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MONETARY POLICY AND INFLATION

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Monetary Policy and Inflation[1]

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[1] Forthcoming in D. Salvatore and M. Fratianni (eds.), Handbook of Monetary Policy, Greenwood Publishing Group.

1. Introduction[1]

This chapter will critically discuss the statistical modelling of inflation, defined as the rate of change of a deflator for gross domestic product or gross national product.[2] The importance of this topic goes beyond the obvious point that producers, wage earners and consumers want to make informed guesses about the rate of price change in the future, and that holders of assets know that inflationary expectations are important for the valuation of stocks, bonds, foreign exchange and all tangible assets.

Statistical work on inflation is not only important for forecasting future inflation, but also for the design, implementation and evaluation of monetary policy. In a closed economy, or an open economy on floating exchange rates, the rate of growth of the money supply is correlated with the rate of inflation, but usually with a long and variable lag. Estimation of this relationship, therefore is difficult, but essential for policy purposes. However, in a forecasting context, it is likely that regressions of inflation on current or immediate past rates of change in prices, wages and other cost factors, together with measures of demand in the goods or labor markets, will produce more explanatory power than regressions on monetary variables only. This explains why professional forecasters tend to emphasize cost factors and the state of "excess demand" rather than monetary developments. At the same time, academic researchers criticize such work for being ad hoc and not based on optimizing behaviour, for data-mining, especially as far as lags are concerned, and for causing confusion between changes in relative prices and changes in the absolute price level.

In the next two sections of this chapter I shall summarize both the monetarist and the "excess demand" model of inflation and discuss the practical

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[1] I am grateful to Camiel de Koning, and Tom van Veen for their assistance with this research, and to Ivo Arnold for useful discussions. Jolande Quik, Erna Zwaanswijk-ten Cate and Peter Gerbrands helped to prepare the manuscript.

[2] See Carlson (1989) for a comparison of different price indices in the U.S.

difficulties with the former and the theoretical problems with the latter.[3] Section four will contain a historical overview of important statistical studies of inflation performed over the past twenty years. I have tried to select representative examples of the different approaches that have been implemented for the post-war period. Regrettably, the discussion will be limited to inflation in the industrial countries. The link between monetary policy and inflation in developing countries is an important topic, but falls outside of the scope of this chapter.[4]

If one accepts the monetarist view of inflation, one ends up with a forecasting equation for inflation that looks like an inversion of the demand for money schedule. In fact, many such equations were estimated in the 1970s with the rate of inflation a function of lagged money growth, income growth and other variables that temporarily effected the demand for money. But, one crucial set of variables in the demand for money function tended to be omitted in work on inflation: the rate of return on money and the rates of return on its substitutes. The issue was investigated by Sims (1980) who found that it makes a lot of difference for inverted demand for money schedules whether one includes or excludes interest rates as explanatory variables.

During the 1980s statistical research on the link between money and prices continued both in the form of inverted money-demand schedules with the rate of price change as the dependent variable and in the form of money demand equations, but academic activity was far less than during the late 1960s and 1970s. Of course, inflation in the major industrial countries declined on average during the most recent decade, thus reducing the "demand" for such work. Also, both policy makers and public opinion in general became more comfortable with the monetarist notion that inflation is foremost a monetary phenomenon, hence making it less necessary to provide statistical ammunition for now superseded disputes between monetarist and so-called Keynesian

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[3] There has been some interest in attempts to predict inflation using indices for commodity prices. Research by von zur Muehlen (1990) has demonstrated that the relative price effects in indices of raw materials dominate any information they might contain about future trends in the general price level.

[4] See, for example, the May 1990 issue of the "World Economic Outlook" by the International Monetary Fund for a useful recent analysis of inflation and inflationary uncertainty in developing countries.

economists. Finally, monetary theorists became more interested in a range of issues that were far removed from the estimation of reduced forms: much effort was devoted to further refinement of the cash-in-advance model and the overlapping generations model as well as to attempts to develop a quantitative theory of the "real business cycle" hypothesis. The more or less unrestricted reduced form estimates of the connection between money and prices that were popular during the previous period did not fit well with these theoretical efforts.

In recent years the strengthening of the exchange rate mechanism in the European Community area and the prospects of a future European Central Bank stimulated a new wavelet of empirical research in the money demand area. At the end of section 4 I review a representative example, the Kremers and Lane (1990) study of money demand in the European Community. Specific criticisms of this and related work lead to a further statistical discussion in the final section of the chapter. I show how new developments in Kalman filtering and smoothing make it possible for the first time to take into account that the link between money growth and inflation depends on the stochastic trend in the income velocity of money. I first summarize important research by Bordo and Jonung (1987) which has documented the importance of changes over time in the trend of the income velocity of money. One principal reason why regressions of inflation on past money growth - and past income growth -fail is because of over-simplifying assumptions regarding the trend in velocity: the work of Bordo and Jonung has shown that velocity over the longer term cannot be modelled correctly as a function of time. I then introduce a particular Kalman Filter algorithm as a more flexible and realistic way to statistically model the links between money and inflation. The filter and smoother are applied to data sets for the U.S., Japan and Germany in the final section.

2. The "excess demand" model of inflation

A now discarded tradition in Keynesian macroeconomics held that "excess demand "[5] in the goods and labour markets was connected to the rate of inflation. Milton Friedman (1968) pointed out that there was no theoretical justification for such a connection: no possible model of rational price and wage setting by firms could result in such dynamics for inflation and excess demand. Equilibrium in the goods and labor markets requires that agents incorporate expectations about future excess demand in their current behaviour, and it would be inconsistent for practitioners of the science of rational behaviour to assume that such expectations would be irrational.

Also, empirically it was obvious that a cross-section of countries provided no support for the hypothesis of the old Phillips curve: economic growth was no higher on average in inflationary economies, nor did low inflation appear to require permanent sacrifices in the form of sluggish economic growth.

Friedman's (1968) paper and the work by Phelps and others (1970) helped to shift the relationship between inflation and economic growth into the next higher gear: changes in excess demand might be related to changes in the rate of inflation. The connection can be seen in either of two ways:

$$(1) \qquad \Delta \textit{ excess demand} \rightarrow \Delta \textit{ inflation}$$

or

$$(2) \qquad \Delta \textit{ money growth} \begin{array}{l} \nearrow \Delta \textit{ excess demand} \\ \searrow \Delta \textit{ inflation} \end{array}$$

In the case of equation (1), we try to measure excess demand in the labor market, using the difference between actual unemployment and its natural rate,

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[5]The term "excess demand" is ill-defined. I shall use it from here on without the quotation marks.

or in the output market, by comparing actual economic growth to long-run equilibrium real growth or using numbers for capacity utilization, and regress changes in inflation on such measures. The macroeconomic background to the changes in a variety of measures of excess demand may be provided with the analysis, but this is not necessary.

In the case of equation (2), we assume a link between growth in the money supply and inflation as well as a connection between (unanticipated) changes in money and changes in excess demand. The model in equation (2) leaves open the possibility that other macro economic forces have temporary effects on excess demand, but it does stipulate the trend in the rate of growth of the money supply as the prime cause of sustained inflation.

The first equation is implemented in all excess demand models of inflation. Here follows a model that summarizes the modelling behind many of the empirical studies of inflation in the past twenty years:

(3) $\Delta p_t = \Delta p_{t-1} + \alpha \, gap_t + v_t$

(4) $gap_t = y - y^* + \Delta p_t - \Delta p_{t-1}$

(5) $\Delta M_t - \Delta p_t = m + \Delta y_t - \epsilon \Delta i_t + w_t$

(6) $\Delta Y = \Delta p + \Delta y.$

Meaning of symbols:

p	price level
gap	gap between normal and actual nominal gdp
Y	nominal gdp
y	real gdp
M	nominal money supply
m	average rate of growth of the demand for real balances
i	representative opportunity cost of money
ϵ	semi-interest rate elasticity of the demand for money

All variables apart from the opportunity cost variable are natural logarithms. The superscript e represents an expectation , Δ stands for the first difference of a variable. *v* and *w* are error terms with zero means and constant variances.

Equation (3) shows how changes in the rate of inflation are related to the variable *gap* which represents the state of excess demand. Equation (6) shows the breakdown of the rate of growth of nominal gdp into real growth and inflation. Equation (4) contains the definition of *gap* as well as two implicit assumptions about the dynamics of y and p. I assume that the rate of growth of output can be regarded as a stationary variable for the purposes of this model, so that discrepancies between the actual and expected levels of output can be proxied by the differences between the actual rate of economic growth and its longer-term average. The dynamics of inflation are different. I have made the simplifying assumption that the rate of inflation is a pure random walk, which is to say that changes in the rate of inflation are unpredictable.[6] Because of the random walk assumption, last period's rate of inflation is the best predictor of the current and all future rates of inflation as long as the forecaster does not possess extraneous sources of information about future changes in inflation.[7]

Equation (5) is a simple demand for money schedule. The rate of growth of the demand for real balances is assumed to be equal to a constant, m, on average, with short term disturbances represented by the error w_t. More appropriate dynamics for the rate of growth of the demand for money will be discussed extensively later. Equation (5) does not contain the own rate of return on money, but is limited to a single opportunity cost variable. In practice, if the researcher has available a time series that indicates how much utility the

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[6]We call a time series a "random walk" if its change between measurements has an expected value of zero and a constant variance; the term "martingale" is used for a series which also has period-to-period changes that are unforecastable and have a mean of zero but about whose variance nothing is known.

[7]Statisticians call random walks and martingales "memory-less" processes: knowledge of the most recent value of the series is useful for making forecasts but it makes no sense to use a collection of previous values to construct some type of moving average for predictive purposes: old values can be discarded.

holding of money balances delivers to the owner per unit of time, he will want to include such a series on the own rate of return in his model. Also, advanced empirical work on the demand for money sometimes introduces more than a single rate of return on substitutes for money holdings: two or more rates of interest, or a rate of interest as well as the rate of inflation indicating the substitution margin between money balances and goods.

Solving this model leads to:

$$(7) \quad \Delta\Delta\, p_t = \frac{\alpha}{1-\alpha}(\Delta\, y_t - \Delta\, y_t^e) + \frac{v_t}{1-\alpha}$$

$$(8) \quad \Delta\, M_t - \Delta\, M_t^e = \Delta\Delta\, p_t + \Delta y_t - \Delta\, y_t^e - e\,\Delta\, i_t + w_t$$

In equation (7) I have indicated that changes in the rate of inflation will depend on the forecast error in the rate of growth of real gdp, but this error is equal, of course, to the forecast error in the <u>level</u> of the rate of gdp.

Equation (8) may be developed further if we make assumptions about the dynamics of nominal interest rates[8]. For example, if the real rate is constant, we can replace Δi by $\Delta\Delta p$ and obtain

$$(9) \quad \Delta\, M_t - \Delta\, M_t^e = (1-e)\,\Delta\Delta\, p_t + \Delta\, y_t - \Delta\, y_t^e + w_t$$

It follows from this model that the monetary authorities will try to keep the absolute size of *gap* small if they are satisfied with the most recent rate of inflation. Hence, the planned rate of money growth will be such that little change will occur in the actual rate of price change. In that case most

[8]If we prefer to stipulate that changes in the real rate are related to fluctuations in economic growth and/or to accelerations in money growth, we would have to be precise about the horizon to which the expected rate of inflation applies, before being able to eliminate changes in the real rate of interest and changes in the expected rate of inflation from the model.

changes in the observed rate of price change will be temporary, caused by shocks v_t. It will be hard to determine whether inflation is a sluggish process governed by sticky prices that can be best predicted using a long distributed lag of past rates of price change, or whether inflation is a monetary phenomenon, to be explained by past rates of money growth. The polar case would be that of relatively unimportant temporary shocks to the price level v_t, but important permanent changes in the rate of nominal money growth. Such changes would be part of the expected rate of money growth for all future periods once they had been observed and hence would be incorporated in expected rates of inflation for the complete future. In that case, inflationary expectations would not be based on a long distributed lag of past rates of price change, but depend on the dynamics of monetary growth.

Formalizing these notions, in the first case we would add to equations (7) and (8) an expression for the expected rate of money growth that should be called a reaction function for the monetary authorities. They aim at maintaining the (variance of the) gap variable or a similar expression at a minimum. Deviations between actual and expected money growth are basically a random variable, and with that additional assumption equations (7) and (8) may be solved for the actual rate of price change and the actual rate of economic growth. In the other case one would add to equations (7) and (8) another equation describing the dynamics of money growth that now is exogenous. The expected rate of money growth would be derived from the model for actual money growth and equations (7) and (8) would then again determine the rate of inflation and the rate of economic growth.

In both cases inflation remains a monetary phenomenon in the strict sense that changes in money are in necessary and sufficient condition for persistent inflation, but whether the data will show this in a reduced-form regression of inflation on past rates of inflation and past rates of money growth will depend on the size of the disturbances to equations (7) and (8), on the size of the coefficient α, on the dynamics of money growth, and on the behaviour of the monetary authorities: do they follow a reaction function trying to minimize *gap* or do they follow a more or less exogenously determined monetary policy[9]?

A well-known criticism of the so-called Lucas (1972, 1976) short-term supply curve applies with full force to the model above. Surprises in output according to these models should coincide with surprises in inflation. But, empirical research has shown conclusively that there is no reliable positive correlation between short term fluctuations in output and contemporaneous changes in inflation. The finding is robust against different assumptions about the formation of expectations for future output and prices.

The empirical finding that money does not affect inflation at the same time when it affects output should not surprise readers of Friedman or Brunner-Meltzer (1976, 1989). It does not invalidate the view that inflation is a monetary phenomenon, but it shows the limitations of models that relate the dynamics of inflation to measurements of excess demand in the goods market.

Can one solve this problem by allowing for lags in equation (3)? Yes, using ideas of Fisher (1977) and Taylor (1979, 1980) about staggered contracts in the goods or labor markets.[10] But, it will be hard to determine the correct coefficients, because they will always be a function of the characteristics of the noises in equations (3) and (5), as Lucas (1972) has explained. The optimal forecast formula will depend on the dynamics of the money supply, on the relative importance of the noise terms in all equations as well as on the specified lags in the effects of changes in money on changes in economic growth and inflation.[11]

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[9] See Leamer (1986) for a sophisticated statistical analysis of the relative importance of excess demand versus monetary factors which unsurprisingly does not lead to a clear-cut answer. See also Perry (1980) for a less sophisticated analysis with a comparable outcome.

[10] See Ball, Mankiw and Romer (1988) for an extensive recent analysis of "sluggishness" and lags in the "New Keynesian Economics".

[11] See Gordon (1984) for an empirical analysis of U.S. money demand that emphasizes this interpretation of why such equations are so often unstable.

3 The monetarist model of inflation

An example of a monetarist model is:

(10) $\Delta M_t = \Delta M_{t-1} + a_{1,t} \quad ; \quad \Delta M_t^* = \Delta M_{t-1}$

(11) $\Delta M_t = \Delta p_t + \Delta y_t - e \, \Delta i_t + a_{2,t}$

(12) $\Delta y_t^* = c$

(13) $(\Delta y - \Delta y^*)_t = -\beta_2 \, (\Delta p - \Delta p^*)_t + \beta_3 \, (\Delta g - \Delta g^*)_t + a_{4,t}$

(14) $(\Delta y - \Delta y^*)_t = \alpha_1 \, (\Delta p - \Delta p^*)_t + a_{5,t}$

(15) $r_t = i_t - \Delta p_{t+1}^*$

Meaning of new symbols:

g Government expenditure on goods and services

c Constant

$\mathbf{a}_t$ Vector of serially uncorrelated error terms

The first equation, eq. (10), indicates the dynamics for the money supply. In this monetarist type of model, the money supply is assumed to be exogenous in the sense that it does not depend on the other variables in the model according to a well-recognized reaction function. This is not to say that the money supply is determined by random behaviour, but that its economic determinants are sufficiently far removed from the variables in equations (11) through (14) for the simplifying assumption of eq. (10) to be acceptable. Eq. (11) is a demand-for-money schedule, expressed in relative rates of growth. Once again, the own rate of return on money has been omitted and a single interest rate represents the opportunity cost of holding money. More extensive models might include a measure of the return on money balances as well as other rates of return including the rate of return on the holding of goods (the negative of the rate of inflation). Eq. (12) stipulates that the expected rate of growth of output and real demand is a constant. This simplifying assumption may be justified with an argument formally similar to the reasoning behind eq. (10): economic determinants of the expected rate of economic growth may be demographic variables, (changes in) the tax system, various other supply side factors, the real exchange rate and a host of other variables, but as long as the <u>expected</u> rate of economic growth does not depend significantly on the short-term dynamics of the other variables, g, p, and M in the system, the simplifying assumption that the expected rate of growth of output is a constant could be acceptable. Both equation (13) for short-term movements in aggregate demand and eq. (14), a Lucas-type aggregate supply curve, could well be modified, for instance through incorporation of a term describing changes in the relative price of oil in the supply equation or through inclusion of different fiscal variables in the demand equation. Finally, eq. (15) defines the real rate of interest as the difference between the nominal rate and the expected rate of inflation.

There are two principal problems with this model. First, just as the gap model, it imposes a constraint on the coefficients in the reduced forms for output and prices: any factors that affect aggregate demand (eq. (13)) should have consequences for output and prices that are dictated by the movement of a short-term demand curve that traces out supply-side responses: hence the effects should be simultaneous and also the ratio of the price and output effects should be identical for all impulses to aggregate demand. These so-called cross-equation constraints on the reduced forms for output and prices have been rejected in all applications of the model.

Second, it is difficult to accommodate changes in the trend in the demand for real balances. In equation (11) above, the trend in the equation for real balances is put at zero; a constant term in this equation would represent a constant linear trend. If any changes in the trend in velocity can not be modelled exactly with measurable economic variables, it will be necessary to difference the system of equations once more. In particular, the relationship between expected money growth and expected inflation will have to be estimated as a relationship between changes in expected money growth and changes in expected inflation. However, this will reduce the signal-to-noise ratio in the estimated equations and make the testing of hypotheses harder, especially so if there are long and variable lags between changes in money and changes in prices.

4. Representative empirical studies

The flavour of research in the early 1970s is well conveyed by the following quotation from the introduction to Trevithick and Mulvey (1975):

> 'In our opinion the monetarist explanation of inflation is superior to the 'institutionalist' or cost-push explanations of inflation for it explains in very simple terms two phenomena:
>
> (i) it explains why [prices have] accelerated in the United Kingdom, the United States, Japan and many other advanced economies since around 1967 - there is no evidence of substantial changes in the structure of the economies around this time;
>
> (ii) it explains why, despite ripples of relatively minor magnitude, inflation is under a system of fixed exchange rates essentially a worldwide phenomenon.
> (page 6.)

Despite this advocacy of a monetarist view of inflation, the book retains analyses that concentrated on short-term price dynamics and attempted to connect inflation to cost developments. After a historical introduction, chapters follow about 'theories of cost-inflation', 'wage inflation and excess demand', 'wage and price inflation', 'trade unions and inflation' and 'expectations and inflation'. Much of the book relates to different cost-setting schemes in firms, to the "mark-up" of prices over costs and to the particulars of the wage-setting process. The emphasis is on various extensions of the gap model of section 2.

> '... if we assume that a reasonable indicator of the pressure of demand is the unemployment rate, the income-expenditure and monetarist models produce the identical prediction that a fall in the unemployment rate produced by expansive monetary/fiscal policies should be correlated with a rise in the rate of inflation. The same is true, mutatis mutandis, for a rise in the unemployment rate produced by a contractionary monetary/fiscal policy.
> This consideration led Samuelson and Solow (1960) to propose the following experiment in an attempt to distinguish demand from cost inflation:
>
> > *If a small relaxation of demand were followed by great moderations in the march of wages and other costs so that the social cost of a stable price index turned out to be very small in terms of sacrificed high-level employment and output, then the demand-pull hypothesis would have received its most important confirmation. On the other hand, if mild demand repression checked cost and price increases not at all or only mildly, so that considerable unemployment would have to be engineered before*

the price level updrift could be prevented, then the cost-push hypothesis would have received its most important confirmation.

The methodology of this approach is to examine whether the demand-pull prediction stands up to empirical scrutiny and, should it fail to do so, to deduce, faute de mieux, that cost-push factors were responsible for inflation.
Nor would the situation be much improved if monetarists were to produce a series of statistical equations to demonstrate the dependence of the rate of inflation upon the rate of monetary expansion. The more sophisticated among cost-push theorists, while accepting the statistical association between these two variables, would simply reverse the direction of causation and assert that strong inflationary pressure leads to supportive expansions in the supply of money.
It should be clear by now that, at a high level of aggregation, a number of insuperable hurdles are encountered in testing the cost-push theses. This is due principally to the immeasurability of most of the cost-push variables, such as the degree of social conflict. Apart from the rather negative statement that one would expect to find little or no inverse correlation between the rate of inflation and the unemployment rate, no immediate test of the cost-push diagnosis is readily forthcoming.'
(pp.37 - 38)

As discussed in section 2 above, the terms of the debate have changed soon after publication of this volume. In empirical research the main distinction became between models that view (changes in) inflation as a function of (changes in) excess demand with monetary policy an important determinant of changes in excess demand, and models that allow for direct links between money growth and inflation. In either case the monetary authorities may try to precisely accommodate the expected rate of inflation when setting monetary policy, so that the past rate of inflation is a good predictor of the future rate of inflation (a "sluggish" inflation process). Alternatively, the monetary authorities may try to influence expectations and accept responsibility for steering the rate of inflation.

The debate whether "excess demand" is a useful element in the analysis of inflation continues; the old distinction between cost-push or demand-pull inflation has disappeared because the term "cost-push" became associated with approaches to inflation that either neglected the distinction between relative price changes and changes in the absolute price level or that did not incorporate the assumption of a stable longer-term demand for money. Nevertheless, one could continue to use the term "cost-push" for specific instances where "exogenous" political events, for instance important union activity that results in major increases in economy-wide wages, forced the Central Bank to expand the money supply in order to prevent pressure on profit margins. In such cases the change in the rate of inflation, whether temporary or permanent, derives not from a deliberate change in the rate of growth of nominal demand, but rather from changes in nominal labour costs.

Meiselman and Laffer (1975) published their survey 'The worldwide phenomenon of inflation' in the same year. Allan Meltzer (1975) commented as follows on the enterprise:

> 'We have represented here monetarist, fiscalist, international, European, and Phillips-curve views, plus some other views and even overviews. I am grateful to have been spared the oil-energy view, the beef-shortage view and other examples that I lump together as the worm's-eye view, or perhaps views, on inflation. The first fact to note is that neither economic theory nor evidence sustains anything like the number of separate and independent views of inflation represented on the program.
> More than two hundred years ago economists had learned that prices rise whenever the quantity of nominal money increases relative to real output if money is maintained at the new level. This proposition was tested at the beginning of the eighteenth century, during the last ten years, and on many occasions in between. No exact correspondence exists between the growth of money and the rate of inflation in the eighteenth century, at present, or in most inflations that have been studied, so there is room for supplementary explanations. I find the integration of the dominant monetary explanation of inflation with other explanations more appealing than an attempt to pose the issue as a conflict of 'views'. To me, the notion that there are five or six 'views' of the causes of inflation smacks of the politician, or the economist turned politician, who finds a new explanation of inflation each time he changes anti-inflation policy - about every six months in recent years.'
> (page 53)

David Meiselman (1975) usefully pointed out that rates of growth of the money supply in most industrial countries moved very similarly from 1966 trough 1970, but that the correlations were broken in 1971. He emphasized the rapid growth of dollar-denominated reserves outside of the U.S. , supplied through investment of the U.S. current account deficits in dollar paper, and the introduction of the Special Drawing Rights by the International Monetary Fund in 1970 which provided another source of supply of international reserves and hence of money in the world economy.

Whilst the Trevithick-Mulvey and the Meiselman-Laffer books were eclectic as noted by Meltzer, the work by Parkin, Zis and their co-workers exhibited a systematic preference for monetary models of inflation. In the two final collections of papers (1976a,b) that resulted from the research project supervised by Parkin and Laidler at Manchester University, they presented a number of attempts to empirically connect money growth to inflation, both for national economies and for world aggregates.[12]

A paper by Spinelli (1976) on inflation in Italy, for instance, begins by testing whether the wage-price nexus has its own dynamics that derive from negotiations in the labor market, so that central bank attempts to steer inflation through changing aggregate demand become very costly: the old debate between cost-push and demand-pull inflation, subsumed now under the more sophisticated question whether the central bank validates whatever happens or is likely to happen in the labor market, or whether the central bank is responsible for inflationary expectations.

Spinelli tests the dynamics of the wage-setting process by regressing the rate of change of earnings on (a function of) unemployment and on various measures of strike activity by the Italian trade unions. He finds no effect for union activity and concludes that wages reflect a time-varying equilibrium in the labor market: "the evidence strongly denies any usefulness in augmenting the Phillips curve with some measure of strike activity".[13] The issue is important in Spinelli's analysis because he deduces that "some sort of incomes policy as the major anti-inflationary weapon cannot be justified" (pp. 218-219).

Spinelli then adds the lagged rate of world inflation for this period of fixed exchange rates to his regressions for inflation in Italy. We observe in his paper:

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[12] A very similar analysis of inflation in a number of industrial countries was performed by Keran (1975).

[13] Smyth (1978) notes correctly in a markedly hostile review of "Inflation in open economies" that strike activity has costs that depend on employer attitudes and that if these change over time it is no longer correct to map union behaviour on strike activity.

1) autonomous events in the labor market may have one-time effects on the rate of inflation because the monetary authorities feel obliged to accommodate, but these are the exception. The rule is that wage setting is an equilibrium process and that wages do not cause inflation.

2) the inflation equation does not incorporate specific notions about price setting behaviour by firms, but is simply a distributed lag of past inflation and excess demand.

3) international factors have a place in the model for inflationary expectations in the fixed-rate period.

The international monetarist approach could provide a systematic story about the general increase in inflation throughout the O.E.C.D. area during the final years of the Bretton Woods period. Parkin (1977), for instance, offered a model that is very similar to equations (3)-(6) above. His paper shows how richer dynamics in equation (3) - connecting changes in inflation to excess demand - and in equation (5) - the demand for money schedule - together with a richer but ad-hoc formula for inflationary expectations result in a much more complicated reduced form equation for the rate of inflation. The latter is now a function of lagged rates of inflation and lagged rates of money growth. As in most other papers of this period, Parkin accepts a constant term as sufficient for modelling all changes in the demand for real money balances that are not explained by changes in income.

The 1977 Brookings Volume 'Worldwide inflation', edited by Krause and Salant, shows the rapid progress in the theoretical debate about inflation, particularly by providing international channels for the transmission of inflation. The two introductory papers by Swoboda and Branson emphasize the international transmission of inflation through the goods and asset markets. Branson's paper is titled 'A "Keynesian" approach to worldwide inflation', but he only fleetingly refers to wage setting and concentrates on the interaction between the goods and asset markets in a spirit very similar to that of Brunner and Meltzer's earlier work. The main interest in both opening papers is on the endogeneity of the central bank's international reserves under fixed exchange rates.

The conference volume 'The problem of inflation' , edited by Brunner and Meltzer (1978), contains a number of country studies that apply versions of the monetary model of equations (10) - (15) above. The crucial expectations of future money growth as well as growth in other exogenous variables are computed using Box-Jenkins time series models. Typically a two-step procedure is followed in the different papers. First, the econometrician computes expected values for all his exogenous variables and subtracts the expectations from the realizations to obtain a time series for the unexpected changes. In the second step the expected and unexpected parts are used in the model equations. The reduced form equations for inflation is this volume are generally similar to "St. Louis equations" but with two important differences:

1) the dependent variable is the rate of inflation rather than the rate of growth of nominal gdp;

2) sharp distinctions are made between expected and unexpected changes in all explanatory variables and allowance is made for the possibility that expected changes in money have a proportional effect on the rate of inflation whereas unexpected changes in money have a less-than-proportional effect on the price level. Similarly, expected trends in fiscal policy may not effect inflation at all, whereas unexpected changes in fiscal policy have effects on the rate of price change. The same applies to expected and unexpected changes in the world trade, import prices and other explanatory variables.

The papers are similar in spirit and execution to the well-known paper by Barro (1977) on the effects of unanticipated money on unemployment in the U.S. His discussion of the so-called observational equivalence problem applies as well to the papers in the Brunner-Meltzer volume: if inflation is claimed to be a function of (lagged) expected money and (lagged) unexpected changes in money, it is hard to reject the possibility that inflation is correlated with a distributed lag of past rates of money growth, without any need to distinguish between expected and unexpected changes in money. In fact, one either needs a richer model (as in Barro, 1977) or data from another period in which the dynamics of money were different in order to settle the issue.

The Carnegie-Rochester conference volume (1978) and the Barro papers represent the peak of activity in applying either of the two theoretical models above to the analysis of inflation. After 1978 one observes a rapid shift of interest away from this type of applied work. The principal reason was a perceived instability in the demand for money schedule in the U.S. that made it harder to connect changes in inflation to earlier changes in money. The case that the demand for money had become less predictable was made very effectively by Goldfeld (1976). It is important for the discussion in section 5 to note that Goldfeld and many other researchers tested specifications for the change in real money balances that allowed for only the following two causes of a trend in the income velocity of money:

1) a significant interest rate elasticity together with a secular increase or decline in that interest rate;
2) an income (or wealth) elasticity that was different from one.

The majority view became that these two assumptions were not sufficient to explain the behaviour of money demand in the U.S. There were trends in velocity that could not be modelled as a function of changes in interest rates and growth in income.[14]

A second reason why empirical research on inflation became much less popular in academic journals was the conflict between the evidence of substantial lags between changes in money and changes in the rate of inflation and the theoretical difficulties in developing a well-founded story to account for such lags. Theoretical research in monetary macroeconomics shifted to deriving a demand for money from a bequest motive in the so-called "overlapping generations model" or from the need to accumulate money before making purchases, the "cash-in-advance model". Whatever the merits of these theories[15], they did not lead to useful testable hypotheses in the area of inflation.

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[14]But see Judd and Motley (1984) for a defense of the continued stability of M1 in the U.S. These authors assert that allowance for some change in the interest rate elasticity of U.S. M2 is sufficient to also retain the usefulness of that aggregate.

[15]See Gavin (1991) for a series of articles on these theories together with critical comments by Howitt, Summers and others.

Empirical work on inflation continued to be published in the Brookings Papers on Economic Activity and in the Carnegie-Rochester conference series. Bomhoff (1982) derived a statistical model for inflation using Kalman filtering techniques that allowed for both permanent and temporary shocks to the income velocity of money. A representative example of the papers published by Brookings is Robert Gordon's (1985) paper. Gordon makes assumptions about the labor market to derive a series for "natural real gnp".[16] The ratio of real to natural real gnp represents the "output ratio" and appears (with lags of up to eight quarters) as the most significant cause of changes in the rate of inflation. Differences between trend and actual movements in productivity play a similar role.

In a later section of his paper Gordon adds a monetary variable which is computed as the quarterly difference between money growth and the rate of growth of "natural real gnp". By itself this variable does not add to the explanation of changes in U.S. inflation, given the other causal factors, but if it is included together with the rate of change of the income velocity of money, the two variables are jointly significant in a single equation for the period 1954:2 - 1984:4. Gordon experiments in this and earlier papers with several international variables, but finds no significance for import prices or the exchange rate of the dollar. Gordon does not address the question whether the limited influence of money in his model is caused by problems with lags and measurement errors, or whether it derives from a persistent lack of stability in the demand for money schedule.

A later analysis by Gordon (1990) confirms that for U.S. inflation past rates of change in wages are not required once the regression includes past rates of price change and some measure of excess demand and/or the cyclical position of productivity: "inflation depends on past inflation, not past wage changes". Gordon concludes that the dynamics of wages are important for the distribution of income, but not for explaining changes in the aggregate price level.

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[16] A series of earlier papers in the Brookings Papers used much more detailed assumptions about wage formation in the U.S. See for instance Perry (1980) for one of the more recent examples of an analysis that emphasizes differences in wage formation between the unionized and non-unionized sectors.

The Economic Review of the Federal Reserve Bank of San Francisco is a good source of empirical work on inflation in the 1980s that specifically takes into account a variety of open-economy effects.[17] Here is a representative example from a paper by Rose McElhattan. Table 6 of her paper shows a reduced-form equation for inflation with the following coefficients that may be interpreted as elasticities: (page 51).

$$(16)\quad \Delta p_t - \Delta p_{t-1} = \underset{(-4.2)}{-12.090} + \underset{(4.3)}{0.148}\ CU_t - \underset{(-1.9)}{1.44}\ WPON_t$$

$$+ \underset{(1.4)}{0.95}\ WPOFF_t + \underset{(3.6)}{0.039}\ DDIPE_t + \underset{(5.4)}{0.058}\ DDIPE_{t-1}$$

$$+ \underset{(1.2)}{0.059}\ DDEX_t + \underset{(2.4)}{0.107}\ DDEX_{t-1}$$

$R^2 = 0.80$

D.W. = 2.24

S.E.E. = 0.69

Period: 1979:1-83:4 (quarterly data)

Meaning of symbols:

CU	Capacity Utilization rate
WPON	Wage/Price controls "on"
WPOFF	Wage/Price controls "off"
DDIPE	Acceleration in relative price of oil
DDEX	Acceleration in exchange rate of U.S. Dollar

Once again, we observe that quarterly analyses of the change in the rate of price change require a measure of excess demand - and in this case also an

[17] See also Koch, Rosensweig and Whitt (1988) for an analysis using causality tests of the bivariate relationship between the exchange rate of the dollar and a variety of domestic U.S. price indices. In their bivariate context, a permanent 10 percent decline in the dollar leads to a 5 percent rise in U.S. price level.

important relative price, the acceleration in the relative price of oil - but not a monetary variable. The long and variable lag between changes in money growth and changes in inflation as well as the incorporation of other variables such as capacity utilization and the exchange rate, that are influenced by past money growth, imply that there is little place for a monetary variable by itself in this type of regression.

In the late 1980s the dearth of empirical studies of inflation continued, but there was a modest revival of empirical work on the demand for money. Papers by Poole (1978) and Lucas (1978) had helped to re-ignite the debate, but were not sufficiently sophisticated econometrically to convince those who maintained that no stable demand for money schedule existed in the U.S. The apparent success of the Swiss and German Central Banks to produce low and stable inflation after the shock of the first oil crisis (a few years around 1980 excepted) using targets for the money supply or for the monetary base should already have suggested that the problem of lack of stability in the demand for money schedule might be to some extent specific to the U.S. The even more impressive performance of the Bank of Japan to deliver low and stable inflation as a consequence of low and stable money growth for an even longer period after the inflationary episode during the early 1970s suggested that monetary targeting becomes easier once the markets are accustomed to a stable and predictable monetary policy that is not subject to continuously changing degrees of political pressure or frequent changes in the regulatory and tax environment.

However, very little comparative research was done on the relative stability of the demand for money in different countries until the political movement towards a European central bank stimulated fresh research on the demand for money in Europe. Kremers and Lane (1990), for example, collected evidence about the stability of the demand for money and produced their own estimate of a money demand schedule for aggregate data relating to the European Community. I reproduce their preferred equation because it is representative of the most recent output on the demand for money.[18]

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[18]See Boughton (1991) and Hendry and Ericsson (1991) for very similar studies of money demand, all using the co-integration technique.

$$(17) \quad (m-p-y)_t = \underset{(0.01)}{-5.92} - \underset{(0.15)}{0.67}\, i_{s,t} - \underset{(0.53)}{1.40}\, \Delta p_{t-1}$$

$$+\underset{(0.007)}{0.079}\, ecu_t$$

$R^2 = 0.91$

$\sigma = 1$ percent

Quarterly data 1978:4 - 1987:4

Meaning of symbols:

- m — Logarithm of narrow money, taken from the International Financial Statistics
- p — Four-quarter moving geometric average of the ERM-wide CPI
- y — Real gnp converted to Deutsche Mark at ppp rates.
- i_s — Short-term interest rate
- Δp_t — Rate of price change, used as indicator of the opportunity cost of money
- ecu — nominal exchange rate of the ECU in terms of U.S. Dollars

$$(18) \quad \Delta(m - p)_t = \underset{(0.002)}{0.002} + \underset{(0.32)}{0.67}\, \Delta y_t - \underset{(0.31)}{0.86}\, \Delta i_{l,t}$$

$$- \underset{(0.29)}{0.46}\, \Delta i_{s,t-3} - \underset{(0.18)}{0.95}\, EC_{t-1}$$

$R^2 = 0.66$

$\sigma = 0.82$ percent

Quarterly data 1979:1 - 1987:4

Meaning of symbols:

- i_l Long-term interest rate
- EC Residuals of equation (17)

Equation (17) is the first part of a so-called co-integration model. It stipulates that velocity is a function of an average short-term interest rate, i_s[19]. Additionally, the opportunity cost of money is modelled by the rate of inflation, lagged one quarter, and Kremers-Lane also introduce the exchange rate of the ECU. Equation (18) is the second part of the co-integration model. This equation shows how changes in real balances depend on yet another opportunity cost variable, the long-term interest rate in the community, changes in real income, lagged changes in the short-term interest rate and - in particular - on the one quarter lagged residual EC from the first equation.

Before the arrival of co-integration, severe serial correlation of the residuals in an equation such as eq. (17) was taken as the sign of an omitted variable; this technique, however, tells the user not to worry about serial correlation because the second step - the error-correction model - will offer a chance to eliminate it. The only diagnostic test on serial correlation of the residuals that really matters is the test on the residuals of equation (18). As a consequence of this procedure, the issue of a variable trend in the income velocity of money is swept under the carpet: the residuals of equation (17) quite possibly exhibit non-stationary behaviour, but all the explanatory variables in equation (18) can contribute to produce well-behaved second-stage residuals.

Equation (17) has two strongly non-stationary variables on the right hand side (the past rate of inflation and the nominal exchange rate of the ECU) and a third variable (the short-term interest rate) that may also be regarded as non-stationary. This set of non-stationary variables is used in the first stage of the co-integration to produce the best possible fit in a linear model for the level of velocity, but the question whether there are trends in velocity related to introduction of new substitutes for money, changes in

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[19] See Kremers and Lane (1990) for details about the aggregation procedures for income, prices and money to get European totals in terms of Dmark. They reject aggregation at current nominal exchange rates, and prefer to use purchasing power parity exchange rates.

payments techniques or other developments in the financial services industry cannot be addressed in this framework, nor will the co-integration technique show up diagnostics that point to a non-constant trend in velocity.

The residuals in the Kremers-Lane analysis are small, as indicated by the standard error of estimate of approximately 1 percent per quarter and this would suggest a demand for money function on the European scale that is sufficiently stable to be exploited for monetary targeting by the future European System of Central Banks. Equations such as (17) and (18) contain a rather large number of explanatory variables and are the selected outcomes of an extensive search over different lags (this description also applies to the other studies cited in footnote 18). Because it is not clear on the basis of such historical studies how robust the estimated standard errors would be once we move to the forecasting context, the next and final section of this chapter approaches the same relationship between money and the price level from a technically different perspective, that of the Kalman Filter.

5. Dynamic modelling of the income velocity of money

The analysis in this section is performed with annual data for the United States, Japan and Germany over the post-war period. Use of a long period and emphasis on annual rather than quarterly data allows one to focus on the connections between money growth, velocity and inflation without having to specify lag structures that are very unlikely to be time-invariant.[20] The single equation to be estimated is as follows:

$$(19)\quad p_t + y_t - M_t = V_t = c + \alpha tr_t + \theta i_t + u_t$$

In equation (19), p_t represents the natural logarithm of the price level in an economy, y_t the log of a measure of income appropriate to the demand for money, M_t the log of the money supply and hence V_t the log of the income velocity of money. c Represents a shift term in the regression, tr_t a linear trend for the log of V, i_t the log of some relevant interest rate and u_t the residual in the regression. α and θ are regression coefficients to be estimated by linear least squares.

The economic model is the simplest possible one. The income elasticity of money demand is fixed at unity and a single interest rate is used to represent the opportunity cost of money, using the simplifying assumption that the own rate of return on money in each country is constant over time at the margin. With such simple assumptions the resulting models will not be the optimal forecasting tools for velocity. However, the results from these minimal specifications may contribute more convincingly to the debate about the predictability of velocity, because uniform and simple models for six different countries are less subject to the suspicion of being based on data mining than multi-parameter models with extensive lag structures and many free parameters that are tuned to the actual data in each country.

More sophisticated versions of equation (19) have been used to make the point that velocity has become highly unstable and unpredictable, at least in the

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[20] See Boughton and Tavalas (1990) and Cuthbertson and Taylor (1990) for useful surveys of econometric estimates of money demand using quarterly data. They concentrate on various implementations of the so-called buffer stock approach.

United States since 1979. I shall with little loss of generality focus on the simple equation (19), however[21].

Should this rock-bottom model for velocity be estimated in terms of levels, first differences or second differences? Harvey (1980) discusses whether one can use some goodness-of-fit criterion to decide the issue. He concludes that this is likely to work in long data sets, but that in shorter sets big losses are bound to be incurred from time to time by wrongly failing to differentiate non-stationary data. Many subsequent papers on variance ratio tests, co-integration or error correction models have made the point that in non-experimental data sets of limited length there is no test with strong discriminating power to decide whether differencing the data is called for or not[22].

Bordo and Jonung (1987) contributed to the empirical literature on money demand and velocity in the longer term by documenting trends in velocity in five different countries over a hundred-year period. Their research convincingly shows that over the longer term velocity is non-stationary. They test a number of hypotheses about the changes in the trend in velocity and prefer an institutional approach that emphasizes the secular decline in velocity as an economy makes more and more use of money for transactions, followed by a secular rise in velocity as agents devise ways to economize on money, and as the technology of making payments and shifting money from transaction balances to interest-baring-savings accounts improves. Eventually velocity may also increase more slowly or not at all if advances in technology

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[21]The simple specification in this paper does not separate the changes in V into changes in money, M, and changes in gross national product, y. It has been argued that such a disaggregation of the changes in V is useful, since the dynamic impact of a change in M on velocity will differ from the dynamic impact of a change in y. Gains in forecasting accuracy that are based on this disaggregation may be particularly valuable in longer-term forecasts, and/or in multi-equation models. In this chapter I limit the discussion to the single-equation analysis of V with one interest rate as the only explanatory variable.

[22]Diebold and Nerlove (1988) provide a "selective survey" of the literature on unit roots.

and competitive pressures force banks to offer market-determined rates of return on money balances.[23]

The variable trend in velocity poses severe problems for empirical research on the demand for money, both in its normal and in inverted forms, beginning with the problem mentioned before: whether to work with (natural logarithms of) levels, or with differenced data. Some researchers do not reject the hypothesis that the levels (of the natural logarithms) of money, income and possibly a relevant interest rate are co-integrated, meaning that a regression of the level of real balances on the level of income (and the opportunity cost variable) is permissible (see Boughton and Tavlas,1990, who uses data from five of the G-7 countries; see also Hendry and Ericsson, 1991, for the U.K. only, and Hoffman and Rasche, 1989, for the U.S.). Others prefer to work in terms of first differences of money, income and interest rates without reliance on a long-term relationship in terms of the levels (see, for example, Rasche, 1987, Mehra, and, Hetzel and Mehra, 1989 for the U.S.). Unless explanatory variables can explain all changes in the rate of growth of velocity - and the work by Bordo and Jonung suggests that neither income nor institutional variables that represent monetization or economic development can provide more than a partial explanation - it follows that even regressions in first differences are misspecified: one would have to difference at least twice.[24]

It is hard to resolve the dispute with least squares regression techniques. Recall that the natural context for any least squares model is that of stationary variables, because least squares regressions for non-stationary variables have to work with a system matrix X'X that is a function of the

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[23]Bordo and Jonung (1988) test whether empirical proxies can be found to represent some longer-term dynamics of the demand for money. They are careful not to claim that inclusion of such variables captures all permanent changes in level or growth rate of velocity. Kenny (1991) has additional tests of institutional and demographic variables in an extensive cross-country analysis.

[24]See Nelson and Plosser (1982) for discussion of traditional econometric tests of the levels versus first-differences specification. Such tests have low power. More recent work on co-integration allows one to work with levels, but only if some linear combination of the series in the analysis is exactly stationary. That condition is unlikely to be met in the context of the demand for money where there are likely to be permanent shocks to the level of velocity that cannot be modelled by causal economic variables.

number of data points. Such regressions do not satisfy ergodicity, meaning that it is not plausible that a single collection of historical data can be used for the estimation of coefficients with distributions that relate to repeated sampling.[25]

Of course each differencing operation increases the probability that the transformed series are stationary. But, if the relationship when specified in terms of levels is subject to both temporary and permanent disturbances, differencing results in a deterioration of the signal-to-noise ratio and less well-determined coefficients.

By contrast to linear regression techniques, Kalman Filters and smoothers are designed to work with non-stationary data, because the filters and smoothers produce distributions of the so-called state variables that are conditional on the previous realization of the states. For that reason, non-stationarity in itself presents no problem and ergodicity can be satisfied, implying that the distributions of the coefficients have a meaningful interpretation. The only reason why Kalman Filtering has not yet become the natural way to model multivariate time series has been the technical difficulty to combine estimation of the states with estimation of other parameters required to run the filter successfully.

In this paper I present a method for estimating states and parameters jointly, using smoothing algorithms developed by Maybeck (1979, 1982) together with an estimation technique developed by Dempster, Laird and Rubin (1977) and adapted to the Kalman Filter case by Shumway and Stoffer (1982).[26]

The Kalman Filter model will be estimated in terms of levels, with allowance for three types of shocks to velocity (V):

(1) temporary shocks to the level of V;

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[25]Durlauf and Phillips (1988) provide an excellent theoretical analysis of the difficulties that arise when ordinary least squares are applied to non-stationary time series with the possibility that the errors are also non-stationary and non-ergodic. See also Plosser and Schwert (1979) and Nelson and Plosser (1982). This line of research originated with Paul Newbold, see Granger and Newbold (1974).

[26]This section is based in part on my 1991 paper. The models are similar to those in Harvey (1989) who, however, uses a different estimation technique.

(2) permanent shocks to the level of V;

(3) permanent changes in the trend of V.

Note that type (2), permanent shocks to the level, can be described also as representing temporary disturbances to the rate of growth.

The variances of the different types of shocks and hence their relative importance will be estimated on the basis of the data. In this way the methodological difficulties associated with indirect tests for non-stationarity or co-integration are avoided: the data will tell us whether it is useful or not to account for stochastic changes in the trend.[27]

The general state-space notation is as follows:

$$(20) \quad V_t = \begin{pmatrix} 1 & 0 & i_t \end{pmatrix} \begin{pmatrix} c_t \\ tr_t \\ \vartheta_t \end{pmatrix} + u_t$$

$$var\ (u) = R$$

$$(21) \quad \begin{pmatrix} c \\ tr \\ \vartheta \end{pmatrix}_{t+1} = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} c \\ tr \\ \vartheta \end{pmatrix}_t + \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix}_t$$

$$var \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix} = \begin{pmatrix} Q_1 & 0 & 0 \\ 0 & Q_2 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Equivalently:

$$(22) \quad V_t = m_t + \vartheta i_t + u_t$$

In equation (5), m_t is no longer a fixed intercept, but a dynamic stochastic trend, subject to both permanent shifts in its level and a time varying rate of growth. Analysis of equations (3) and (4) will show that they can be summarized in the more easily recognized equation (5) which differs from

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[27]See Swamy, Von zur Muehlen and Mehta (1989) for a very critical methodological discussion of co-integration tests.

standard reduced forms for the demand for money only by a much more flexible intercept term.

Eq.(3) is the observation equation. It states that the level of the log of velocity, V, equals the sum of a shift parameter, the product of the interest rate elasticity, θ, and the long-term interest rate, i_t, and a residual term u_t. This observation equation is identical to an ordinary regression equation. The column vector in equation (3) contains the three so-called state variables of the Kalman Filter model. These three variables together provide sufficient information about the current level of the natural logarithm of velocity. In each year velocity is a linear function of the three state variables together with the residual term of equation (3) which is assumed to be serially uncorrelated.

To model the dynamics of velocity, the Kalman Filter methodology adds equation (4), the so-called state update equation. It shows how three state variables change from period to period. The equation has a predetermined part and a stochastic part. In the predetermined part, the shift parameter is adjusted upwards in each period by the amount, tr_t, which represents a trend. In the stochastic part of equation (4), the trend term, tr_t, is subject to a stochastic shock, w_2, and the shift parameter is subject to permanent stochastic shocks, w_1. The interest rate elasticity is not subject to stochastic shocks over time.

The two stochastic shocks w_1 and w_2 are not observed and forecasts of velocity have to be made before these shocks are realised in each period. Obviously, the residuals u_t in equation (3) also are only observed after the fact. The Kalman Filter will be used to generate forecasts that are produced "on-line": starting in the first year of the period of estimation the filter moves forward and generates a forecast for each period that uses the long-term interest rate for that year but does not use knowledge of any of the three shock terms that will effect velocity in the forecast year. However, the Kalman Filter requires estimates of the average relative importance of the three different types of shock over time. In other words, the user needs to specify estimates of the variances Q_1, Q_2, and R. These estimates are obtained with the use of Kalman Filters and smoothers in combination with the Expectation Maximization algorithm, described by Dempster et al. (1977) and

Watson and Engle (1983) and adapted to our case by Shumway and Stoffer (1982)[28] The variance terms Q1 and Q2 as well as the residual variance R indicate the relative importance of the three types of different shocks that impact velocity. With different values for Q1 and Q2 the Kalman Filter can include both a least-squares specification for the level of log velocity and a specification for its rate of growth. The level specification is obtained by putting both Q1 and Q2 equal to zero, a least-squares specification for the rate of growth of velocity inclusive of a constant deterministic trend, is obtained by allowing for non-zero Q1 but keeping Q2 equal to zero. The Kalman filter includes both specifications as particular cases, so that comparisons between a least-squares model in terms of levels and a least-squares model in terms of rates of growth can be made within the context of a single encompassing Kalman Filter model. Other statistical techniques for comparing levels and first difference specifications suffer from the disadvantage that the two competing hypotheses are non-nested [29]. Note that the regression coefficients in the least-squares model become state variables in the Kalman filter.

The crucial advantage of the state-space-formulation is that it allows for estimation in terms of levels whilst at the same time incorporating all three different types of shocks to the logarithm of velocity: temporary shocks to the level (u_t), permanent shocks to the level (w_1) and permanent changes to the rate of growth of velocity (w_2). The Kalman Filter approach allows for analysis of non-stationary series such as the logarithm of the income velocity of money, because all variances that are computed with the Kalman Filter refer to conditional second moments, conditional on the complete history up to the present time of all the observable variables in the system. By contrast,

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[28]See Nelson (1988) for evidence from his univariate research of U.S. gnp that optimization with respect to the unknown variances of the different shocks to the level and the shocks to the trend of a non-stationary time series may be a delicate matter. This is a topic for additional research.

[29]See Nelson and Plosser (1980) for discussion of traditional econometric tests of the levels versus first-differences specification. Such tests have low power. More recent work on co-integration allows one to work with levels, but only if some linear combination of the series in the analysis is exactly stationary. That condition is unlikely to be met in the context of the demand for money where there are likely to be permanent shocks to the level of velocity that cannot be modelled by causal economic variables.

ordinary least squares estimation is meant to compute unconditional variances for the computed least-squares coefficients including the constant term.

The only free parameters in the models are the interest elasticity which is assumed to be constant over time, and two variance terms: the variance of the permanent shocks to the level of the series and the variance of the permanent shocks to the trend in velocity.[30]

The income elasticity of money is not a free parameter in this Kalman Filter model. I hypothesize that financial innovations lead to changes in velocity trends that are spuriously picked up by non-unitary income elasticities in the traditional money demand specifications. The principal attraction of this hypothesis is that it is not troubled by the substantial differences between the income elasticities in different countries over identical time periods in traditional models that do not allow for stochastic trends but include the income elasticity as a free parameter.

The exogenous explanatory variable is the domestic yield on long-term government bonds. No experiments were undertaken with other rates of return or with lag structures, and the same specification was imposed for all countries. I have tested for stability of this interest rate elasticity by allowing for a different value before and after 1980. The hypothesis that the interest rate elasticity did not differ between these two sub-periods was not rejected.

Table 1 shows the results for Germany, the U.S. and Japan. For each country the interest rate elasticity is shown for M1-velocity and M2-velocity, together with the estimated standard error of the coefficient. For M1 all interest rate elasticities are significant at the 0.05 level. In the case of M2, statistical significance is reached for Japan and Germany. In both these countries, the interest rate elasticity of M2 is smaller than that of M1.

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[30]The variance of the temporary shocks to the level of velocity could be seen as a third variance parameter, but the models are homogeneous of the first degree in all the variance and covariance terms. Hence, this variance is best viewed as computed ex-post from the results of the Kalman filter.

Table 1 also shows the size of the forecast errors. These are conditional on the realized value of the long-term domestic bond yield and the estimated interest rate elasticity and on the optimal estimates of the relative importance of the three different types of shocks that effect velocity. As far as the intercept and the trend in velocity are concerned, the forecasts are purely ex ante and computed recursively without any smoothing. The stochastic trend does change over time, but the filter does not utilize future observations to fit a trend to the complete period; instead it moves through the data and learns from the data how to adjust the trend as time proceeds.

The reasons for computing the forecasts conditional on the interest rate for the current year are first, that the outcomes are directly comparable to results from studies of the demand for money. Second, interest rates are observed without lag and without measurement error, so that policymakers can always adjust any targets for a monetary aggregate if interest rates during the planning period deviate from their predicted values when the targets were set. Hence, forecasts conditional on interest rate realizations produce more useful evidence about the forecastability of velocity than forecasts that are conditional only on past values of velocity, income and interest rates.

For each velocity model, table 1 presents two indicators of the forecast accuracy. The first number of each pair is the root mean square error of the forecasts produced by the Kalman Filter, expressed in percent. The second number of each pair is an estimate of the same r.m.s.e., but computed using a robustified procedure. The mean is computed of the absolute values of all forecast errors, and this mean value is divided by the correction factor 0.6745, resulting in a robust estimate of the r.m.s.e., which is less sensitive to single outliers in the residuals.

The bottom part of table 1 compares root mean square errors before and after 1980. The velocity of M1 became harder to predict according to the Kalman Filter for M1 in model in the United States, but easier to forecast in the other two countries. Forecast errors in M2 velocity in the United States also became substantially larger after 1980 according to this statistical model, but once again M2 velocity became rather more easy to predict in Japan and Germany. The data show, therefore, how dangerous it is to generalize on the basis of experience in a single country.

The results of this Kalman filter exercise suggest that given a proper forecasting model that allows for learning about any possible changes in the stochastic trend in velocity, it is certainly possible to produce forecasts of the velocity of money that are sufficiently accurate to be used in setting up a monetary rule. Hence, this chapter can end on a positive note. Both the analysis of Kremers and Lane for a European monetary aggregate using quarterly data and the Kalman filter analysis for the united States, Japan and Germany suggest that velocity, even though often non-stationary, can still be predicted with sufficient accuracy to be used in the implementation of a monetary targeting rule. As we have seen this finding is not contradicted by the observation that short-term forecasts of inflation are often made without recourse to lagged rates of growth in the money supply, because other macroeconomic variables such as changes in the rate of capacity utilization, are available that can help, together with lagged actual rates of price change and possibly lagged rates of change in the price of energy, to produce accurate short-term forecasts of inflation. Sluggishness in the actual rate of price change means that multivariate autoregressions are the proper practical way to produce optimal short-term inflation forecasts; the fundamental dependence of inflation on lagged money growth is confirmed by recent work on the stability of the demand for money and serves as a basis for the setting of monetary policy.

Table 1.

A: Forecast errors of velocity

Country	M1 Semi-interest Elasticity (S.E.)	R.M.S.E. (robust estimate)	M2 Semi-interest Elasticity (S.E.)	R.M.S.E. (robust estimate)
United States 1956 - 90	0.23 (0.036)	2.45 % (1.80 %)	0.24 (0.36)	2.28 % (2.45 %)
Japan 1968 - 90	0.20 (0.058)	5.35 % (4.84 %)	0.13 (0.049)	4.37 % (2.27 %)
Germany 1958 - 90	0.20 (0.036)	3.45 % (3.15 %)	0.16 (0.032)	2.93 % (2.36 %)

B: Forecast errors of velocity before 1980 vs. 1980 - 90

Country	M1 R.M.S.E. before 1980	M1 R.M.S.E. 1980 - 90	M2 R.M.S.E. before 1980	M2 R.M.S.E. 1980 - 90
United States	2.18 %	2.94 %	2.04 %	2.72 %
Japan	6.74 %	3.20 %	5.69 %	2.14 %
Germany	3.62 %	3.08 %	3.46 %	1.36 %

References

BALL, L. AND S.G. CECCHETTI, 'Inflation and uncertainty at short and long horizons', *Brooking Papers on Economic Activity*, 1, 1990, 215-254

BALL, L., N.G. MANKIW AND D. ROMER, 'The New Keynesian economics and the output-inflation trade-off', *Brooking Papers on Economic Activity*, 1, 1988, 1-82

BARRO, R.J., 'Unanticipated money growth and unemployment in the United States', *American Economic Review*, 67, 1977, 101-115

BOMHOFF, E.J., 'Predicting the price level in a world that changes all the time', in Brunner, K. and A.H. Meltzer (Eds.), 'Carnegie-Rochester Conference Series on Public policy', 17, 1982, 7-56

BOMHOFF, E.J., 'Stability of velocity in the major industrial countries', IMF Staff Papers, 38, no.3, sept. 1991, 626-642

BORDO, M.D., L. JOHNUNG, 'The long-run behaviour of the velocity of circulation, the international evidence', Cambridge: Cambridge University Press, 1987

BOUGHTON, J.M. AND G.S. TAVLAS, 'Demand for money in major industrial countries: A comparison of error correction an buffer stock models', 1990

BOUGHTON, J.M. AND G.S. TAVLAS, 'Modeling money demand in large industrial countries: buffer stock and error correction approaches', *Journal of Policy Modeling*, 12(2), 1990, 433-461

BOUGHTON, J.M., 'Long run money demand in large industrial countries', IMF Staff Papers, 38, no. 1, March 1991, 1-32

BRANSON, W.H., 'A "Keynesian" approach to worldwide inflation', in Krause, L.B., W.S. Salant (Eds.), 'Worldwide inflation', Washington: The Brookings Institution, 1977

BRUNNER, K., A.H. MELTZER, 'An aggregative theory for a closed economy', in J.L. Stein (Ed.), 'Monetarism', Amsterdam: North Holland Publishing Company, 1976

BRUNNER, K. AND A.H. MELTZER, 'The problem of inflation, Carnegie-Rochester Conference Series Public Policy, Vol. 8 (1978)

BRUNNER, K., A.H. MELTZER, 'MONETARY ECONOMICS, OXFORD: BASIL BLACKWELL, 1989

CARLSON, K.M., 'Do price indexes tell us about inflation? A review of the issues', *Review Federal Reserve Bank of St. Louis*, **vol. 71, no 6**, november/ december 1989, 12-30

CHOPRA, A., 'The speed of adjustment of the inflation rate in developing countries: a study of inertia', *IMF Staff papers*, december 1985, **32**, 693-733

COOLEY, T.F., S.F. LEROY, 'Identification and estimation of money demand', *The American Economic Review*, 71, december 1981, 825-844

CUTHBERTSON, K. AND M.P. TAYLOR, 'Money demand, expectations, and the forward-looking model', *Journal of Policy Modeling*, **12(2)**, 1990, 289-315

DEMPSTER A.P., LAIRD, N.N. AND D.B. RUBIN, 'Maximum likelihood from incomplete data via the EM-algorithm', *Journal of the Royal Statistical Society*, Series B, 39, 1977, 1-22

DIEBOLD, F.X. AND M. NERLOVE, 'Unit roots in economic time series: A selective survey', *Finance and Economics Discussion Series nº 49*, Division of Research and statistics, Federal Reserve Board, Washington, DC, 1988

DURLAUF, S.N. AND P.C. PHILIPS, 'Trends versus random walks in time series analysis', *Econometrica*, **56**, November 1988, 1333-1354

FISHER, D., 'Money demand and monetary policy', The university of michigan press, 1989

FISHER, S., 'Long term contracts, rational expectations and the optimal money supply rule', *Journal of Political Economy*, **85**, february 1977, 191-205

FRIEDMAN, M., 'The role of monetary policy', *American Economic Review*, **58**, 1968, 1-17

GAVIN, W.T., 'Price Stability, A Conference Sponsored by the Federal Reserve Bank of Cleveland', *Journal of Money, Credit and Banking*, **23, no. 3 part 2**, August 1991

Goldfeld, S.M., 'The case of the missing money', *Brookings papers on economic activity*, 3, 1976, 683-730

GOODHART, C.A.E., 'Money, information and uncertainty', 2nd ed., Hong Kong: MIT Press, 1989

GORDON, R.J., 'The short-run demand for money: A reconsideration', Journal of Money, Credit and Banking, 16, no. 4, nov. 1984, 403-434

GORDON, R.J., 'Understanding inflation in the 1980's', *Brookings papers on economic activity*, 1985, 1, 263-302

GORDON, R.J., 'U.S. inflation, labor's share, and the natural rate of unemployment', in H. Koning (Ed.), 'Economics of wage determination', New York: Springer verslag 1990, 1-34

GRANGER, C.W.J. AND P. NEWBOLD, 'Spurious regressions in econometrics', *Journal of econometrics*, 2, 1974, 111-20

HARVEY, A.C., 'On comparing regression models in levels and first differences', *International Economic Review*, 21, october 1980, 707-720

HENDRY, D.F. AND N.R. ERICSSON, 'An econometric analysis of UK money demand in monetary trends in the United States and the United Kingdom by Milton Friedman and Anna J. Schwartz', *American Economic Review*, vol. 81, March 1991, 8-38

HENDRY, D.F. AND N.R. ERICSSON, 'Modeling the demand for narrow money in the United Kingdom and the United States', *European Economic Review*, 35, 1991, 833-886

HETZEL, R.L., AND YASH P. MEHRA, 'The Behavior of Money Demand in the 1980s, *Journal of Money, Credit and Banking*, Vol. 21 , 1989, 455-63.

INTERNATIONAL MONETARY FUND, World Economic Outlook, Washington, May 1990

JUDD, J.P., B. MOTLEY, 'The "great velocity decline" of 1982-83: A comparative analysis of M1 and M2', *Economic Review Federal Reserve Bank of San Francisco*, Summer 1984, 3, 56-74

KENNY, L.W., 'Cross county estimates of the demand for money and its components', Economic Inquiry, 29, 1991, 695-705

KERAN, M.W., 'Towards an explanation of simultaneous inflation-recession', *Business Review Federal Reserve Bank of San Francisco*, Spring 1975, 18-30

KOCH, P.D., J.A. ROSENSWEIG AND J.A. WHITT JR., ,The dynamic relationship between the dollar and prices: an intensive empirical investigation', *Journal of International Money and Finance*, 7, no 2, june 1988, 181-204

KOCH, P.D. ET AL., 'The dynamic relations between the dollar and US prices: an intensive empirical investigation', *Journal of international money and finance*, june 1988, 7, 181-204

KRAUSE, L.B., W.S. SALANT (EDS.) , 'Worldwide inflation, theory and recent experience', Washington: The Brookings Institution, 1977

KREMERS, J.J.M. AND T.D. LANE, 'Economic and monetary integration and the aggregate demand fo money in the EMS', forthcoming in IMF staff papers, dec. 1990, vol. 37 no 4, pp. 677-705

LAIDLER, D., 'Understanding velocity: new approaches and their policy relevance-introduction', *Journal of Policy Modeling*, 12(2), 1990, 141-163

LEAMER, E.E., 'A bayesian analysis of the determinants of inflation', in Belsley, P.A., and E. Kuh (Eds.), *'Model Reliability'*, MIT press, Cambridge, Mass., 1986, 62-89, reprinted in Granger, C.W.J. (Ed.), *'Modelling economic series'*, Clarendon Press, Oxford, 1990, 235-259

LEVY, M.D., 'Factors affecting monetary policy in an era of inflation', *Journal of Monetary Economics*, vol. 8, no. 3, november 1981, 351-373

LJUNG, L AND T. SÖDERSTRÖM, 'Theory and practice of recursive identification, The MIT Press, 1983

LUCAS JR. R.E., 'Expectations and the neutrality of money', *Journal of Economic Theory*, 4, april 1972, 103-24

LUCAS, R.E., 'Understanding business cycles', in Brunner, K. and A.H. Meltzer, 'Theory, policy, institutions: Papers from the Carnegie-Rochester Conferences on public policy', Amsterdam: Elsevier science publishers, 1983, 1-24, reprinted from 'Stabilization of the domestic and international economy, *Carnegie-Rochester series on public policy*, 5, 1977, 7-30

LUCAS, R.E., 'Money demand in the United States: a quantitative review', *Carnegie-Rochester Conference Series*, 29, 1988, 137-168

MACKINNON, J.G. AND R.D. MILBOURNE, 'Are Price equations really money demand equations on their heads?, *Journal of Applied Econometrics*, Vol.3, 1988, 295-305

MAYBECK, P.S., 'Stochastic models, estimation and control volume 1, Mathematics in science and engeneering, 141-1, Academic Press, 1979

MAYBECK, P.S., 'Stochastic models, estimation and control volume 2, Mathematics in science and engeneering, 141-2, Academic Press, 1982

MCCALLUM, B.T., 'Price level determinacy with an interest rate policy rule and rational expectations', *Journal of Monetary Economics*, vol. 8, no. 3, november 1981, 319-329

MCCALLUM, B.T., 'The role of overlapping-generations models in monetary economics', *Carnegie Rochester Conference Series on Public Policy*, vol. 18, spring 1983, 9-44

MCELHATTAN, R., 'Inflation, supply shocks and the stable inflation rate of capacity utilization', *Economic Review Federal Reserve Bank of San Francisco*, Winter 1985, 1, 45-63

MEHRA, Y.P., 'Some further results on the source of shift in M1 demand in the 1980s', *Economic Review Federal Reserve Bank of Richmond*, vol. 75, no 5, september/ oktober 1989, 3-13

MEISELMAN, D.I., 'World-wide inflation: a monetarist view', in D.I. Meiselman and A.B. Laffer (eds.), The phenomenon of world-wide inflation (1975)

MELTZER, A.H., 'Comment' in: Meiselman, D.I. and A.B. Laffer (eds.), The phenomenon of worldwide inflation (1975), p. 53-56.

MEISELMAN, D.I., A.B. LAFFER (EDS.), 'The phenomenon of worldwide inflation', Washington D.C.: American enterprise institute for public policy research, 1976

MUEHLEN, PETER VON ZUR, 'Predicting inflation with commodity prices', *Finance and Economics Discussion Paper Series*, 118, Board of Governors of the Federal Reserve System, march 1990

NELSON, C.R., 'Spurious trend and cycle in the state space decomposition of a time series with a unit root', *Journal of Economic Dynamics and Control*, 12, 1988, 475-488

NELSON, C.R. AND C.I. PLOSSER, 'Trends and Random walks in macroeconomic time series: Some evidence and Implications', *Journal of monetary ecomomics*, 10, 1982, 139-162

PAGAN, A., 'Some identification and estimation results for regression models with stochastically varying coefficients', *Journal of Econometrics*, 13, 1980, 341-363

PARKIN, M., 'A "monetarist" analysis of the generation and transmission of world inflation 1958-1971', *American Economic Review*, 67, february 1977, 164-171

PARKIN, M., G. ZIS (EDS.), 'Inflation in open economies', Manchester: Manchester University Press, 1976a

PARKIN, M., G. ZIS (EDS.), 'Inflation in the world economy', Manchester: Manchester Universit Press, 1976b

PERRY, G.L., 'Inflation in theory and practice', *Brookings papers on economic activity*, 1980, 1, 207-260

PHELPS, E.S. ET AL., 'Microeconomic foundations of employment and inflation theory', London: MacMillan and co., 1971

PLOSSER, C.I. AND W.G. SCHWERT, 'Money, income and sunspots: Mearuring economic relationships a the effects of differencing', *Journal of monetary economics*, 4, november 1979, 637-60

POOLE, W., 'Monetary policy lessons of recent inflation and disinflation', *Journal of Economic Perspectives*, 2, Summer 1988, 73-100

SAMUELSON, P.A. AND R.M. SOLOW, 'Analytical aspects of anti-inflation policy', *American Economi Review*, 50, may 1960, 177-194

SARGENT, T.J., AND N. WALLACE, 'Rational expectations, the optimal monetary insrument, and the optimal money supply rule', *J.P.E.*, 83, april 1975, 241-154

SARGENT, T.J., 'Dynamic macroeconomic theory', Cambridge, Massachusetts: Harvard University Press, 1987

SHUMWAY, R.H. AND D.S. STOFFER, 'An approach to time series smoothing and forecasting using the EM algorithm', *Journal of time series analysis*, 3, 1982, 253-264

SIMS, C.A., 'Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered', *American Economic Review*, vol. 70, no. 2, 1980, 250-257

SPINELLI, F., 'The determinants of price and wage inflation, the case of Italy', in M. Parkin and G. Zis (eds.), 'Inflation in open economies', p. 201-236

STOKEY, N.L., R.E. LUCAS, JR., 'Recursive methods in economic dynamics', Cambridge, Massachusetts: Harvard University Press, 1989

SWOBODA, A.K., 'Monetary approaches to worldwide inflation', in Krause, L.B., W.S. Salant (Eds.), 'Worldwide inflation', Washington: The Brookings Institution, 1977

TAYLOR, J.B., 'Staggered wage setting in a macro-model', *American Economic Review Papers and Proceedings*, 69, may 1979, 108-13

TAYLOR, J.B., 'Aggregate dynamics and staggered contracts', *Journal of Political Economy*, 88, february 1980, 1-23

TREVITHICK, J.A., C. MULVEY, 'The economics of inflation', London: Martin Robinson, 1975

WATSON, M.W. AND R.F. ENGLE, 'Alternative algorithms for the estimation of dynamic factor, mimic and varying coefficient regression models', *Journal of Econometrics*, 23, 1983, 385-400

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