vpu

a

FROM 1951 UNTIL 1979
OBSERVATIONS 29 DEGREES OF FREEDOM 13

R^2 .83740692 $\bar{R}^2$ .64979951
Standard error of the regression .19703370E-02
DURBIN-WATSON 1.61169989
Q(14) = 5.83270 SIGNIFICANCE LEVEL .970534

VARIABLE	LAG	COEFFICIENT	T-STATISTIC	SIGNIF LEVEL
Vpu	1	.1965	.72	.482
Vpu	2	.4344	1.99	.068
Vpu	3	-.0437	-.17	.866
DPW	1	.0227	2.40	.032
DPW	2	-.0034	-.25	.808
DPW	3	.0179	1.30	.216
DP	1	.0226	.64	.531
DP	2	-.0336	-.77	.453
DP	3	.0284	.69	.504
DW	1	-.0399	-1.56	.142
DW	2	-.0130	-.50	.622
DW	3	.0062	.26	.801
DU	1	.0022	.77	.453
DU	2	.0025	.88	.396
DU	3	.0013	.49	.631
CONSTANT	0	.0045	1.47	.167

F-TESTS, DEPENDENT VARIABLE Vpu

VARIABLE	F-STATISTIC	SIGNIF. LEVEL
Vpu	4.09736	.2987801E-01
DPW	2.40099	.1147138
DP	.39407	.7594010
DW	1.33357	.3061492
DU	.70555	.5655494

Note. Q is the Box-Pierce statistics.

EQUATION 2

DEPENDENT VARIABLE DPW
FROM 1951 UNTIL 1979
OBSERVATIONS 29 DEGREES OF FREEDOM 13

R2 .72487537 R2 .40742388
Standard error of the regression .60442883E-01
DURBIN-WATSON 2.33918723
Q (14) = 7.32558 SIGNIFICANCE LEVEL .921431

VARIABLE	LAG	COEFFICIENT	T-STATISTIC	SIGNIF.LEVEL
Vpu	1	-11.8446	-1.42	.179
Vpu	2	12.4676	1.86	.085
Vpu	3	-8.3048	-1.07	.306
DPW	1	.7660	2.64	.020
DPW	2	-.6467	-1.54	.147
DPW	3	.3791	.90	.387
DP	1	.8369	.78	.451
DP	2	.5603	.42	.681
DP	3	.9074	.72	.486
DW	1	-.1781	-.23	.823
DW	2	-.6637	-.84	.416
DW	3	-.3543	-.48	.641
DU	1	-.0149	-.17	.869
DU	2	.0696	.79	.443
DU	3	.1106	1.34	.203
CONSTANT	0	.0692	.73	.477

F-TESTS" DEPENDENT VARIABLE DPW

Note. Q is the Box-Pierce statistics.

VARIABLE	F-STATISTIC	SIGNIF.LEVEL
Vpu	2.79700	.8190713E-01
DPW	3.27046	.5580083E-01
DP	.66809	.5865034
DW	.58052	.6381281
DU	.93512	.4516824

EQUATION 3

DEPENDENT VARIABLE DP
FROM 1951 UNTIL 1979
OBSERVATIONS 29 DEGREES OF FREEDOM 13

R^2 .79096516 $\bar{R}^2$ .54977111
Standard error of the regression .22597841E-01
DURBIN-WATSON 2.06075244
Q(14) = 10.1260 SIGNIFICANCE LEVEL .752913

VARIABLE	LAG	COEFFICIENT	T-STATISTIC	SIGNIF. LEVEL
Vpu	1	-5.8804	-1.89	.081
Vpu	2	4.2497	1.70	.113
Vpu	3	-2.2060	-.76	.462
DPW	1	.3946	3.64	.003
DPW	2	-.1483	-.94	.362
DPW	3	.2828	1.79	.100
DP	1	.1339	.33	.745
DP	2	.2496	.50	.625
DP	3	-.3282	-.69	.501
DW	1	.0520	.18	.862
DW	2	-.3843	-.30	.216
DW	3	.2165	.78	.449
DU	1	.0377	-1.13	.277
DU	2	.0230	.70	.496
DU	3	.0110	.36	.727
CONSTANT	0	.0621	1.76	.102

F-TESTS, DEPENDENT VARIABLE DP

Note. Q is the Box-Pierce statistics.

VARIABLE	F-STATISTIC	SIGNIF.LEVEL
Vpu	3.38023	.5119422E-01
DPW	5.54837	.1125937E-01
DP	.23266	.8719982
DW	.64588	.5992476
DU	.61442	.6177065

EQUATION 4

DEPENDENT VARIABLE DW
FROM 1951 UNTIL 1979
OBSERVATIONS 29 DEGREES OF FREEDOM 13

R^2 .80363957 $\bar{R}^2$ .57706985
Standard error of the regression .26686164E-01
DURBIN-WATSON 2.17212060
Q(14) = 14.4697 SIGNIFICANCE LEVEL .415339

VARIABLE	LAG	COEFFICIENT	T-STATISTIC	SIGNIF.LEVEL
Vpu	1	2.5215	.68	.505
Vpu	2	-3.3237	-1.23	.281
Vpu	3	-5.8487_	-1.70	.113
DPW	1	.5108	3.99	.001
DPW	2	.2493	1.35	.201
DPW	3	.2621	1.40	.184
DP	1	-.5820	-1.22	.243
DP	2	-1.1097	-1.89	.082
DP	3	.5722	1.02	.325
DW	1	-.1510	-.44	.669
DW	2	.2815	.81	.435
DW	3	-.2167	-.66	.716
DU	1	.0146	.37	.716
DU	2	-.0575	-1.48	.162
DU	3	-.0506	-1.39	.188
CONSTANT	0	.1623	3.89	.002

F-TESTS, DEPENDENT VARIABLE DW

VARIABLE	F-STATISTIC	SIGNIF.LEVEL
Vpu	2.63827	.9358116E-01
DPW	6.44379	.6569383E-02
DP	2.06774	.1540883
DW	.26788	.8473827
DU	1.61117	.2348464

Note. Q is the Box-Pierce statistics.

EQUATION 5

DEPENDENT VARIABLE DU
FROM 1951 UNTIL 1979
OBSERVATIONS 29 DEGREES OF FREEDOM 13

R^2 .67211565 $\bar{R}^2$ .29378755
Standard error of the regression .17417574
DURBIN-WATSON 2.43348774
Q(14) = 14.3326 SIGNIFICANCE LEVEL .425238

VARIABLE	LAG	COEFFICIENT	T-STATISTIC	SIGNIF.LEVEL
vDU	1	.7430	.03	.976
Vpu	2	5.6820	.29	.773
Vp	3	14.1197	.63	.540
DPW	1	-.6744	-.81	.434
DPW	2	-.6432	-.53	.603
DPW	3	-.3486	-.28	.779
DP	1	4.3428	1.40	.185
DP	2	-.8834	-.23	.822
DP	3	0 -6.0369	-1.65	.122
DW	1	-1.1020	-.49	.633
DW	2	2.0225	.89	.391
DW	3	3.0346	1.42	.179
DU	1	-.0076	.03	.977
DU	2	-.2017	-.80	.440
DU	3	-.4886	-2.05	.061
CONSTANT	0	-.3118	-1.14	.273

F-TESTS, DEPENDENT VARIABLE DU

VARIABLE	F-STATISTIC	SIGNIF.LEVEL
Vpu	.55114	.6562582
DPW	.33601	.7996000
DP	1.50158	.2605702
DW	1.50920	.2586847
DU	1.80682	.1955824

Note. Q is the Box-Pierce statistics.

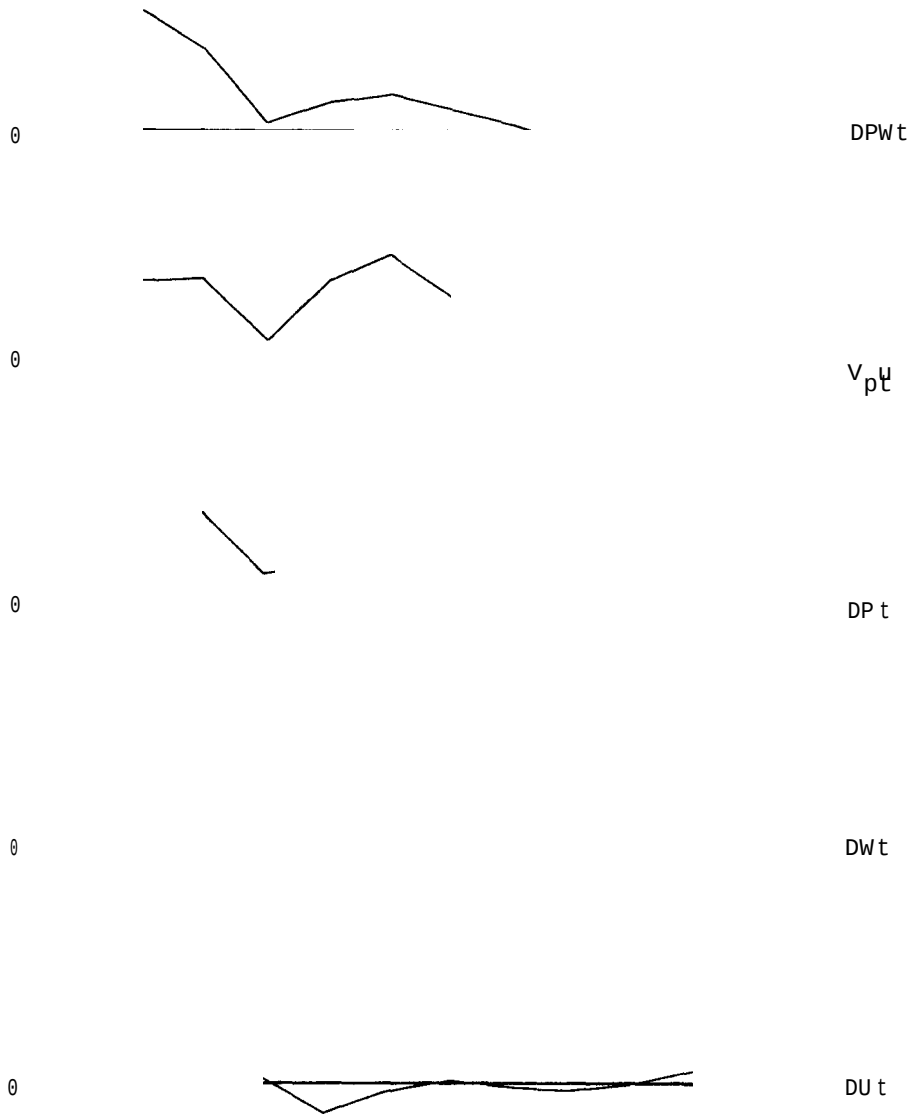


Figure 1. Dynamic responses in DPWt, Vpt, DPt, DWt and DUt to shock in DPWt, 10 periods ahead. Units are one standard deviation in each regression equation.

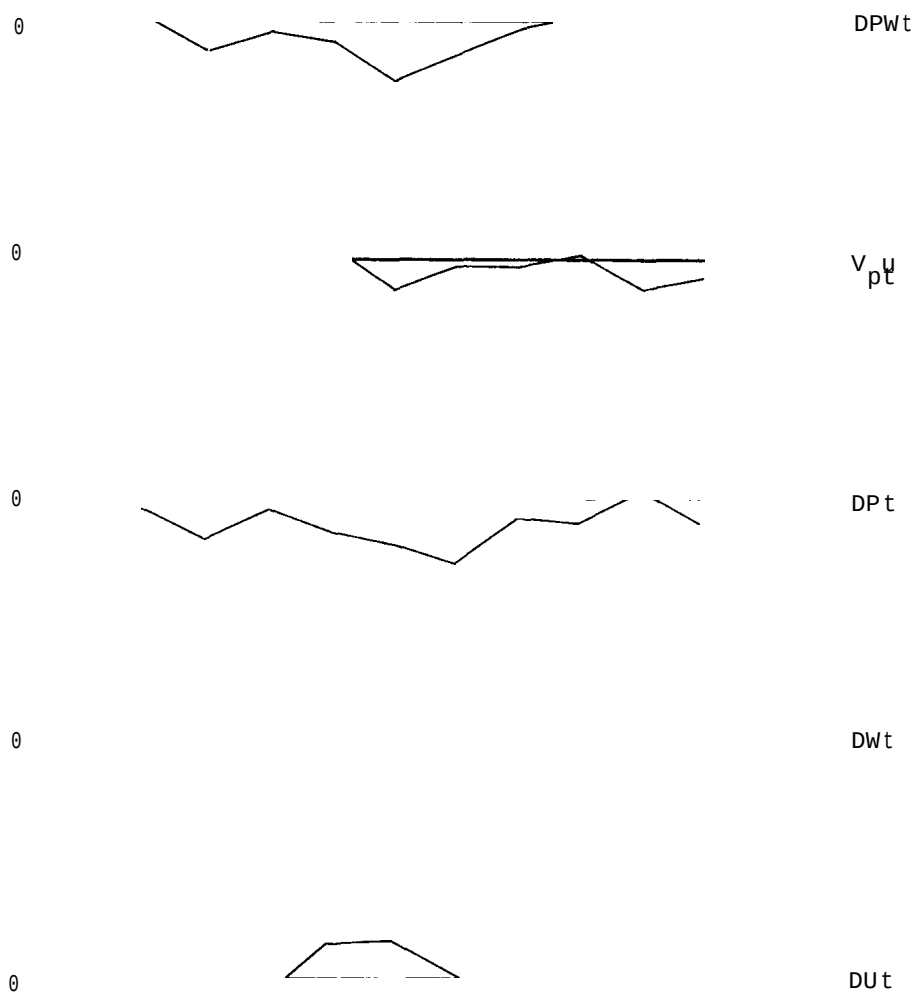


Figure 2. Dynamic responses in DPWt, Vpt, DPt, DWt and DUt to shock in Vpt, 10 periods ahead. Units are one standard deviation in each regression equation.

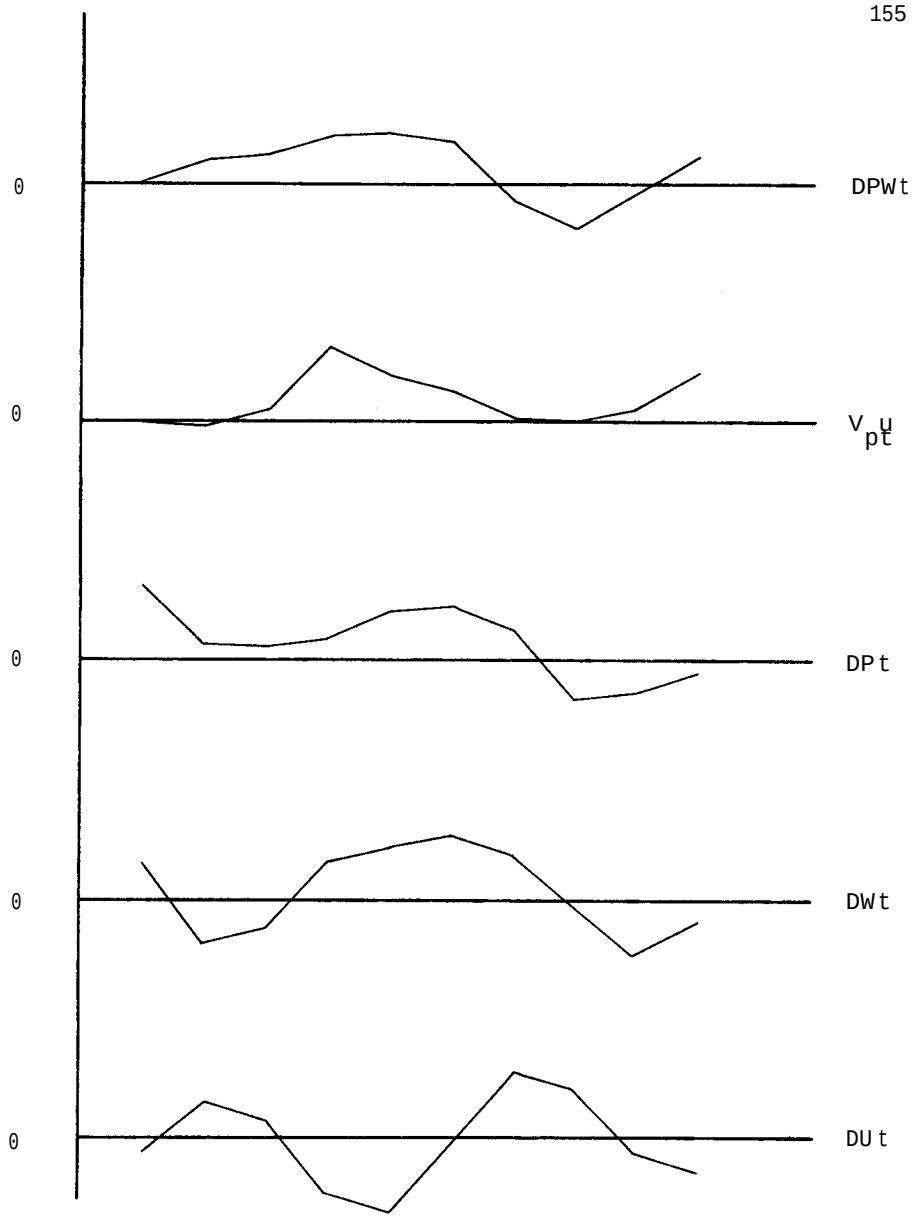


Figure 3. Dynamic responses in DPWt, Vpt, DPt, DWt and DUt to shock in DPt, 10 periods ahead. Units are one standard deviation in each regression equation.

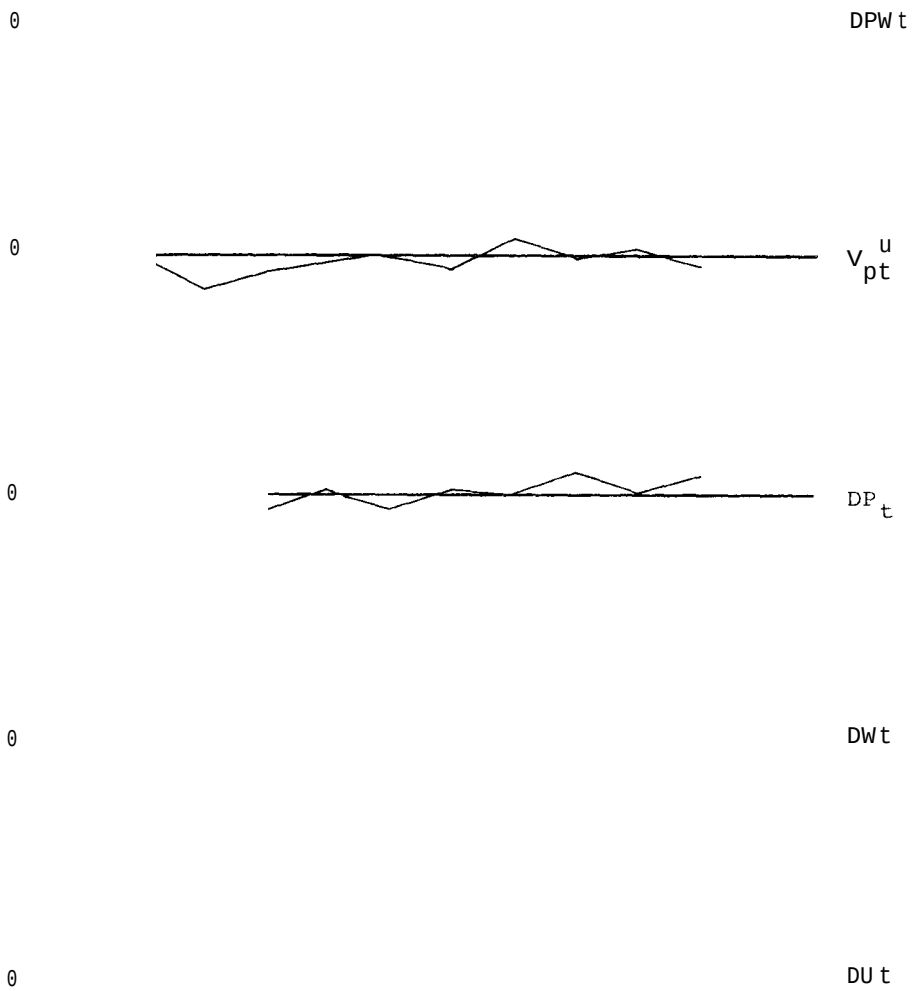


Figure 4. Dynamic responses in DPWt, Vpt, DPt, DWt and DUt to shock in DWt, 10 periods ahead. Units are one standard deviation in each regression equation.

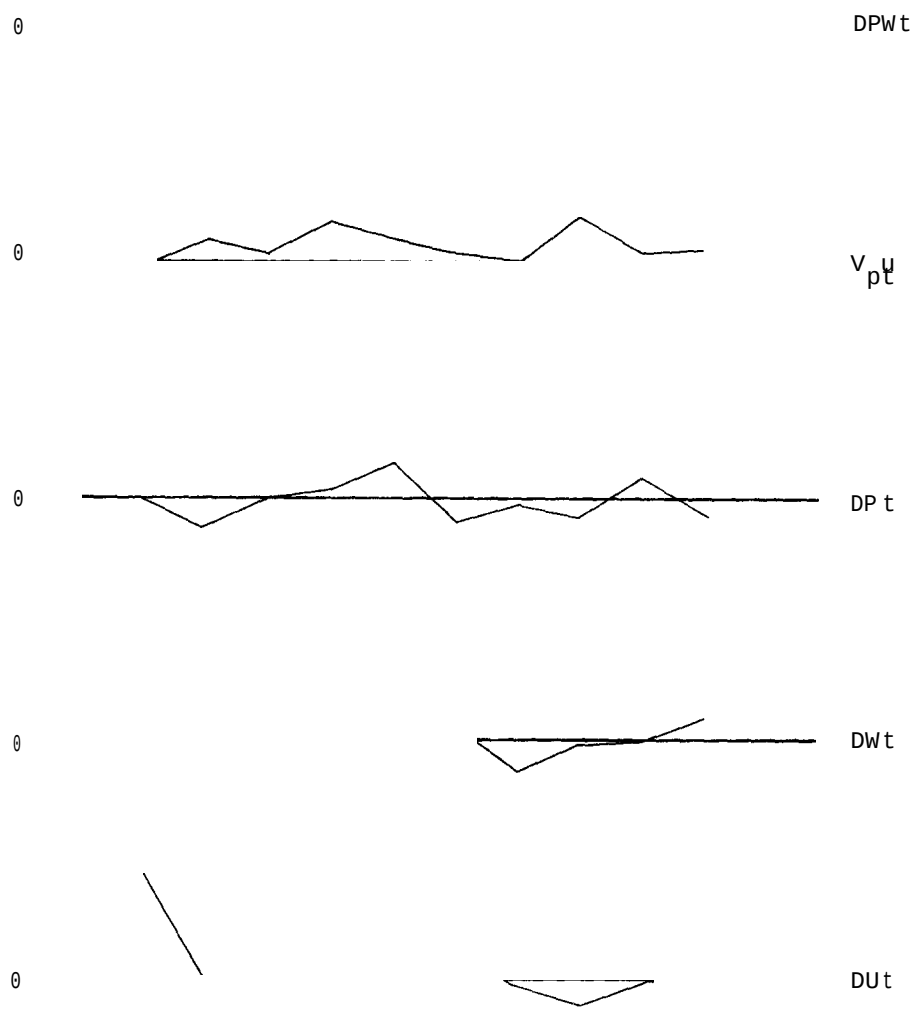


Figure 5. Dynamic responses in DPWt, Vpt, DPt, DWt and DUt to shock in DUt, 10 periods ahead. Units are one standard deviation in each regression equation.

Figure 6. Historical decomposition of DPW, 1970 1979.
& is plotted when two or more values are the same, and
the variables are indicated to the right of the box.

Symbol *: Prediction of DPW
Symbol I: Prediction of DPW + innovation in DPW
Symbol V: Prediction of DPW + innovation in Vp
Symbol P: Prediction of DPW + innovation in DP
Symbol W: Prediction of DPW + innovation in DW
Symbol U: Prediction of DPW + innovation in DU

MIN VALUE .18263E-01 MAX VALUE .24242 SPACING .25186E-02

```
1970                    &        I                                                    *VPWU
1971  -          IV  &U W                                                            *P
1972                U & &                                                            *P VW
1973                        U     * MPV      I
1974                                              W *V P      U
1975                        I             W   * U PV
1976  ·1         I      W U *P              V
1977     U  P    *W              I  V
1978  -       P             *W  U    &                                               Iv
1979            p                * U W     i      V
```

Figure 8. Historical decomposition of DP, 1970 - 1979.
& is plotted when two or more values are the same, and
the variables are indicated to the right of the box.

Symbol *: Prediction of DP
Symbol I: Prediction of DP + innovation in DPW
Symbol V: Prediction of DP + innovation in Vp
Symbol P: Prediction of DP + innovation in DP
Symbol W: Prediction of DP + innovation in DW
Symbol U: Prediction of DP + innovation in DU

MIN VALUE .45199E-01 MAX VALUE .11090 SPACING .73818E-03

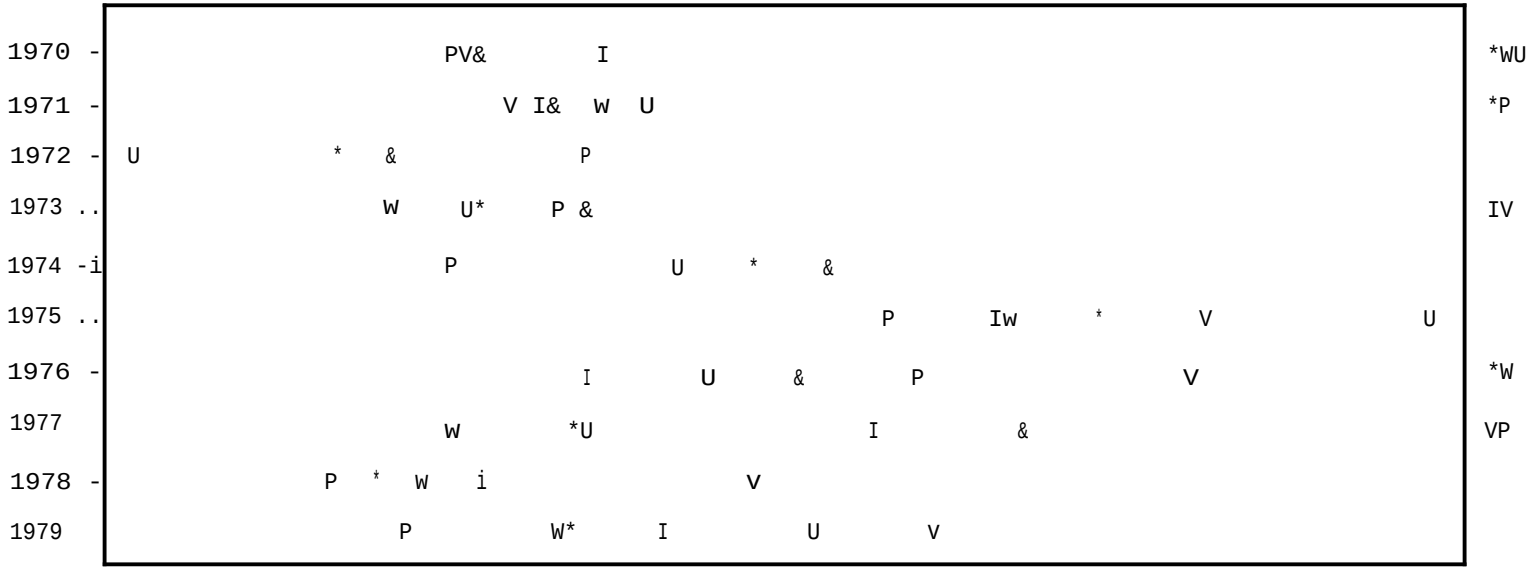


Figure 7. Historical decomposition of VP, 1970 - 1979.
& is plotted when two or more values are the same, and
the variables are indicated to the right of the box.

Symbol *: Prediction of VP
Symbol I: Prediction of VP + innovation in DPW
Symbol V: Prediction of VP + innovation in Vp
Symbol P: Prediction of VP + innovation in DP
Symbol W: Prediction of VP + innovation in DW
Symbol U: Prediction of VP + innovation in DU

MIN VALUE .34123E-02 MAX VALUE .99569E-02 SPACING .73535E-04

```
1970 -                                                                                                  *PWU
1971 -    &          W                                                                                  VII *IP
1972  FV   I            &     U                                                                         *PW
1973                       V       U & *          I                                                     PW
1974 -I                                                & *  P          U
1975 -i                                 V  I          *W  U            P
1976 -               V           I   W      * U       P
1977                    P    &          *W                                                              VU
1978                                PV                  * W          UI
1979                                                P       U   *     I   W                 V
```

Figure 8. Historical decomposition of DP, 1970 - 1979.
& is plotted when two or more values are the same, and
the variables are indicated to the right of the box.

0

Symbol *: Prediction of DP
Symbol I: Prediction of DP + innovation in DPW
Symbol V: Prediction of DP + innovation in Vp
Symbol P: Prediction of DP + innovation in DP
Symbol W: Prediction of DP + innovation in DW
Symbol U: Prediction of DP + innovation in DU

MIN VALDE .45199E-01 MAX VALDE .11090 SPACING .73818E-03

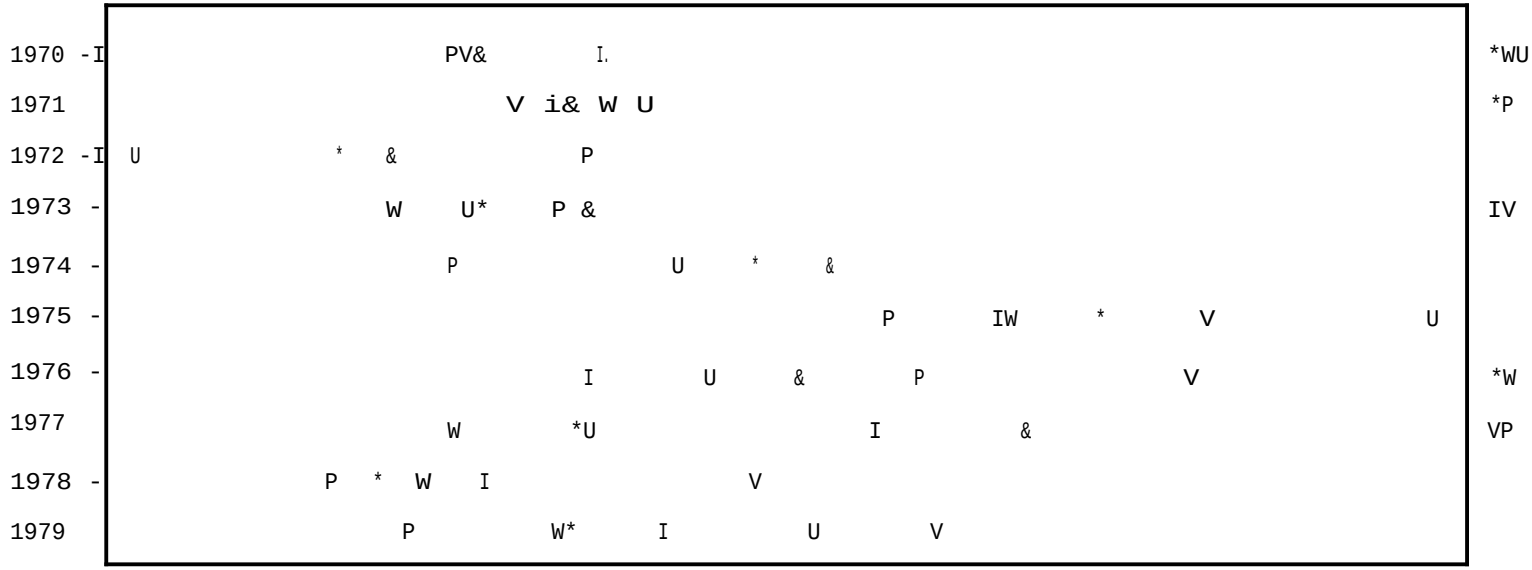


Figure 9. Historical decomposition of DW, 1970 - 1979.
& is plotted when two or more values are the same, and
the variabler are indicated to the right of the box.

Symbol *: Prediction of DW
Symbol I: Prediction of DW + innovation in DPW
Symbol V: Prediction of DW + innovation in Vp
Symbol P: Prediction of DW + innovation in DP
Symbol W: Prediction of DW + innovation in DW
Symbol U: Prediction of DW + innovation in DU

MIN VALDE .78828E-01 MAX VALDE .16936 SPACING .10172E-02

```
1970 -                      VP&     I                                                  *U
1971 -               U  *&  V         W                                               ip
1972 -        I            * V W PU
1973 -           &         *VI      W                                                 PU
1974 -                         P           U  VW*                                I
1975 -                                                        * W U I     VP
1976 -                                        I                  W   *       U    V            P
1977 -                   W         U       *       I      VP
1978             W            &          I              V                                 *U
1979            U           &   &                                                        *W
```

Figure 10. Historical decomposition of DU, 1970 - 1979.
& is plotted when two or more values are the same, and
the variablas are indicated to the right of the box.

N

Symbol *: Prediction of DU
Symbol I: Prediction of DU + innovation in DPW
Symbol V: Prediction of DU + innovation in Vp
Symbol P: Prediction of DU + innovation in DP
Symbol W: Prediction of DU + innovation in DW
Symbol U: Prediction of DU + innovation in DU

MIN VALUE -.34793 MAX VALUE .42803 SPACING .87186E-02

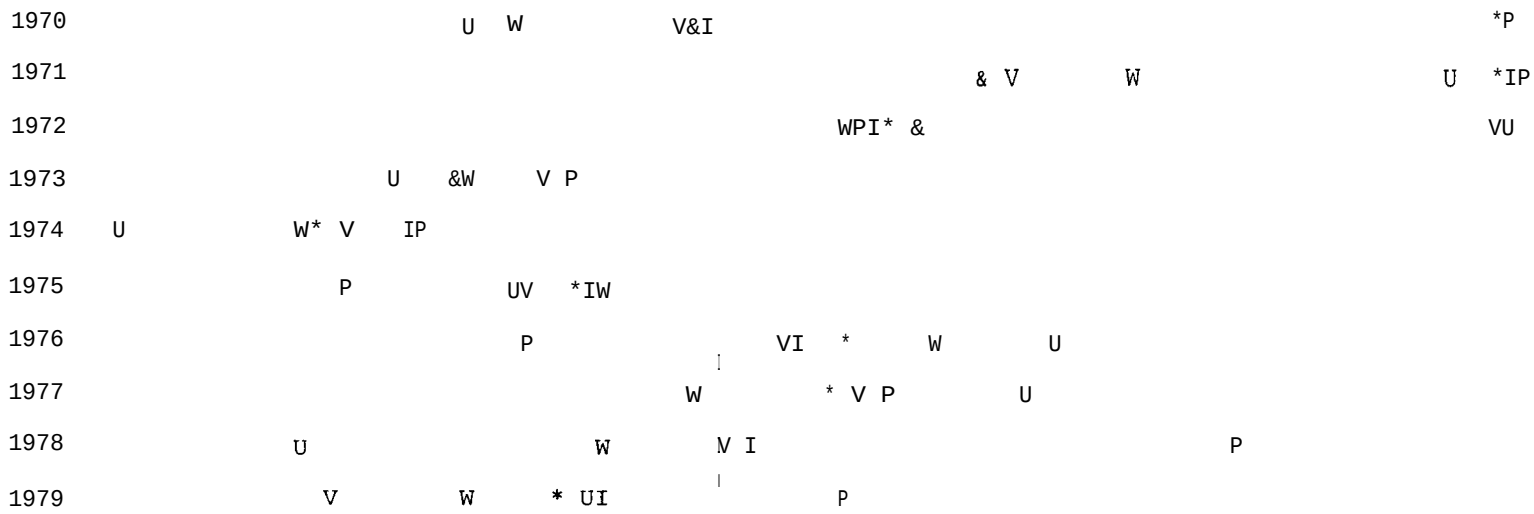


Figure 10. Historical decomposition of DU, 1970 - 1979.
& is plotted when two or more values are the same, and
the variables are indicated to the right of the box.

N

Symbol *: Prediction of DU
Symbol I: Prediction of DU + innovation in DPW
Symbol V: Prediction of DU + innovation in Vp
Symbol P: Prediction of DU + innovation in DP
Symbol W: Prediction of DU + innovation in DW
Symbol U: Prediction of DU + innovation in DU

MIN VALUE -.34793 MAX VALUE .42803 SPACING .87186E-02

```
1970                        U  W                                                                  *P
1971                                                          & V       W                     U  *IP
1972                                                     WPI* &                                  VU
1973                     U   &W    V P                                                            *I
1974  U            W* V   IP
1975                  p
1976                                              VI  *     W       U
1977                                         W        * V P        U
1978              U                     W       V I                                P
1979                V         W     * UI                P
```

Table 6. Decomposition of variance of k-step ahead forecast errors with variables orthogonalized in the indicated order.

Variance in:	k	Shock in: DPW	DP	DW	DU	Vp
DPW	1	100.00	0	0	0	0
	2	93.13	2.98	.04	.05	3.80
	3	89.36	6.33	.14	.05	4.12
	5	65.21	19.96	.86	3.55	10.42
	10	54.92	27.51	2.95	4.67	9.95
DP	1	58.92	41.08	0	0	0
	2	66.31	24.63	.09	3.18	5.79
	3	66.20	23.95	.60	3.00	6.26
	5	56.18	26.11	1.19	7.14	9.38
	10	43.00	31.82	5.34	7.39	12.45
DW	1	38.56	11.89	49.55	0	0
	2	57.44	14.57	26.94	.32	.73
	3	53.63	15.29	24.38	2.52	4.18
	5	43.56	24.70	20.81	2.95	7.98
	10	32.21	34.50	17.12	4.58	11.59
DU	1	2.43	.74	21.03	75.79	0
	2	3.05	8.87	20.21	67.86	0
	3	2.81	9.79	19.30	67.26	.84
	5	4.16	36.57	10.46	43.16	5.65
	10	3.71	46.67	8.46	36.14	5.02
Vp	1	52.69	.99	6.55	.07	39.71
	2	62.65	.77	10.64	1.69	24.26
	3	62.44	1.18	11.20	2.06	23.12
	5	63.75	14.24	5.59	4.41	12.00
	10	65.86	14.64	4.80	5.71	8.99

APPENDIX 5: RESULTS OF CAUSALITY TESTS

1. Test of DP=>Vn. (t-values in parentheses)

a)

Dift = -.000815 - .1984 (Sunt - Sum) R^2 = .27
(-3.228) (-1.603)

F(2,7) = 6.493 Significance level = .025

Dift = ot(Vp | I - DP) - at(Vp | I) and

Sumt = ot(Vp | I - DP) + 0t(Vp | I).

b)

Dift = .000248 - .0713 (Sumt - Sum) R^2 = .16
(2.048) (-1.140)

F(2,7) = 2.747 Significance level = .132

Dift = ot(VP | VP) - at(Vp | Vp,DP) and

Sumt = 0t(Vp | VP) + 0t(Vp | Vp,DP)

2. Test of Vp=>DP. (t-values in parentheses)

a)

Dift = .00.3804 - .1641 (Sumt - Sum) R^2 = OS
(.628) (--.802)

F(2,7) = .519 Significance level = .616

Dift = ot(DPI I - Vp) - at(DPII) and

Sumt = ot(DPI I - Vp) + at(DPII).

b)

Dift = .000391 - .1175 (Sumt - Sum) R^2 = .21
(.352) (-1.384)

F(2,7) = 1.019 Significance level =- .409

Dift = 0t(DPIDP) - at(DPIDP,Vp) and

Sumt = at(DPIDP) + at(DPIDP,VP).

u

Studies

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INFLATION AND RELATIVE PRICES IN AN OPEN ECONOM)

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INFLATION AND RELATIVE PRICES IN AN OPEN ECONOMY

Abstract

This study analyses the relationship between inflation and changes in relative prices. According to "classical" macroeconomic theory, absolute and relative prices are independent. In Chapter 2 we refer to Lucas' Phillips curve model as an example of a model in which inflation may affect relative prices if inflation is unanticipated. Chapter 3 reviews different theories in which a relationship between inflation and relative prices exists, even if the rate of inflation is expected. In Chapter 4 a simple empirical analysis is carried out, to compare to earlier evidence for other countries. The relationship between the variance of relative-price changes (Vp) and expected and unexpected inflation, where inflationary expectations are assumed to be formed adaptively, is analysed in regression studies for Swedish annual consumer price data for 1951-79. Both expected and unexpected inflation are found to be significantly related to Vp. In Chapter 5 a multi-inarket deterministic equilibrium model for an open economy is developed. Though inflationary expectations are more restricted than in Lucas' model, the model here is more general in other respects, since it incorporates raw material prices, open economy characteristics and allows unequal supply responses between inarkets. The expected rate of inflation is added to the model and tests are performed which show that expected and unexpected inflation, as well as raw material prices and foreign demand, significantly affects changes in relative prices and Vp. The question of causality between these variables is addressed in Chapter 6, where we use a vector autoregression and apply the Granger causality concepts in tests of causal order between inflation and Vp. No direct causality from inflation is found, but the results indicate that inflation abroad is important for both these variables and that the oil-price shocks were also important. Since.inflation has non-neutral effects ort relative prices, even

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