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Essays on Money, Inflation and Asset Markets

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Contents

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This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understand the regulations of University College Cork concerning plagiarism.

Overview

1. Introduction

1.1 Research Journey/Rationale

The eight publications that comprise this dissertation cover a subset of research that I undertook, including with colleagues at the Central Bank of Ireland, from the mid-2000s until 2016. The articles are all in the area of monetary economics. Within that field, their focus is on how the money stock (that is, the stock of media that are widely accepted in payment for goods and services and also act as a store of value to their holders) affects other economic variables, in particular inflation, asset prices and uncertainty. The research covered in the dissertation has both a traditional focus (of looking at the relationship between money and goods prices) and an emphasis on a topic that has gained a lot of attention since the mid-2000s or so (of how money and asset markets are interacting with one another in recent times).

Monetary economics has always been an area of economics that has been of particular interest to me since I first studied the subject at undergraduate level. While my Masters' dissertation focussed on financial economics, my subsequent employment as an economist at the Central Bank (Ireland's monetary authority), from 1992 onwards, provided the opportunity to engage in research in monetary economics as well as in other related areas such as payments and banking. Not only is this branch of economics fundamental to central banks' work (they do, after all, exercise monetary policy) but Ireland has been party to the euro which eleven EU member states adopted as a single currency in 1999 (and in cash form in 2002). With the new currency, the Bank became part of the European System of Central Banks (ESCB), within which a monetary policy based on a "two pillar" strategy was in place from the outset. Under this strategy, the ESCB members - the European Central Bank (ECB) and national central banks (NCBs), of which the Central Bank of Ireland is one - set monetary policy, with the aim of maintaining inflation close to but below 2 per cent, by assessing both economic developments (the first pillar) and monetary developments (the second pillar).

For my initial years in the Central Bank, I worked in its research function (considering, among other projects, the implications of electronic money for banking and monetary systems; modelling bank retail interest margin determination; quantifying the impact of derivatives trading on spot markets). Later, I was the Bank's public finance analyst and delegate to the ECB Fiscal Experts' Group. I moved to the Central Bank's monetary policy division, on internal transfer, as a senior economist in 2003. Not only was monetary research a longstanding focus of that department but there was also a need to respond to the new ESCB monetary policy framework and strategy that had come into effect only four years earlier with the introduction of the euro. Since my undergraduate days, I had been attracted to the type of analysis that occurred under the ESCB's second pillar, that is assessing money's influence on inflation and output. David Laidler's (1988) observation that "money matters" to macroeconomic developments and Milton Friedman's dictum that inflation was always and everywhere a monetary phenomenon had stuck with me over the years and, on transferring to the monetary policy division, I was anxious to undertake research that would explore money's influence on the economy and financial markets.

Notwithstanding its prominence in the ESCB monetary policy strategy, money had started to lose its standing in macroeconomics by the mid-2000s, with the New Keynesian Phillips Curve providing the dominant model of inflation. This shift reflected both fresh theoretical developments and new empirical observations. Models of output and inflation that do not include money aggregates were developed and promoted at the same time as the relationship between those aggregates and economic activity became more difficult to observe and predict in empirical work. The ECB, through its two-pillar monetary strategy, however, gave analysis of monetary aggregates equal standing to that of real economic variables in its assessment of general price and output developments.[1]

That the ECB and NCBs in the ESCB considered money important to its monetary policy strategy gave my head of division, Frank Browne, and me the opportunity to undertake research on money's influence on inflation and related areas, although I believe we would have pursued it anyway.[2] [3] Conjunctural developments also happened to provide interesting subject matter to consider. Research and thinking emanating from the Bank for International Settlements (BIS) from the early 2000s onwards proved of interest and was encouraging to us in its view that money and credit developments were having a strong influence on asset market developments and so ought to be of interest to policymakers. Claudio Borio and other BIS economists argued that excess money and credit growth arose in developed economies and posed a threat to financial and economic stability.[4] They were concerned that a surplus of liquid balances was driving asset prices away from values consistent with their economic determinants.

The BIS view suggested to us that while the traditional focus on examining money's influence on inflation and output remained relevant (particularly to researchers working within the ESCB), a contribution to the literature and policy debate by examining money's relationship to asset market developments was also

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[1] See European Central Bank (2010).

[2] Frank Browne and I had worked previously in the Bank's research function in the early-to-mid 1990s where we had collaborated on papers considered the regulatory and monetary consequences of electronic payment devices such as debit cards, prepaid cards and internet-based payments.

[3] In due course, I was able to present some of our research output at various fora within the ESCB, including at an ECB monetary analysis workshop in Frankfurt in October 2006 and a workshop of European and Latin-American central banks in Paris in December 2008. The *Journal of Economics and Business* (2010) article included in this dissertation was initially published in the ECB *Working Paper* series in 2007 after its presentation at the ECB. I was also invited to be a discussant at another monetary analysis workshop in the ECB in 2005 where I commented on Deutsche Bundesbank and European Central Bank papers on measuring longer-term trends in money. My attendance at a Bundesbank workshop in Eltville-am-Main in 2007 alerted me to ESCB research on money and uncertainty and stimulated the research later published in the *Empirica* article included in this dissertation.

[4] See, for example, Borio and Lowe (2002) and Borio and White (2004).

possible. Three articles in the *Financial Times* in 2004 and 2005 were important too in framing a work agenda.[5] Those articles suggested that excess money growth at that time might be causing strong growth in commodity prices, particularly oil prices. The relationship between the money stock and commodity prices is of particular interest to monetary economists given that changes to both are often seen in the economics literature as alternative causal influences on final goods price inflation (with that arising from commodity markets being described as a cost-push influence on final good prices, such as consumer goods). There was also a view, as suggested in the *Financial Times* articles, that changes in commodity prices are driven by changes in money supply and, thus, commodities' influence on the consumer price index is monetary in nature.

Bringing these various influences together (the ECB monetary policy, the new BIS research, the *Financial Times* articles), the genesis of a line of research was in place, summarised as a consideration of money's influence on inflation, output and asset market developments. In later years (from 2009 onwards), the enactment of quantitative easing programmes – where central banks buy financial assets with settlement balances (base money) at the central bank - in response to the financial crisis of 2008 and its aftermath also proved important, reemphasising the need to examine the money-asset prices relationship in particular.

Assessing money's influence on the real economy and financial markets would require me to use time series data and to learn new quantitative skills. My M.Econ.Sc. dissertation (completed in University College, Cork in 1991) had utilised times series econometric methods and, on moving to the monetary policy division, I was eager to learn new methods and to apply them to data. In the mid-2000s, data availability was improving and becoming more accessible. This was particularly the case for US data. The Federal Reserve Bank of St. Louis's *FRED*

[5] Those articles were: "More to oil shocks than the Middle East" (Clover and Fifield, 29 July 2004); "Too much money to blame for rising price of oil, economists claim" (Fifield, 18 August 2004); and "How real interest rates cast a shadow over oil" (Frankel, 15 April 2005). Clover and Fifield are financial journalists, while Jeffrey Frankel is a Harvard economics professor.

database at its website had series on US narrow and broad money stocks (and their opportunity cost), US inflation rates, and US national output going back to, at least, the late-1950s. Bloomberg and Datastream services also provided US asset price data (and some euro area and UK data) for utilisation in econometric studies. Over the years, I combined my growing knowledge of these data sources (and the series therein) with learning and applying time-series techniques (in particular, the Johansen cointegration/ vector error correction model (VECM) and vector autoregressions (VAR), using the Microfit and RATS econometric packages) to conduct research in the monetary sphere (as well as in other areas of research). I was aware that delivering research that would meet high editorial and peer-review standards would require the meticulous application of up-to-date econometric methods.

On data issues, seven of the eight articles contained in this dissertation focus exclusively on US data (while the eighth uses US data alongside euro area and UK data). Large samples are needed for the efficient estimation of VARs and VECMs. US data were preferred because time series (at a quarterly or higher frequency) are available for the relevant macroeconomic variables (CPI, GDP, interest rates, and money aggregates) back to 1959 for that country. Data for those variables for the euro area are not as long-dated and any data available before 1999 are synthetic in nature given that the euro only came into being in that year. For the study of the interlinkages between money and asset prices, US data were again preferred because of both the relative long length of the series and the wide coverage of asset classes available for that country.

It is against this background of a work requirement to conduct monetary research, a personal desire to learn new time-series econometric techniques and apply them to data, and a stimulating international economic and financial environment that the research contained in this dissertation was conducted. Its written output took the form of eight articles, variously published in peer-reviewed economics journals, in other periodicals, and in an edited book volume. The eight articles are presented in two tranches below. The first tranche of four publications concerns the relationship between money, asset markets and uncertainty, while the second tranche, also of four articles, focusses on the transmission of changes in the money supply to final goods prices and output.

1.2 Research overview

In relation to the first tranche, the literature on the relationship between monetary policy and asset market developments in the mid-2000s, when the research recorded here commenced, was focussing on scoping out hypotheses and questions for testing and explanation. There were few, if any, formal models of the relationship and the employment of econometric techniques was rare. Contributors, such as the aforementioned BIS economists mentioned above, were making their case predominantly through graphical analysis of data. The oldest article, published in the 2005 edition of the Central Bank of Ireland's *Financial Stability Report*, among the eight in this dissertation takes a similar approach to other studies of the time. It compares patterns in how variables under the influence of the central bank (in particular, money stocks) had behaved over time, including through periods of recession, and compared them to concurrent developments in asset market variables. That article informed other lines of more formal enquiry that followed, with the results of that research recorded in the other three articles in this tranche of publications.

One of those three, published in the journal *World Economics*, focusses on a particular money-asset relationship – that between the US broad money aggregate M2 and US stock prices – and analyses how the relationship responds to changes in the economic environment (including elevated uncertainty), again, by graphical means, but also by the application of statistical and econometric tools to data.[6] The second article, published in the *Journal of Macroeconomics*, considered a wider spectrum of money aggregates and asset classes. Whereas the aforementioned two contributions identified prevailing economic conditions *a priori* (based on, for example, the NBER's categorisation of periods of

[6] The term "uncertainty" has both colloquial and technical meanings, with it often used interchangeably with the words 'risk' and 'volatility' when a more careful choice of word(s) should be made. I endeavour to qualify such words where they arise in the articles discussed here.

recession in the US economy), the econometric methodology used in the *Journal of Macroeconomics* article allowed the data to identify critical events and developments. Episodes of increased economic or financial volatility were shown in that article to have an impact on the money-asset price relationship.

The final article in this tranche, published in the journal *Empirica*, does not use or address asset data but ties in with the other articles by examining the relationship between money and uncertainty by econometric means. This particular topic was one that I was exposed to at an ECB workshop I attended in the mid-2000s.[7] Following attendance at the workshop, it occurred to me that a multivariate GARCH technique focussing on money growth and output growth series, combined with Granger causality tests, could make a contribution to the money-and-uncertainty literature. The application of these techniques to, again, US data was recorded in the *Empirica* article.

The second tranche of research in this dissertation, also comprising four publications, focuses on a topic long familiar to monetary economists, that of inflation determination. The neglect of money in models of inflation in the 2000s literature provided a lacuna in the literature for those who believe that money matters: could new formal models and econometric techniques show that money developments explained goods and services price developments? Two distinct contributions were made in that research among the articles in this tranche of the PhD dissertation. The first is contained in three articles published between 2008 and 2012 in the *Journal of Economics and Business*, in the Central Bank of Ireland's *Quarterly Bulletin*, and in a chapter in a book considering inflation-sensitive assets. All three rely on a formal model outlined in the *Journal of Economics and Business* article based on the hypotheses that commodity prices exhibit overshooting behaviour in response to a money shock and that the extent of that overshooting (measured as a commodity-price gap) has explanatory power for subsequent final goods inflation. A reading of an article by Alvarez, Lucas and Weber (2001) was influential in the formulation of the formal model in the

[7] Greiber and Lemke (2005) was a paper discussing the topic at that workshop.

Journal of Economics and Business article. It was also obvious to me that the Johansen procedure with its tests of cointegrating relationships among the variables and impulse response functions could test the predictions of the formal model, which indicated there should be two long run relationships in the data: between consumer prices, money and output, and between commodity prices, money and output. The econometric and statistical evidence presented in that journal article and in the other two publications proved supportive of the theoretical model.

The second contribution in this tranche was made in the final article, recently published in the journal *Empirical Economics*, of the four in this tranche. It also supports a monetary determination of inflation. It applies a new variant of VAR-based forecast error variance decompositions (owing to Diebold and Yilmaz 2009, 2012) to the monetarist-based P-star model of inflation introduced in an *American Economic Review* article by Hallman et al. (1991) and provides fresh backing to the relevance of the monetary variables identified there. In common with the first tranche of articles, it finds money variables having particular prominence in explaining the behaviour of other variables (in this case, inflation and output) at times of increased economic instability.

Before discussing the two tranches of articles in turn in sections 4 and 5 of this overview, section 2 discusses the monetary theory and academic studies that influenced the monetary research recorded in this dissertation. Conjunctural developments, that is what was going on concurrently in the economy and in financial markets, helped orientate the research undertaken and in making it relevant to both academic and policy audiences. Those developments are discussed in section 3. Both sections 2 and 3 may then help in reading sections 4 and 5, where each tranche is considered in turn, by setting out the background against which the articles comprising this dissertation were written. Section 6 concludes.

2. Money's Impact on Inflation and Asset Markets: Theoretical Influences

An important starting point for economists when commencing research in this area is to be cognisant of what money is and what services it provides to its holders. The study of these roles of money has helped shape the development of monetary economics over time. At a basic level, money can be defined as the medium that settles payments (i.e., it acts as the medium of exchange) within an economy. It is used in the purchase of goods and services, and of assets. With that comes the ancillary functions of providing the economy with a unit of account (a unit of the medium of exchange defines prices) and a store of value to its inhabitants (possession of money confers purchasing power on its holder whenever he/she wishes to spend it).[8] In the latter capacity, it is an asset to its holder.

The quantity theory of money was a central part of the monetary economics course that I took as an undergraduate and it made a lasting impression on me with its long historical legacy (dating from, at least, Hume, 1752) and the support it receives in numerous studies (e.g., Lucas (1980), McCandless and Weber (1995), Gerlach (1995)). Fisher (1911) provided the equation of exchange ("the Fisher equation") that assists in explaining the quantity theory. It is shown here as:

$$M.V = P.Y$$

Where M is the money stock, V is the average rate at which a unit of money is used to settle transactions within the economy in a given period, P is the general price level, and Y is the output of goods and services within the economy.[9] While

[8] The possibility that the unit of account could be defined as something other than a unit of the medium of exchange has been the subject of articles that I have written or co-written on alternative monetary standards (Browne and Cronin, 1995, 1997; Cronin and Dowd 2001; Cronin 2012; Cronin 2017).

[9] Fisher used 'T', denoting the total volume of monetary transactions in the economy within a given year, instead of 'Y' in his outlining of the quantity theory. The difficulty is that T is unobservable and so the modern version of the Quantity Theory (the income version, as opposed to the earlier transactions version) uses national output, i.e. Y above.

Y is the measure of real output, $P.Y$ provides the measure of nominal output, i.e. the monetary value of the goods and services produced within the period.

The equation is a tautology, or truism, because if money intermediates, or settles, all goods transactions within the economy in a given period then $P.Y$ (net national income) must equate with the amount of money in the economy (M) multiplied by the average number of times (V) that money is used in transactions. The equation can be used as the basis for a theory of how the price level is determined when certain assumptions are imposed, in particular that V and Y are pre-determined while the money stock, M, is exogenous.[10] The price level, P, is then the endogenous variable among the four and will adjust *pari passu* to changes in M to maintain the equality. Thus, the price level is determined by the money stock.

The quantity theory of money caters for a richer determination of the interaction between output and prices by recognising that P will not adjust instantaneously to its new equilibrium level when there is a change in M. Relaxing the assumption that Y is pre-determined, Y will vary in the short run after changes to the money stock occur; specifically when the money stock increases (decreases), output will rise (fall), maintaining the equality above. Over time, as the price level rises in response to a larger money stock, output will start to revert to its original level and be at it when the price level has adjusted fully to its new equilibrium value. Consequently, a change in the money stock will have a short run impact on output but will not affect it in the long run. The quantity theory then provides an explanation of long run price determination and of why output varies over the short-to-medium term (business cycle theory) but remains neutral to changes in the money stock in the long run.

Milton Friedman (1968) restated the quantity theory of inflation by maintaining that changes in the money supply have an impact on aggregate demand in the

[10] The pre-determination of V and Y reflects in the case of V the state of payment technology in the economy, while Y will depend on labour, capital and productivity.

short term but have no long-term effect on output. The form of the quantity theory put forward by Friedman – monetarism – argued for the stability of the public's demand for money. An excess supply of money (or real money balances) would transmit itself to final prices with a long and variable lag as that excess is not easily cleared within the economy. In the short term, prices are sticky and so output would initially be affected by a change in the money supply. Over time, prices would rise and the temporary effect on output would recede. The proportional rise in prices (to an increase in the money supply) could take years to complete but inflation would be always and everywhere a monetary phenomenon, i.e. owing to money growth differing from that of output. The implication of this theory for central banks is that they need to estimate the public's demand for money balances. Monetary growth in excess of increases in that demand will lead to inflation. Another implication of monetarism is that the appropriate policy response to high inflation rates is to exercise restraint on growth in the money supply.

While the quantity theory and monetarism emphasised money's role as the economy's medium of exchange, the Keynesian focus on the characteristics of money as an asset was also an influence on the research in this dissertation (particularly, the first tranche of articles dealing with the money-financial assets relationship). Money provides a store of value to its holder and has a property lacking in other assets: constant nominal purchasing power. Its standing as the economy's medium of exchange also means money has the property of deferred payment: the holder does not have to spend the money immediately but can allow a period of time to elapse before using it in the purchase of goods and services, or other assets. These properties make money attractive as an asset to hold, something that would make it particularly appealing if there was a downturn in economic activity, a rise in macroeconomic volatility, or a fall in financial asset prices. In such circumstances, economic agents could exercise liquidity preference, i.e. a desire to hold liquid assets, of which money is the most liquid. Holding money, however, has a cost in terms of interest foregone and so the amount of money held by the public is affected by the yield on competing financial assets.

This perspective would be one to which Frank Browne and I would turn as we sought to understand the linkages between money and asset market developments through the 2000s and into the current decade. Any views Milton Friedman had on the money-asset price relationship were ones we also sought out in the literature. One important article that we found was Friedman (1988). It identifies four factors affecting the nature of the relationship between stock prices and money velocity. Three of those factors will generate an inverse relationship between stock prices and money velocity (that is the nominal output of the economy divided by its money stock) with velocity falling as stock prices rise, and vice versa. Those factors are that (i) money is a luxury good (so that an increase in stock prices increases the demand for money, causing velocity to fall); (ii) a rise in stock prices requires a greater amount of money to facilitate asset transactions; (iii) higher stock prices make them appear riskier and this generates a greater demand for the safe asset of money. Friedman (1988, p. 221) argues that these are the dominant factors in the money velocity-asset prices relationship and that they explain "the close inverse relation between the level of the Dow Jones stock market index and the velocity of the money aggregate now designated M2 by the Federal Reserve System" over the period 1961 to 1986. The fourth and final factor identified by Friedman is a substitution effect between money and equities. It operates by an expected rise in stock returns leading agents to switch their wealth holdings out of money and into equities (or vice versa). Thus, this factor leads the velocity of money to rise when stock prices are increasing, and vice versa.

3. Monetary Developments in the 2000s: Setting the Research Agenda

Alongside these academic influences, particular economic events of the previous thirty years were important to Frank Browne and me in identifying a monetary research agenda. First, the money supply's influence on inflationary developments and its importance for monetary policy was emphasised to us by the success of the so-called Volcker disinflation in the United States in the late 1970s and early 1980s. After taking up the position of Federal Reserve chairman in 1979 against a background of high inflation rates prevailing in the US, Paul Volcker indicated that he would focus on restraining the growth of the money supply to improve US economic performance. The Federal Reserve changed its monetary policy operational framework from day-to-day management of the Federal Funds rate of interest to managing the amount of bank reserves held by the Federal Reserve System. The purported advantage of this strategy was that it would prove easier and quicker to taking control of money supply growth and reducing inflation rates. Although greater variability in interest rates was an outcome of this policy, the new policy procedure succeeded in bringing inflation rates down substantially from high levels in a little over two years.

Inflation rates in developed economies fell from double-digit rates to low, single-digit rates from the late-1970s through to the early-1990s. Money's relative importance in monetary policy then declined (to be replaced by a greater focus on developments in the real economy, such as in unemployment and in the deviation of output from trend) in parallel with central banks being mandated to keep inflation close to the low rates that had been achieved, with specific numerical targets being set in some cases. In part, this reflected difficulties in understanding monetary dynamics occurring at that time, with a breakdown in the stability of money demand functions – a critical proposition of monetarism - being observed.[11] This made it more difficult to gauge what rate of money growth would be consistent with price stability.

A monetary policy strategy – inflation targeting – started to find greater favour over monetary targeting (which involved setting a target for money growth as a basis for keeping inflation close to a preferred rate) with many central bankers and academics. As its name suggests, inflation targeting involves a central bank seeking to achieve a particular rate of inflation, often set by government, as a

[11] See Carlson et al. (2000).

medium-term target. Inflation targeting operates on the premise that general price developments – whether the consumer price index is rising or falling, and at what rate – originate in the labour market and that providing a specific numerical target for inflation can help maintain inflation expectations at low levels. A variant of the Phillips curve (Phillips, 1958) plays the main analytical role within this "New Keynesian" paradigm, with the size of the output gap capturing the extent of inflationary pressures within the economy. From this, a Taylor Rule (Taylor, 1993) showed how central banks appeared to set the short-term interest rate as a function of the deviation of the actual inflation rate from its target rate and the deviation of output (GDP/GNP) growth from its long-run potential growth rate. The Taylor Rule came to play a prominent role in analysing monetary policy in the 1990s and 2000s.

Within the inflation-targeting paradigm, there is no need for a money demand function or, indeed, any money variable. The focus is on how real economy variables (e.g., output, unemployment) are behaving. The inflation-targeting framework's attraction to its advocates lies in what they see as its parsimonious but integrated and realistic description of aggregate demand and inflation determination.[12] For policymakers, it proved helpful at a time when a breakdown in the stability of money demand functions was being observed, making a money-based analysis of inflation developments more difficult. In the United States, the demand for money among the public proved hard to estimate accurately from about the early-1990s onwards, owing, at least in part, to the arrival of near-money substitutes such as transactions balances held with mutual funds. The information coming from the monetary sphere then was not as helpful to monetary policy formulation as previously.

At the turn of the 21st century, the inflation-targeting framework, focussing on analysis of the real economy, was to the fore in how monetary policy was

[12] See Bernanke and Mishkin (1997).

practised by many central banks. Inflation targets were being broadly met and monetary developments took a backseat in policy-making. Some academics and policy-makers, however, continued to stress monetary variables' role in monetary policy. Contributors such as Issing et al. (2001) and Hafer et al. (2007) argued that monetary developments remained crucial features of the transmission of monetary policy and were often better leading indicators of inflation than non-monetary variables. Commenting in the mid-2000s, Robert Lucas acknowledged that central banks that did not make explicit use of money stock data had impressive recent records in controlling inflation (Lucas, 2006). He stressed, however, that this was still but a "brief period of success" and that any attempt to render monetary analysis "superfluous" would "lead monetary policy analysis back to the muddled eclecticism that brought us the 1970s inflation" (Lucas, 2006, p. 168).

In contrast to the more doctrinal adherents to inflation targeting (see, for example, Woodford 2003, 2008), who often argued for dispensing with assessing developments in the money stock entirely, the position of many advocates of monetary analysis was not to counter that it should dominate real economy analysis or be used on its own to determine monetary policy. The New Keynesian approach to monetary policy did not adequately meet the needs of monetary policymakers, not least because it did not make use of all available information. The ECB took a broad approach to monetary policymaking from its inception with the intention of capturing all available information that could be used as an input into policy decisions.[13] It had a numerical inflation target, albeit a slightly imprecise one of maintaining inflation below, but close to, two per cent over the medium term, and it monitored monetary and economic developments in assessing at what level to set official interest rates. For the ECB, analysis of monetary variables, such as assessing the behaviour of the euro area broad money aggregate, M3, served as a means of cross-checking, from a

[13] For example, new money data observations are available more frequently and with less of a delay than output data and, therefore, could help the policymaker understand macroeconomic developments more quickly.

medium- to long-term perspective, the short- to medium-term indications coming from the economic analysis. This so-called two-pillar approach sought to use the full information set of economic and monetary analysis available when making monetary policy.[14] It also provided a well-formulated and broad basis for communicating in a consistent manner with the public (compared to the more simplified representation of inflation targeting).

The ECB perspective and the views expressed by eminent economists like Robert Lucas proved encouraging to Frank Browne and me. What we took away from those viewpoints was that money *should* still matter but that it might require new techniques, particularly econometric methods, to be applied to data to bring out its relationship to inflation. This was the basis for the overshooting model developed and tested in the *Journal of Economics and Business* article. The need to compare quantity theory-based models of inflation to other models of inflation was also noted, and applied in the *Empirical Economics* article published in my own name.

Besides striving to maintain inflation at low levels, a new, related issue came into focus for central banks in the 2000s: the need to understand better the nexus between monetary policy and the stability of the financial system. A concern arose that with many central banks maintaining a narrow focus on price stability, financial imbalances would be ignored and that these could eventually prove disruptive and pose a threat to the general well-being of economies. The "democratisation" of financial markets in the 1990s and 2000s would have played a role in awakening economists' interest in the money-asset prices relationship. A series of deregulation measures took place in financial markets from the early 1980s onwards. These included interest rate deregulation, the phasing out of Regulation Q, and the elimination of portfolio restrictions on thrifts in the United States. Financial markets responded to this new regulatory environment by

[14] The practical difficulties in measuring potential output and other economic variables, particularly in real time, also provide a role for the use of more-timely monetary data.

providing new financial products to the public, giving households and firms cheaper and easier access to financial markets. It gave them greater latitude in using their money holdings (in particular, any excess real balances) to purchase assets. New financial products, such as mutual funds, also made it easier to shift wealth between money and financial assets.

A narrow focus of monetary policy on the short term, such as occurs under inflation targeting (with the Bank of England, for example, having an inflation rate target of two per cent), might pose risks to price stability in the longer run if financial stability issues were overlooked.[15] This reflected episodes of severe financial distress, with serious macroeconomic implications, having increased in number since the 1980s, at a time when inflation had declined substantially from 1970s levels, and as financial markets had been liberalised at the same time. These economic and financial crises often took place after a period in which inflationary pressures were absent. In the BIS economists' view, financial market liberalisation in conjunction with the near-term, price-stability focus of monetary policy changed the dynamics of economic and financial market interactions. In such an environment, the maintenance of low and stable inflation would mean that excess demand pressures would manifest themselves in strong credit aggregate and asset price growth, rather than in higher final goods inflation. Financial imbalances (such as in the form of large debt-to-income ratios or highly-inflated asset price-to-earnings ratios) could develop and build up before eventually unwinding rapidly and at great cost to both the economy and financial system.[16] Such developments were not picked up by New Keynesian models whose basic form comprised three equations representing, in turn, an IS curve, Phillips curve and interest rate-based monetary policy rule.

[15] Bean (2004) makes a similar point in saying that the build-up of financial imbalances in conjunction with asset price cycles poses a challenge to conventional inflation targeting frameworks.

[16] Economists based at the ECB were also raising these issues in the early 2000s. Detken and Smets (2004) show how real credit and money growth are quite strong before and during asset price booms. The asset price collapses that prove most costly are preceded by stronger pre-boom and early-boom real money growth and real credit growth than at other times.

The views of the BIS economists proved to be prescient when the financial and economic crisis of 2007/8 and subsequent years came to pass, with large rises in money, credit and asset prices in the preceding years playing their part in the crash. This brought into focus a sharp questioning of the inflation-targeting approach from economists who would have been considered to be in the mainstream of 1990s-2000s macroeconomic thinking. For example, John Taylor, the originator of the eponymous monetary rule, acknowledged that part of the blame for the financial crisis that emerged in 2007 was due to "monetary excesses" in the years preceding it (Taylor, 2009). There was an acknowledgment that the inflation-targeting monetary policy framework could not have foreseen, or catered for, the build-up in asset prices or excess money and credit growth that occurred in the years prior to the crash because of its not allowing for asset market developments in monetary policymaking.

After the financial crisis, a renewed interest in the role of changes in money and credit in consumer price, output and asset market developments took place. Not only had the crisis raised the issue of the role of money in economic and financial developments once more but central banks started to pursue a form of monetary policy – quantitative easing – that expanded the size of the monetary base in an effort to tackle deflationary pressures within the economy. The effects of such a novel policy have been the subject of research in recent years, including on how it has affected asset prices and how it feeds through to inflation and output developments. It plays a prominent role in the analysis of money-financial asset relationships in the *Journal of Macroeconomics* article published in my own name.

It is against this background that the articles in this dissertation were written. The academic and conjunctural developments summarised above provided a number of avenues to explore in setting out on a research path. First, although money's influence on inflation and real economy developments was being discounted, or minimised, by many in the economics profession at that time, money should still matter but discerning its influence in the data might be more difficult than in the past. A goal of the research then was to show through statistical and econometric work that money, inflation and short-run fluctuations in output were connected. The Keynesian perspective on money as an asset and Friedman's (1988) study of the money-financial asset relationship was also an important source of reference. There was now greater scope for households and firms to substitute between money and financial assets and that raised the question of how that substitutability affected the relationship between the two and whether it was complicating the transmission of changes in the money supply to final goods price. If the motivation for substituting between money and assets was owing to greater economic uncertainty then that variable needed to be borne in mind in empirical work.

Some of the output from that research is the basis for this dissertation. As with all research, the direction it took developed and changed as papers were completed and new ones commenced but each article contained herein follows from the influences outlined above. I have chosen to present the papers in two tranches in the dissertation and discuss each in turn in the next two sections. Section 4 then deals with the first tranche, comprising four articles, and addressing the relationship between money aggregates and asset prices. The second tranche, also involving four articles, examines the monetary determination of inflation and is considered in section 5. The concluding section to the dissertation discusses the contribution to knowledge of these articles.

4. Money and Asset Prices Tranche

The article, **"Recent Developments in Asset Prices and Liquidity in the Context of an Evolving Relationship",** published in the Central Bank of Ireland's *Financial Stability Report 2005* (*FSR*), addresses the money-asset price relationship.[17] It can also be viewed as a ground-clearing article for the other

[17] "Recent Developments in Asset Prices and Liquidity in the Context of an Evolving Relationship." With F. Browne and E.J. O'Brien, Central Bank and Financial Services Authority of Ireland *Financial Stability Report 2005*, pp. 93-110.

three articles covered in this section. It establishes some of the major themes examined more rigorously in the later contributions: a pattern of substitution between money and assets being evident during the 2000s, and the level of uncertainty in the economy playing a role in that substitution. At its outset, the *FSR* article initially notes that rising prices were being observed across almost all asset classes in the early 2000s; it asks whether asset prices were becoming detached from economically-determined, or fundamental, values at that time, or not; and it sets out to assess how money aggregates' behaviour may help explain asset price performance during that period.

The initial part of the *FSR* article illustrates that an excess amount of money arose in the global economy by the mid-2000s. This is done by examining the behaviour of broad monetary aggregates since the early 1980s in three economies: the United States (through its M2 money aggregate), the euro area (its M3 aggregate) and the UK (its M2 money stock). Real (i.e. inflation-adjusted) money growth rates are shown in all three cases to have been rising over the previous ten years or so, i.e. from the mid-1990s onwards. Those money growth rates are compared to those of output growth. To do this, the rate of nominal GDP growth is subtracted from the nominal broad money growth rate. The residual for each economy shows strong percentage growth rates in the 2000s compared to earlier years, pointing to excess money balances arising at that time.

Having concluded that there was an excess of liquid balances in all three economies by the mid-2000s, the *FSR* article asks what might be the reasons behind this development and what consequences it might have. One possibility is that firms and households were building up money balances to hoard, i.e. to be used in transactions in the future rather than immediately. The velocity of money (measured as nominal GDP divided by the money stock) can give an indication as to whether that was the case or not. Plots of the velocity of money for each of the three economies indicate a trend decline in it from the mid-1990s onwards, so that consumers and firms seemed to have been holding more liquid balances than were needed for trade in goods and services. Historically, the velocity of money tends to decline when the opportunity cost of holding money falls. In the early-

2000s, however, the opportunity cost of holding money is shown in the article to have been rising. An interest elasticity effect does not seem then to explain velocity developments. It is concluded that an increased desire to hoard money may explain at least some part of the rise in liquidity observed at that time.

With the supply of goods and services being relatively inelastic, an excess supply of money would have been expected to lead to a rise in final goods and services prices. The *FSR* article shows that by the mid-2000s CPI inflation was well below money growth rates in the three economies and that the gaps between money and price growth rates were larger than the historical norm. Strong money growth was not then having the expected effect on inflation.

If money was not being used for the purchase of goods and services then it could have been used for the acquisition of assets. The *FSR* article examines price developments across six asset classes: government bonds, corporate bonds, equities, commodities (oil), property, and emerging market (bond and/or equity) indices. The analysis of asset prices is undertaken over the horizon 2000Q1 to 2005Q2. Within that five-year-long window, 2002Q3 is adjudged to be a turning point in the perceived level of uncertainty and risk aversion in financial markets and, thereof, in asset price developments. From 2000Q1 to 2002Q3, there was a diverse performance across asset classes, with some seeing declining prices and others experiencing rising prices. Thereafter, a generalised increase in asset prices is observed with, for example, aggregate asset prices in the US rising, on an unweighted basis, by close to 40 per cent from 2002Q3 to 2005Q2. Over this entire period, as the earlier part of the *FSR* article shows, an excess supply of money arises.

It is argued in the *FSR* article that roughly the first half of the five-year period from 2000 to 2005 was marked by political and economic instability, following the US stock market reversal of 2000 and the September 2001 terrorist attacks. The public was inclined at that time to hoard its liquid balances, given the uncertain environment. When economic circumstances appeared to be improving in late-2002, agents started to dishoard their money holdings by buying assets, as opposed to purchasing goods and services. This would help explain CPI inflation remaining low, while the prices of different asset classes rose sharply and broadly together in all three economies.

The second article in the dissertation, **"The New Dynamic Between US Stock Prices and Money Holdings"**, published in *World Economics* (*WE*) in 2012, examines the relationship between asset markets (through the behaviour of the US stock market) and money and complements the *FSR* contribution.[18] It argues that the new, democratised financial market setting of recent decades, whereby households and small firms have easier and cheaper access to financial markets, has implications for the relationship between money and financial assets. Whereas the *FSR* article examines the money-asset price relationship over a relatively short period marked by shifts in the state of the economy, the *WE* article is more specific in focussing on the relationship between money and one asset, stocks, and in using US data over a relatively long period. Both articles, however, share the view that an effect of a more liberalised and democratised financial market environment has been to generate patterns of substitution between money and financial assets that are dependent on economic performance.

While the *FSR* article describes money and asset price developments, the *WE* article is more specific in using Friedman's (1988) identification of four factors governing the relationship between money and one asset class, stocks, as the theoretical basis for its empirical analysis. In that article, Friedman argues that there are three factors that will act to produce an inverse relationship between stock prices and money velocity, while a fourth factor generates a positive relationship between them. The *WE* article contends that the importance of this fourth factor, based on a substitution of wealth between money and stock holdings dependent on stock market performance, would have been strengthened in the

[18] "The New Dynamic between US Stock Prices and Money Holdings." With F. Browne, *World Economics*, 2012, 13, 1, pp. 137-156.

wake of the liberalisation and deregulation of financial markets in the 1990s and 2000s. This process would have enhanced the demand for money as an asset, or a store of value, and made substitution of wealth between money and stocks much easier. Thus, Friedman's contention, under the fourth factor, that an expected increase in stock returns would cause a substitution from money into stocks, and vice versa, should be observed in the data from the 1990s onwards. The *WE* article adds that substitution would not be dependent on expected rises or falls in stock markets alone but on economic and financial conditions more generally.

In writing the article, the empirical challenge was to see whether the observed relationship between money velocity and stock prices had changed from that reported in Friedman (1988), where his first three factors were shown to dominate the fourth, to one where the substitution effect prevailed. As with the Friedman article, the data examined in the *WE* article are the real (i.e. inflation-adjusted) Standard and Poors 500 (S&P 500) price index and real US M2 money holdings. The data cover the period 1967Q2 to 2010Q2, with the starting date dictated by it being the first quarter in which observations of the third variable employed, the Consumer Confidence Index (CCI), became available. The CCI is a consumer sentiment indicator calculated from survey data by The Conference Board. Its inverse is used as a measure of uncertainty in the *WE* article. From the overall sample, data between 1985Q1 to 1992Q4 are removed from the analysis to provide a buffer between two sub-periods. The first of those, 1967Q2 to 1984Q4, was a period when households' participation in financial markets was repressed, while the second period, 1993Q1-2010Q2, was one when US financial markets were liberalised and increased household participation in those markets arose (as argued in Bertaut and Starr-McCluer, 2001).

Initially, the relationship between the CCI measure of uncertainty and the income velocity of the US M2 money stock across the two periods is assessed. A positive relationship between the two exists in the first period (a contemporaneous correlation of 0.36) and a negative one (a correlation of -0.81) in the second period. The explanation put forward for these changes is that in the earlier period a rise in uncertainty (i.e. a deterioration in consumer sentiment) would have reduced the need for money as a transaction medium, be it to buy goods and services or to engage in financial transactions. In the later period, an increase in uncertainty would have seen investors taking the new option available to them, owing to the democratisation of financial markets, of substituting out of equities and into broad money aggregates (and vice versa) depending on the level of uncertainty in the economy. A greater demand to hold liquidity by the public when economic conditions deteriorated would be accommodated by the central bank to avoid interest rates rising at a low point of the economic cycle.

Having assessed the relationship between uncertainty and money, the next step taken in the *WE* article is to see if the observed interaction between M2 velocity and the S&P 500 index is consistent with the view that Friedman's fourth factor had become the dominant influence on the money-stocks relationship. Plots of the movement of both over time reveal that in the earlier 1967Q2-1984Q4 period, a large negative contemporaneous correlation (of -0.70) arises between the two variables. In the later, 1993Q1-2010Q2 period, a low, positive correlation value of 0.16 occurs. When the pre-2000 quarterly observations are trimmed from this later sample (i.e. the sample becomes 2000Q1-2010Q2), the correlation between the two rises to 0.85. The stark change in the relationship between the velocity of money and uncertainty between the earlier and later periods was accompanied then by a distinct change in the relationship between that money variable and the stock market index. A further examination of the data reveals that when 70-quarter rolling window estimations are undertaken over the entire 1967-2010 sample period, an increasing correlation between changes in the S&P 500 index and changes in M2 velocity arises, from a value of -0.26 in the first window (1967Q3-1984Q4) to a value of 0.41 in the last (1993Q1-2010Q2).

The empirical analysis is completed by vector autoregressive (VAR) econometric estimations, involving the quarter-to-quarter changes in M2 velocity and the quarter-to-quarter changes in the (real) S&P 500 index. Estimating separately for the 1967Q2-1984Q4 and 1993Q1-2010Q2 periods, the impulse response output from the VARs shows how each variable responds to a shock in the other. The results indicate that a positive shock to the money stock (stock price) has a negative, short-term impulse effect on the stock price (money stock) in the earlier period. In the later period, the opposite holds, with a positive impulse arising. In the earlier, 1967-1984 period, the effects of a positive S&P 500 shock can be interpreted as generating a demand for money and a lower velocity of money, be that for any of the first three factors put forward by Friedman, such as higher stock prices increasing the transaction demand for money. A positive M2 velocity shock leads to a contemporaneous fall in the stock index, as a lower transactions demand for money coincides with fewer stock trades and lower equity prices.

For the later, 1993-2010 period, a positive shock to velocity causes a relatively long-lasting rise in equity prices, while a positive change in the S&P 500 index initiates a positive response from M2 velocity. The results for this period are consistent with a dishoarding (hoarding) of money balances occurring alongside an increase (decrease) in the price of equities, while the second indicates rises (declines) in equity prices causing investors to dishoard (hoard) money balances. The econometric evidence then is supportive of Friedman's fourth factor now being dominant in the money-stocks relationship owing to money's store of value function having gained much greater importance in recent years.

The relationship between monetary variables and financial assets is also the focus of the third article in this particular stream of work: **"The Interaction Between Money and Asset Markets: A Spillover Index Approach"**, published in the *Journal of Macroeconomics* (*JMACRO*) in 2014.[19] It shares with the *WE* article the assessment that households readjusting their wealth between holdings of risky financial assets and nominal-certain money is an important factor at play in US financial markets in recent times. The focus is on the interaction between asset prices and two US money aggregates: M2 and the monetary base. The M2

[19] "The Interaction between Money and Asset Markets: A Spillover Index Approach." *Journal of Macroeconomics*, 39 (2014), pp. 185-202.

aggregate is the commonly-used broad money supply in US economics studies (and it is also the money stock used in the *FSR* and *WE* articles). The monetary base had particular relevance in 2008 and the years that followed when the Federal Reserve started to employ “balance-sheet policies” (Borio and Disyatat, 2010), alternatively termed quantitative easing, in response to the financial and economic crisis of that time.

It is noted at the outset of the *JMACRO* article, that consistent with Brainard and Tobin (1968), quantitative easing works through a “portfolio balance effect”, with changes in the relative supply of assets held by the private sector leading to changes in their relative yields. Thus, the relationship between the monetary base and financial asset prices during a period of quantitative easing is worthy of investigation. The literature review also recognises the link between bond markets and the monetary base as a standard feature of the monetary policy transmission mechanism. In relation to the broad money supply (as represented by M2), it acknowledges, following Friedman (1988), that there are two conflicting influences on the nature of its relationship with equities: a wealth effect (the first three factors mentioned in the *WE* article) and a substitution effect (his fourth factor). The *JMACRO* article also notes the findings of the *WE* article (2012) on the money-equities relationship. Following Friedman (1988), portfolio adjustment in other financial assets besides equities can occur as a result of monetary policy. Asset price volatility can also affect money aggregate behaviour, with Slovin and Sushka (1983) showing that greater interest rate variability increases money demand and Tatom (1984) positing that bi-directional causality between money growth and interest rate variability arises. The purpose of the *JMACRO* article then is to examine the interaction between financial asset prices (and the volatility of asset prices) and money aggregates over time to shed light on the relationships between them, including in ‘normal’ times (such as arose prior to 2008) and in ‘crisis’ periods (e.g. during 2008-9).

As well as employing two money aggregates, representative indices for three asset classes are used in the econometric analysis in the *JMACRO* article: stocks (represented, again, by the S&P 500 index), commodities (the DJ-UBS commodity index), and a currency index (the ICE US dollar index futures contract). A fourth asset class, government bonds, is represented by yield data (US Generic Government 10-year bonds). The data are weekly in frequency and cover a period from 2000 to 2012. In the article, the interactions between money aggregates and asset classes are analysed in two ways: between week-to-week changes in the real (inflation-adjusted) money aggregates and week-to-week changes in the real returns of the asset classes, and between the changes in the real (inflation-adjusted) money aggregates and intra-week volatility measures for the four asset classes. Following Garman and Klass (1980) and Alizadeh et al. (2002), asset price volatility series are calculated using a formula that utilises weekly opening, closing, high and low values for each asset class.

The empirical approach in the *JMACRO* article corresponds to that of Diebold and Yilmaz (2009, 2012). Those papers show how to produce spillover measures between variables based on forecast error variance decompositions produced from VAR models using, in this case, six (two money, four asset) variables. The decompositions show the proportion of the movement in a variable's development over time due to its own shocks (own-variable, or own-market, shocks) and due to shocks in the other variables (cross-variable, or cross-market, shocks) in the VAR. A spillover index, with a possible range of values between 0 and 100, is then calculated from these decompositions to provide a measure of interdependence, or interaction, among the variables. A higher index value implies that a larger proportion of the shocks in markets as a whole is accounted for by cross-market shocks. Spillover measures can be produced for all the variables taken as a group, between a money variable and the four asset variables, and on a bilateral basis between variables, including the two money variables.

The spillover between variables over time is assessed using rolling-sample estimation, thus ensuring that interaction can be studied in periods of 'crisis' and otherwise. In the *JMACRO* article, 52-week rolling windows are employed with the first window covering the weeks from 24 May 2000 to 16 May 2001, and the final window observations from 7 December 2011 to 28 November 2012. The resultant spillover values are then plotted. Sharp upward spikes in index values at particular junctures in the 2000-2012 period are the main feature of the charts. In the case where the four asset returns and changes in the two monetary aggregates are the variables in the VAR (dubbed the returns spillover index in the article), spikes arise at the time of the September 11 terrorist attacks in 2001, the Lehman Brothers collapse in September 2008, and the downgrade of US sovereign debt in August 2011. In the second case (termed the volatility spillover index in the article), where the four asset volatility measures and two monetary aggregate variables are those in the VAR, the same three dates exhibit spikes in the spillover index, while a fourth spike coincided with a "flash crash" in the US government bond market, which occurred on 6 May 2010.[20]

The components of the two total spillover indices are the main focus of the article, in particular those showing the interaction between the monetary aggregates and asset returns, and between the monetary aggregates and asset volatilities. There are two salient features of the observed interactions between the money stocks and asset classes. The first is that the spillover of shocks between money and financial assets, in both returns and volatility index cases, tends to be much stronger during periods of financial market turbulence than in calmer times. This is explained by the same substitution effect emphasised in the *WE* article, i.e. the nominal-certain property of money balances matters to investors at times of financial and economic stress and causes greater interaction between money and the four asset classes at such times. The second feature is that the interaction between M2 and the financial assets tends to be greater than between the monetary base and those assets. The particularly high level of interaction between M2 and stocks is noticeable. The effects of quantitative easing (which affects the monetary base directly) then seems to be less important than the portfolio adjustment that occurs between broad money and financial assets.

Finally, the bilateral spillover between the two money aggregates is also considered in the article. There is strong bilateral spillover between them during

[20] A flash crash refers to a situation where there is a sudden, rapid decline in an asset price within a trading day, often with no obvious reason as to why it occurred.

the twelve months after the September 2001 terrorist attacks when monetary accommodation by the Federal Reserve at that time may have met an increased demand for broad money (and, thus, caused the greater interaction between the two money stocks). There is also a large net spillover from M2 to the monetary base in the nine months after the collapse of Lehman Brothers. Shocks to M2 having large effects on the financial assets arise in the VAR output at that time as well. The large spillover to the monetary base from M2 may reflect the Federal Reserve having had to increase the monetary base, at least in part, to facilitate portfolio adjustment from financial assets to M2.

The final article in this tranche, **"Money Growth, Uncertainty and Macroeconomic Activity: A Multivariate GARCH Analysis"**, published in *Empirica* in 2011, shares with the previously-discussed three articles a focus on the impact of uncertainty on the money supply.[21] It opens by noting that understanding the effects of uncertainty on money growth had become a concern of central banks, in particular the ECB and other euro area central banks, in the mid-2000s.[22] The *Empirica* article contributes to the literature on this topic by using a multivariate GARCH (generalised autoregressive conditional heteroskedasticity) model, which measures uncertainty by the conditional variance of the data series, to investigate whether macroeconomic uncertainty and monetary uncertainty Granger-cause changes in real money.

As Greiber and Lemke (2005) note, terms such as "macroeconomic uncertainty" are difficult to conceptualise. They use that specific term to refer to "a fairly broad concept capturing the bundle of forces that have led to a shift in the preference in liquidity" (Greiber and Lemke, 2005, p. 2). They cite stock market losses, "high experienced volatility", and geopolitical events as influencing

[21] "Money Growth, Uncertainty and Macroeconomic Activity - A Multivariate GARCH Analysis." With R. Kelly and B. Kennedy, *Empirica*, May 2011, 38, 2, pp. 155-167.

[22] As articulated and examined in, for example, European Central Bank (2005) and Greiber and Lemke (2005).

uncertainty. The terms used in the *Empirica* model are more specific: macroeconomic uncertainty and monetary uncertainty are capturing, in turn, the stochastic processes of output growth and money growth. The conditional second moments of both growth rate processes provide measures of uncertainty in the real economy and in money supply, respectively.

In estimating conditional volatilities, the article addresses the critique of Serletis and Shahmoradi (2006) that studies such as Hall and Noble (1987) and Thornton (1995), in using moving sample standard deviations of variables as measures of uncertainty, are using ad-hoc measures of variability, rather than of uncertainty. In contrast, if specific features appear in time-series data, namely the presence of ARCH effects in the series, a GARCH model will produce consistent measures of uncertainty if the conditional variances are correctly parameterised.

Among the propositions considered in the article is that macroeconomic uncertainty should have a positive influence on money growth. This could be expected, inter alia, on the basis of the content of the three articles discussed earlier in this section and other contributions to the literature. Two monetarist propositions are also tested. First, Belongia (1984), referencing earlier monetarist perspectives, posits that a pickup in monetary volatility generates, or adds to, macroeconomic uncertainty within the economy, increasing the precautionary demand for real money balances. Secondly, monetary uncertainty has a negative effect on output growth within the economy.

The first-differences (changes) in the natural logs of two monthly US data series are employed: the real (i.e. CPI-adjusted) M2 stock and the Composite Index of Lagging Indicators. The Index is a broadly-based indicator of macroeconomic activity in the US economy (in contrast to more narrowly-defined indicators such as industrial production). The dataset covers the period from 1959M1 to 2007M4. A two-step modelling approach is undertaken. In the first step, the conditional variances of both the M2 and Index variables are estimated. Unit root tests indicate both first-difference variables to be stationary series, while descriptive statistics show those first-differences to have excess kurtosis and nonnormal distributions. The residual diagnostic tests of VAR regressions of the first-difference series indicate non-normality to be present in the regression residuals, which is prima facie evidence that ARCH arises. A bivariate BEKK GARCH model is then applied to the regression residuals, generating measures of macroeconomic uncertainty (from the Lagging Indicators residuals) and monetary uncertainty (from the real money residuals). The uncertainty measures show a sustained rise in monetary uncertainty and episodes of heightened economic uncertainty in the United States in the 2000s, backing up central banks and other commentators' interest in their effects.

The second step in the modelling approach involves undertaking Granger causality tests among the four variables to hand: the first-differenced real money and Lagging Indicator series and the two measures of uncertainty. Tests of significance indicate whether causality runs in a particular direction (espoused, for example, by a particular hypothesis), in the opposite direction, in a bidirectional manner, or in no direction (i.e. causality is absent). The tests indicate whether causality from one variable to another (if it arises) is positive or negative in nature.

The initial finding reported in the article is that macroeconomic uncertainty has a positive influence on real US M2 money growth. This contrasts with Choi and Oh (2003) who find macroeconomic uncertainty to have a negative effect on the narrower US monetary aggregate, real M1. Those authors' theoretical model helps reconcile the differing results. They show that the influence of uncertainty on money holdings is ambiguous a priori and can only be determined empirically. In relation to the monetarist propositions, the relevant Granger-causality tests on the hypothesised relationships offer mixed support. The test indicate no significant causality occurring from monetary uncertainty to real money, rather a positive causal impact from real money growth to monetary uncertainty arises. An explanation for this may be provided in Choi and Oh's model where monetary uncertainty evolves from a stochastic process in money supply growth. The causality tests indicate monetary uncertainty having a significant, negative influence on macroeconomic uncertainty, in contrast to that argued by Friedman

(1984). A significant, negative causal effect from monetary uncertainty to economic growth is reported, consistent with the monetarist view.

5. Money, Commodity Prices and Inflation Tranche

Where the articles discussed in the previous section focussed primarily on the interaction between money and asset prices, the four considered in this section address the traditional monetary economics topic of looking at how money and inflation relate to one another. Three articles examine the relationship between consumer prices, commodity prices and the money stock. The article ***"Commodity Prices, Money and Inflation"***, published in *Journal of Economics and Business* in 2010, is the most important of these, with the other two articles following on from it.[23] It provides both a formal "overshooting" model of the relationship between the three variables and an econometric investigation of the propositions arising from the theory articulated in the model. The articles, ***"A Monetary Perspective on the Relationship between Commodity and Consumer Prices"***, published in the Central Bank of Ireland's *Quarterly Bulletin* in 2008, and ***"Monetary Policy, Inflation and Commodity Prices"***, published in Perrucci, S., and Benaben, B., *Inflation Sensitive Assets: Instruments and Strategies* (London: Riskbooks) in 2012, provide an additional application of the overshooting model to components of the CPI, and discuss price and money developments in the 2000s and early 2010s using the model's main tenets, respectively.[24] [25] The fourth article of this second tranche, ***"US Inflation and***

[23] "Commodity Prices, Money and Inflation." With F. Browne, *Journal of Economics and Business*, 2010, 62, pp. 331-345.

[24] "A Monetary Perspective on the Relationship between Commodity and Consumer Prices." With F. Browne, Central Bank and Financial Services Authority of Ireland *Quarterly Bulletin*, No. 1 2008, pp. 77-90. Also published as "Una Perspectiva Monetaria de la Relación Entre los Precios de Productos Básicos y los Precios al Consumidor." With F. Browne, *Monetaria,* XXXII, 2, pp. 271-296, Centre for Latin American Monetary Studies, Abril-Junio 2009.

"Monetary Policy, Inflation and Commodity Prices." With F. Browne, in Perrucci S. and Benaben B. (ed.s), *Inflation Sensitive Assets: Instruments and Strategies*, London: Riskbooks, 2012, pp. 255-276.

[25] The article published in the *Journal of Economics and Business* was initially made available as a Central Bank of Ireland working paper in 2006 and as an ECB working paper in 2007. The *Quarterly Bulletin* article and Perrucci-Benaben chapter were written subsequently.

Output since the 1970s: A P-Star Approach”, published in *Empirical Economics*, examines the P-star model of inflation, which follows from the quantity theory of money, and does so by the application of the VAR-based spillover index of Diebold and Yilmaz (2009, 2012) to US data.[26] As with the overshooting model, its focus is on the money-inflation relationship.

The *JEB* article was motivated, in part, by three *Financial Times* articles that asked whether sharp commodity price increases at that time were owing to a loose monetary stance in major industrialised economies.[27] The views of Jeffrey Frankel (one of the financial press contributors) were particularly interesting to Frank Browne and me. He had provided an overshooting theory of commodity prices (Frankel 1984 and, subsequently, Frankel 2008). It argued that because commodities are exchanged in financial markets, they will respond quickly to changes in monetary conditions. Although consumer prices will also adjust to monetary stimuli, they do so more slowly. Consequently, commodity prices will adjust more than proportionately (i.e. overshoot) in the short run to compensate for consumer goods’ price stickiness.

Frankel’s theory had a Keynesian basis (it drew on the Dornbusch (1976) theory of exchange rate overshooting), with the dynamic responses of commodity prices following from changes in real interest rates in the presence of sticky consumer prices. His theory led us to ask how commodity prices, consumer prices and the money stock would interact in a monetarist setting. In particular, how would the price variables respond in the short to medium term to an exogenous change in the money supply where long run proportional relationships between each and the money supply are proposed and a varying degree of price stickiness between

[26] “US Inflation and Output since the 1970s: A P-Star Approach.” *Empirical Economics*, 54, 2 (March 2018), pp.567-591. This article was accepted for publication on 19 October 2016 and was published on-line on 10 February 2017.

[27] The specific articles were published in *The Financial Times*: “More to oil shocks than the Middle East” (Clover and Fifield, 29 July 2004); “Too much money to blame for rising price of oil, economists claim” (Fifield, 18 August 2004); and “How real interest rates cast a shadow over oil” (Frankel, 15 April 2005).

consumer goods and commodities arise. Le Chatelier's principle in the field of chemistry, which says that if any change is imposed on a system that is in equilibrium then the system will adjust to a new equilibrium counteracting the change, was a concept that we also bore in mind in writing the *JEB* article. The principle could be applied to price theory as follows: if not all goods prices in the economy are free to adjust readily to a change in economic conditions then other goods prices must initially overshoot their new equilibrium values to compensate, a dynamic feature that holds until all prices are able to adjust to their new equilibrium values.

These influences and ideas led us to put forward a formal two-good, two-period model of the money-commodity price-consumer price relationships and to investigate it empirically. Two monetarist propositions are noted at the outset of the article to give it a theoretical basis. The first is that an exogenous change in the money stock leads to an equivalent percentage change in the overall price level under conditions of stable money demand. The second proposition is that such changes are neutral in the long run steady state implying that all individual prices, whether they be consumer goods or commodities, adjust in the same proportion as the money stock, thus leaving all relative prices unchanged in the new steady state relative to their pre-money stock change configuration. The overall price level is defined as comprising a weighted average of a consumer (final goods) price index and a commodity price index. The prices of the two goods are assumed to have varying speeds of adjustment to changes in the money stock, with the consumer good adjusting more slowly.

The propositions that frame the model imply that, say, a doubling of the money stock causes the overall price level to increase two-fold immediately, and that in the long run its two components will also rise by that same amount. The differing speeds of adjustment of commodity and consumer prices, however, affect the trajectory of how they move to their new long run values. In particular, the stickiness of consumer prices means those prices adjust slowly upwards over time to their new, higher equilibrium value. To ensure the overall price level immediately rises *pari passu* with the larger money stock, commodity prices must then compensate for consumer price sluggishness by rising more than proportionately to the change in the money stock. Commodity prices must overshoot their new equilibrium value in the short run before reverting back in the long run.

The algebraic model provided in the *JEB* article formalises this theory of commodity price overshooting. It also provides a number of hypotheses for empirical investigation. They are that (i) commodity prices and consumer prices move in proportion to the money stock in the long run; (ii) commodity prices will initially overshoot a new equilibrium value following a shock to the money supply to compensate for the sluggish response of consumer prices to the same shock; (iii) the mean-correction of commodity prices to their new equilibrium explains subsequent consumer price inflation.

The first hypothesis indicated the need to apply a cointegration procedure to test for and estimate long run relationships within the data. When there are more than two unit root variables in the time series dataset, the Johansen cointegration procedure is efficient in comparison to the Engle-Granger approach to cointegration. Besides providing more efficient estimation, Johansen also offers better graphical output than Engle-Granger. In particular, its innovation accounting output allows one ascertain whether commodity price overshooting (as indicated under hypothesis (ii)) arises or not.

These hypotheses are then tested in the *JEB* article through the application of the Johansen cointegration procedure to US data for the period 1959Q1 to 2008Q4. The data comprise a commodity price index, the consumer price index (CPI), the M2 money stock and an output variable, real GDP. Three commodity price indices (the Commodity Research Bureau Spot Index, the Commodity Research Bureau Raw Industrials Index, the Sensitive Materials Index) are used as alternatives to one another in the estimations.

Each VAR estimation comprises four integrated-of-order-one variables: a commodity price index, the CPI, M2 and GDP. The various steps of the Johansen procedure show that the long-run proportional relationships hypothesised between the money stock and consumer prices and between the money stock and commodity prices are upheld; and that the deviation of the commodity price index from its equilibrium value and the deviation of the CPI from its equilibrium value have explanatory power, with the correct coefficient signs, for subsequent CPI inflation. The impulse responses of the three endogenous variables to a positive M2 shock are supportive of the hypothesis that consumer prices adjust slowly toward their new-money-determined equilibrium to that shock, while commodity prices overshoot their new equilibrium value in the short-to-medium term.

Following the *JEB* article, I was anxious to see whether the overshooting model would prove robust in an application to a dataset where the price adjustment characteristics of the variables would seem, at least *a priori*, to be less extreme than what arises between commodities and consumer goods. In the *Quarterly Bulletin* (*QB*) article, written in the months after the *JEB* article, the commodity price index and the CPI are replaced in the cointegrating VAR estimations by two components of the US CPI. The motivation is that just as commodity prices are more sensitive than the overall CPI to monetary stimuli, it should also be the case that some components of the CPI will react more quickly than others to money supply shocks. The article refers to evidence (Alvarez et al., 2006, and Bils and Klenow, 2004) that the price of some goods included in the CPI (in particular, energy and food products) are more flexible than those of other goods in it.

The Johansen procedure is then applied to a new US dataset in the *QB* article, comprising, as previously, the M2 money stock and real GDP and, in place of the CPI and commodity index, the CPI-less-food-and-energy index and the CPI food index. The econometric output finds two long-run proportional relationships arising, between CPI-less-food-and-energy index and M2 and between the CPI food index money stock and M2. The impulse response analysis shows both price indices converging over time to their new equilibrium values following a money supply shock. While no overshooting arises, the CPI food index responds more quickly, and with sharper movements (i.e. greater volatility), than the CPI-less-food-and-energy index to changes in the money stock. The policy implications of these results are that the CPI food component is monetary-determined and not a nuisance to be easily discarded in inflation analysis. With the food component reacting more quickly to a money shock, it might also prove to be a leading indicator of core inflation developments

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The central hypothesis of the overshooting model that goods prices are monetary-determined but vary in speed in their response to monetary stimuli had been shown to hold for both a CPI-commodity index pairing and for two components of the CPI in the *JEB* and *QB* articles. These findings proved of interest to the commissioning editors of a book on inflation-sensitive assets (assets whose values are particularly sensitive to the inflation environment, among them commodities). The resultant contribution to the *Perrucci-Benaben volume* uses the overshooting model to analyse US price and money developments between 2000Q1 and 2011Q1. The chapter shows how prior to 2008Q3 (when a period of financial crisis took effect), the US M2 money stock had grown by 68 per cent since 2000Q1 and the CPI by 28 per cent. With such a large growth differential between those two variables, it is unsurprising from the perspective of the overshooting theory that the Commodity Research Bureau Spot Index exhibited a sharper rise, of 115 per cent, over the same period, and greater volatility than the CPI.

Other instances of overshooting during the 2000-2011 period are also observed in the data. One example is the sizeable, positive differential between the M2 growth rate and CPI inflation between 2001 and 2003. The commodity index then starts to rise sharply in 2003 with strong rates of growth in it maintained into 2005. The overshooting theory explains this behaviour by noting that some delay in the effects of a monetary stimulus (such as occurred after the terrorist attacks of September 2001) to commodity prices will occur. Its peak effect on commodity price inflation is shown in the *JEB* article to occur with about a six-quarter lag to the money supply shock. Thus, the 18-to-24 month delay in the response of commodity prices to the monetary stimulus of 2001 should not be unexpected. A second example identified in the chapter is the strong rebound in commodity prices in 2010 and early-2011 following the loose monetary stance of the post-2008Q3 period.

As with the last three articles discussed, the fourth article in this second tranche, **"US Inflation and Output since the 1970s: A P-Star Approach"**, published in *Empirical Economics* (*EE*), addresses the relationship between money and inflation. It examines the P-star model of inflation, introduced by Hallman et al. (1991), with the Diebold-Yilmaz econometric approach that I had previously employed in the *JMACRO* article.

Hallman et al (1991) derive a model of inflation from the quantity theory of money equation. Their argument is that there is an equilibrium price level (P^*, i.e. "P-star") consistent with the current money stock, M, and the equilibrium values of the velocity of money (V^*) and output (Q^*), as follows:

$$P^* = \frac{MV^*}{Q^*}$$

The money stock, M, also satisfies the determination of the current price level, P, and velocity of money (V) and output (Q):

$$P = \frac{MV}{Q}$$

Using natural logs, it follows from these two equations that:

$$p - p^* = (v - v^*) + (q^* - q)$$

Under the P-star theory, the two variables on the right-hand-side of this equation, the velocity gap and the output gap, respectively, will cause the gap between the current price level and the equilibrium level to be closed over time, either through inflation or deflation. Inflationary pressure will arise when $v < v^*$ and/or $q >$

q^*, and deflationary pressure when the gaps have the opposite sign. Inflation then can be modelled as a function of the two gap variables.[28] [29]

The *EE* article then estimates VARs on a rolling window basis with each VAR including the inflation rate, the two gap variables and a fourth variable, oil price inflation. This final variable is included as a measure of cost-push/non-monetary pressures. From VAR estimations, forecast error variance decompositions indicate the extent to which inflation shocks are accounted for by past innovations, or shocks, to the other variables (cross-variance shares) in the VAR and by shocks to inflation itself (the own-variance share). The influence of the two P-star gaps variables on inflation over time, including relative to one another and relative to the cost-push variable, are then quantified.

The VAR estimations use quarterly US data from 1960Q3 to 2016Q2, with the percentage difference between real GDP and potential GDP providing the output gap and changes in the West Texas Crude spot price the oil inflation variable. Following Hallman et al. (1991), percentage changes in the GDP implicit deflator (GDPD) give the measure of inflation. Two measures of money velocity are used: one based on the M2 money aggregate and the other on the MZM money aggregate.[30] Percentage deviations of the current-period aggregates from an estimated equilibrium value for each provide velocity gap measures. Those velocity gaps are used as alternatives to one another in the four-variable VAR estimations, which also include the output gap, the inflation rate and the oil inflation rate. M2 has been the usual choice of money stock variable in US monetary studies, but its previously stable relationship with nominal output broke down during the 1980s and 1990s (Friedman and Kuttner 1992; Estrella and

[28] The P-star model was applied initially to US data by Hallman et al. and others such as Tatom (1990). Variants of the P-star model were also developed by Trecroci and Vega (2002) and Gerlach and Svensson (2003), with the latter, for example, using a real money gap (that is the gap between the current real money stock and the long-run equilibrium money stock) and an output gap in a model of euro area inflation.

[29] According to Humphrey (1989), there are many precursors to Hallman et al.'s formal model, stretching back as far as the writings of David Hume.

[30] The MZM (Money Zero Maturity) money stock is defined as the M2 stock less small-denomination time deposits plus institutional money funds.

Mishkin 1997). Carlson et al. (2000) provide evidence that the MZM money demand function remained stable throughout this period. Both velocity gaps are used as substitutes for one another in the VAR. The rolling-window size chosen is 60 quarters, with the first window ending in 1975Q3 and the final window ending in 2016Q2.

The decomposition output from the VAR estimations is considered in three parts in the *EE* article. The first focusses on spillovers to GDPD inflation. The results are supportive of a P-star/monetary explanation of inflation. The overall finding is that shocks to the two gap variables explain a substantial share of US GDP deflator inflation shocks over time, particularly in the late 1980s-early 1990s and after the financial crisis of 2008. Monetary factors (i.e. the two gap variables), and not oil shocks, underlie price developments in the 1970s and early 1980s. Even during the 1970s, the monetary variables' share of the inflation decomposition is higher than that of the oil price. After the 1970s, oil price shocks take a low share of the decomposition of inflation. This feature of the results supports the views of Barsky and Kilian (2000, 2002) which attribute high and variable inflation and low or negative output growth during that period to monetary expansions and contractions, rather than the popular view that exogenous oil shocks were dominant at that time.

The strength of the impulse from the two gap variables to inflation after 2008 is attributed to the effects of the three programmes of quantitative easing undertaken by the Federal Reserve after the crisis of that year. The goal of quantitative easing was to stimulate the economy through an increased money supply. The econometric evidence in the article is that shocks to M2 velocity have a strong influence on inflation developments during the post-crisis period. The M2 gap's share of inflation is also much lower than that of the MZM gap during the early 1990s, providing support to the view of Carlson et al. (2000) that the MZM aggregate is more informative in explaining the relationship of money to nominal economic activity at that time.

The resurgent view of recent years (and espoused in the *JEB*, *Perrucci-Benaben*, and *QB* articles) that commodities are subject to monetary influences motivates the second portion of the econometric assessment in the *EE* article, that examining the spillover of shocks to oil price inflation. The contention of Barsky and Kilian (2000, 2002) that oil price increases in the 1970s were, at least in significant part, the result of a high rate of monetary growth is explored through the forecast error variance decompositions. The estimations indicate a strong monetary impulse to oil prices in the 1970s, mainly from velocity shocks, before it declines slowly thereafter. Monetary shocks' influence on oil prices has become noticeably stronger since the mid-2000s, supporting the greater attention being paid of late to the impact of the monetary environment on commodity markets.

The third set of results considered in the *EE* article examines the spillover of shocks to the output gap over time. The results indicate money mattering to output developments, with a strong influence of the velocity gap variable being particularly noticeable after the 2008 financial crisis. The money aggregate used in estimating the velocity gap is again important in establishing and quantifying the relationship with economic activity at particular times. As with the inflation decomposition, the influence of the MZM gap on output developments is particularly strong in the late-1980s and early-1990s. GDPD inflation shocks and, to a lesser extent, oil inflation shocks dominate the cross-variance share of output gap shocks in the 1970s and early-1980s. After the Volcker disinflation (of 1980-1982), the influence of both inflation and oil price shocks on the output gap wane and those of velocity gap shocks increase.

The application of the Diebold-Yilmaz spillover index methodology to US macroeconomic data in the *EE* article then provides a number of distinct findings. Most importantly, shocks to monetary variables have explanatory power over inflation developments. This is particularly strong during the 1970s and early 1980s but also in recent years. The P-star model, therefore, continues to have empirical relevance. Money shocks, and not oil shocks, underlie price developments in the period before the Volcker disinflation. Monetary shocks' influence on oil prices has become noticeably stronger over the past ten years or so, supporting the greater attention being paid of late to the impact of the monetary environment on commodity markets.

6. Conclusion

The primary purpose of the research recorded in this dissertation was to consider money's relationship to economic activity (in particular, the inflation rate of goods and services) and to financial markets. Its starting premise was that changes in the money stock affect goods and asset markets and the research predominantly used time series-based econometric methods, informed by economic theory and using US data, to investigate money's links to both. In this concluding section, I argue that this research succeeded in shedding fresh light on the relationship between money and goods and asset markets. How it has been referenced and ties into the economics literature is reviewed. In the second part of the section, I consider how the research and the processes involved in undertaking it, writing it up and getting it published has affected my development as an economist.

6.1 How the research fits into the literature

It can be hard for a researcher to gauge and assess where their output fits into the literature in the area they are working in. That stems, in part, from a reluctance to overegg one's contribution and from the breadth of the literature, even within what one might see as a small corner of, say, the macroeconomics literature. A practical issue is that while an article can be read against the scholarly contributions that precede it, there is usually some delay from its publication date to it being referenced in other articles. This makes it difficult to see how it fits into and is being used in the output of other researchers. In this dissertation, this arises for the *JMACRO* and *EE* articles, which were published in 2014 and 2018, respectively (available on-line from October 2013 and February 2017, respectively).

With these caveats, I consider first the tranche of articles dealing with the money-inflation-output relationship. The research involved succeeded in addressing the empirical difficulty of establishing a monetarist relationship between money and economic activity in two ways, one through the *JEB* overshooting model and follow-on applications, and the other by an innovative application of the P-star model in the *EE* article.

The *JEB* article provided a formal "overshooting" model of the relationship between money, consumer goods prices and commodity prices. The model informed the empirical analysis, in particular the choice of the Johansen cointegration procedure as the basis for investigating whether the purported relationships in the theoretical model are supported by the data. The econometric application was in the affirmative in its support for the model. The first step in the procedure established that commodity and consumer prices are each cointegrated with the money stock and output. The coefficient on the money variable in both cointegrating vectors was found to be statistically insignificantly different from one, so that long run proportionality between money and prices, a tenet of the Quantity Theory, cannot be rejected. The deviations of commodity prices and consumer prices from their fundamental/monetary-determined values were shown to have predictive power for future consumer price inflation, with coefficient signs predicted by the overshooting model and its underlying monetarist theory. The coefficient of the deviation of the actual consumer price index from its monetary-determined (i.e. fitted) value has a statistically significant negative value – the theoretically-correct coefficient value - in the short-run dynamic equation. This is also the coefficient sign posited by Hallman et al.'s (1991) P-star model in its demonstration of the relationship between the consumer price index and its monetary-determined value (i.e., P-star).

A feature of the results is that a stable inverse money demand function is provided in the *JEB* article.[31] It has proved difficult since the early 1990s to establish

[31] The inverse money demand function being referred to here is one where the final goods price level (in this case, the CPI) is on the left-hand-side of the equation and the money stock is on the

well-defined US money demand functions based on the standard specification of the real money stock being dependent on real GDP (or another output variable) and the opportunity cost of the money stock.[32] The *JEB* article differentiates itself in two ways in addressing this issue. First, the inverse money demand equation (the long run equation with the CPI on the left-hand side of the equation) is estimated as one of a pair of equations (within a cointegrating vector approach), where the other equation is a modelling of the determination of the commodity price indices used in the article. Secondly, there is no opportunity cost variable in the equation, because within the overshooting model the overall price level (comprising a weighted average of consumer prices and commodity prices) is unchanging. Thus, there is no need for the interest rate to change to equilibrate money demand to money supply and so it is excluded from both the consumer price index and commodity price index equations. These features suggest that a richer econometric approach to money demand estimation may occur within a system of equations rather than undertaking embellishments of the standard single-equation money demand equation.

Other researchers have used the *JEB* article as a basis and reference point for their published work. Where the *JEB* article tests the overshooting theory using US data, Belke et al. (2010, 2014) apply the theory and the cointegration methodology in it to aggregated OECD data. They find similar relationships to that in the *JEB* article and attribute price developments to the measure of global liquidity provided by the aggregated data. Their contribution then provides a corroboration of the application of the overshooting model with a second dataset. With data comprising time series for the US, euro area, India, China, and Japan (what they term the G5), Ratti and Vespignani (2016) also provide results consistent with the *JEB* article, including cointegration between the money stock,

right-hand side. In contrast, a standard money demand has the real money stock on the left-hand-side (usually calculated as the natural log of the money stock less the natural log of the CPI).

[32] Duca and VanHoose (2004) provide a survey of the issues involved.

output and CPI and changes in the money stock causing changes in the CPI and commodity prices.

Beckmann et al. (2014) cite the *JEB* article in explaining how rapid commodity price adjustments may be attributed to relative consumer price stickiness in response to changes in monetary policy. They also use a VAR-based methodology (a Markov-switching error-correction variant) and find a significant long-run relationship between global liquidity and commodity prices, as well as commodity prices reacting more quickly to global liquidity shocks than consumer goods prices. Belke et al. (2010b) refer to the stickiness of consumer prices in explaining rapid asset price responsiveness to monetary stimuli. They argue that monetary aggregates may then have a role as leading indicators of both consumer price and asset price developments. The *JEB* article has also been referred to in papers that look specifically at commodity price movements as leading indicators of CPI developments (see, for example, Jalil and Zea (2011) and Verhayen (2010)). The overshooting model has also been highlighted in the financial press (e.g. Reuters, Breaking Views) and in fora discussing the conduct of monetary policy, such as the Shadow Open Market Committee (author: Michael Bordo).[33]

The second substantive contribution in this dissertation to research on the money-inflation relationship is contained in the *EE* article. Since it has only been available on-line since early 2017, it is difficult to assess what influence this contribution might have in the years ahead.[34] The Hallman et al. (1991) P-star article has been heavily cited since its initial publication but much less so in recent years. Moreover, references to it since 2014 in *Journal of Economic Literature*-listed journals have tended to be in the context of examining issues such as the appropriate money stock to use for inflation analysis (Anderson et al. (2017)) and

[33] http://uk.reuters.com/article/oilRpt/idUKL2229499520070323;
http://www.livemint.com/Money/dV2LSgl4rk6oNCPTLbHk3L/Oil-price-drop-too-little-and-too-late.html;
http://shadowfed.org/wp-content/uploads/2011/03/Bordo_SOMC-Mar2011.pdf

[34] The *EE* article has been downloaded 309 times (as at 19 March 2018) from the Springer website since it became available online on 10 February 2017 (https://rd.springer.com/article/10.1007/s00181-017-1229-2), which is quite a large number in comparison to other *EE* articles made available online around that time.

employing the P-star model as a starting point for an identification of monetary shocks in explaining inflation (see the state-space models of El-Shagi and Giesen (2013) and El-Shagi et al. (2015)). The *EE* article is much closer to the original Hallman et al. approach as it uses the two gap variables identified in their model and shows how they can explain price developments over time. Their explanatory power is particularly strong at times when inflation rates were high and also in recent years when quantitative easing was being undertaken by central banks. The econometric output also sheds light on the debate as to whether oil price or monetary developments were the primary determinant of the stagflation of late 1970s and early 1980s. The evidence is supportive of the views of Barsky and Kilian (2000, 2002) that monetary factors were the dominant influence on the macroeconomy at that time.

An attraction to policymakers of the *EE* econometric approach, particularly in its rolling-window estimation format, is that it can be used to examine inflation, velocity gap and output gap behaviour and their interaction with one another on an ongoing basis. A regular updating of the rolling windows estimation, with windows being added as new data observations become available, could give policymakers or analysts an insight into whether inflation developments were coming more, or less, from the money channel (velocity gap) than the real economy channel (output gap), and whether own (price) shocks' influence has increased or decreased.[35] Another research option, in the spirit of Orphanides (2001), would be to use the *EE* econometric approach to compare historical real-time measures of the velocity gap's and output gap's explanatory power over observed inflation with that of ex-post gap data.[36] Such an exercise could highlight any informational difficulties faced by central banks in monetary policymaking and how those could be addressed in their decision-making.

[35] F.X. Diebold and K. Yilmaz, co-authors of the eponymous spillover index methodology, maintain a website (http://financialconnectedness.org/) that regularly updates (in some cases, on a daily basis) measures of financial interconnectedness as new observations become available. Indices are provided for global stock, sovereign bond, CDS, and foreign exchange markets.

[36] Using the Taylor rule and US data, Orphanides (2001) shows how monetary policy recommendations based on real-time data differ substantially from those drawn from ex-post data.

In summary, both the overshooting and *EE* articles show that an innovative econometric approach to the modelling of standard monetarist relationships can succeed in establishing a causal link from money to inflation. This can breathe fresh life into longstanding gap variables (such as the output gap and the velocity gap) and provide new ones (such as the pairing of CPI and commodity price index gaps) as indicators of inflationary/deflationary pressures within the economy. The articles then find that what is old (the quantity theory and monetarism) can be new again when explored in innovative, but rigorous, ways.

Of the four articles in the tranche of the dissertation considering the money-financial markets relationship, the *JMACRO* article represents an endpoint to the themes and research set out and developed in the *FSR*, *WE*, and *Empirica* articles, each of which were published prior to it. The *JMACRO* article focuses on the period 2000 to 2012. That timeframe provides data for assessing spillovers between asset markets and money, and between money stocks, in periods of both economic and financial calm and turbulence in the expectation that the greater volatility associated with the latter kind of period will see more interaction arising. It was also a period when there was strong money growth between 2000 and 2005, as documented in the *FSR* article, and after the financial crisis that took hold in 2008.

Beyond considering the effects a volatile economic environment has on it, the relationship between money and asset markets has come into focus in recent years owing to quantitative easing and this is given particular attention in the *JMACRO* article. Over the past ten years, there has been a reliance by central banks on what Borio and Disyatat (2010) call “balance sheet policies”, whereby the central bank uses its balance sheet to affect asset market prices and conditions directly. The efficacy of these policies is posited to rely on the distinctions that arise between asset types, in particular their risk characteristics. This gives central banks – the sole issuer of the monetary base – leverage in those asset markets towards achieving their policy aims. This policy stance highlights the need for the money-asset markets relationship to be examined more closely. While the other articles in the money-asset markets tranche of this dissertation were completed before sufficient macroeconomic data relating to programmes of quantitative easing of the late-2000s/early-2010s were available, the *JMACRO* article pays particular attention to balance sheet policies' effects on asset markets. It does so in the line of enquiry put forward initially in the *FSR* article: that what is identified there as "monetary laxity" will have an impact on asset market developments.

In motivating the *JMACRO* article, reference is made at the outset to the *WE* hypothesis that households substitute their wealth holdings between nominal-certain money and equities in response to changes in the economic climate, and that this could extend to the relationship between money and other asset classes. It also refers to the *JEB* article in espousing the relationship that might arise between money and commodities, another one of the four asset classes considered. While the *Empirica* article is not referenced, its focus on how uncertainty affects money aggregates is reflected in the *JMACRO* contribution by considering how the monetary base and M2 money stock interact with one another, and with financial assets, over a timeframe that includes periods of recession and severe financial stress.

The main finding in the *JMACRO* article is that more sizeable spillovers between money and asset variables occur in periods of economic and financial turbulence than at other times. It argues that households re-adjusting their wealth holdings between money and other financial assets in response to the prevailing economic climate may have been the dominant force at play in generating this behaviour. This view is also put forward in explaining another feature of the econometric results: that the interaction of the monetary base with financial assets was less than that of the M2 money stock with them during the period when quantitative easing was being pursued by the Federal Reserve. The thinking and empirical illustrations of the *FSR* and *WE* articles then receive support from the more involved methodological approach of the *JMACRO* research.[37]

The *JMACRO* article has been cited in various studies since its publication in 2014 (according to Google Scholar, it has been cited 35 times (as of 19 March 2018)). These include references to its monetary policy focus, with Guidolin et al. (2017) referring to its use of a "modern, flexible dynamic time series model" in their study of the mechanisms linking monetary policy to US corporate bond values in both periods of conventional monetary expansion and quantitative easing. How the Diebold-Yilmaz approach is used in the *JMACRO* article is referenced in motivating papers on spillovers between Asian stock markets (Nishimura et al. (2017)), the dynamic interactions between credit and output growth (Antonakis et al. (2015)) and volatility connectedness in EMU sovereign bond markets (Fernandez-Roudriguez et al (2016)).

Nyborg and Ostberg (2014) provide evidence that developments in the demand for liquidity (base money) in the interbank money market have consequences for financial asset markets on a day-to-day basis, irrespective of whether financial stress, or "financial crisis", prevails or not. They conclude that "money matters in financial markets" (2014, p. 30). Taken together, the articles in the money-asset markets tranche of this dissertation could be said to reach a similar conclusion. They contribute to the understanding of the financial cycle by highlighting asset markets' relationship to money developments over time and in particular in response to changes in the economic cycle and to events such as the 11 September 2001 terrorist attacks.

In terms of policy, the articles point to the need for central banks to consider the money-asset market nexus in their deliberations, including with regard to their price stability mandates. Smets (2013, p.4) indicates that the medium-term aspect of the ECB's monetary policy strategy, which always had a money-focus,

[37] The *FSR* article was the focus of a newspaper article in the German financial newspaper, Borsen Zeitung, soon after it was published ("Uberschussige Liquidat blaht Asset-Preise auf", *Borsen Zeitung*, Ausgabe 223 vom 18.11.2005, Seite 7).

now takes "into account the medium-term implications of booming asset prices and credit markets for price stability." The import of the *Empirica* article, which considers money and uncertainty in isolation from financial market developments, for policymakers is similar, with its concluding section arguing that information gathering by central banks should include measures of monetary uncertainty and macroeconomic uncertainty in their holistic assessment of monetary data.

An aspect common to both tranches here (the *JMACRO* and *EE* articles in particular) is that different definitions of the money stock can have an impact on research findings. Following on that, one potential avenue of future research that is of interest to me relates to the components of the broad money stock and their connection to stock markets. The relationship between money market funds (MMFs), a component of the M2 money stock, and stock markets could be explored further. Two articles cited in the *WE* article (Dow and Elmendorf (1998) and Carlson and Schwartz (1999)) argue that this component of the US broad money stock acts as a "gateway" for households in rebalancing the portfolio of assets in liberalised financial markets, with shifts in stock market values seeing funds being channelled through MMFs. More recently, Kacperczyk and Schnabl (2013) find MMFs to have been risk-taking during the financial crisis of the late 2000s and being prone to runs as a result. Strahan and Tanyeri (2015) note that investors ran on MMFs after Lehman Brothers' collapse in 2008, forcing funds to sell their most liquid asset holdings, while Hanson et al. (2014) find MMFs having destabilising effects on financial markets during that crisis period. These recent contributions are alluding back to the late 1990s' "gateway" perspective (although neither refers to the earlier articles). Modelling MMFs' relationship to financial markets then would be of particular interest to me as a future research project. My preliminary investigation of weekly data shows a strong negative correlation between changes in the S&P500 index and changes in the size of the MMF component of M2. Further work on this would include estimating an econometric model of the relationship between the two variables (possibly drawing on a financial econometrics methodology suited to relatively high frequency data), and the consideration of how variables like the VIX index affect it.

6.2 Personal development as a researcher and economist

The research recorded in this dissertation constitutes a coherent subset of my published work since the mid-2000s. The eight articles are a subset of twenty that I had published as the sole author or co-author over the period 2005 to 2018 (of which thirteen were peer-reviewed). I have been doing less research in the area of monetary economics since 2013.[38] This reflects a change in my role in the Central Bank that requires me to conduct research and analytical work in the area of sovereign bond markets and the related area of fiscal policy and the public finances. The monetary research of previous years has stood me well in undertaking this strand of research, particularly its empirical aspects, as I would expect it will continue to do in any future lines of research.[39]

Looking back over the monetary research and how it was conducted, I believe it has enhanced my skills as an economist and deepened and widened my knowledge of monetary economics in three ways in particular:

- <u>Ability to identify a topic worthy of research, formulate a number of propositions for empirical investigation, and choose an appropriate empirical approach and dataset</u>: In my initial ten years working as a professional economist, econometric estimation and assessment played a relatively small role in my analytical work. This has changed significantly since I began undertaking the research captured in this dissertation. While the analysis involved acquiring econometric skills (discussed under the next bullet point), it also enhanced my ability to assess and keep abreast of the economics literature – and contemporaneous developments in the economy and financial markets – as a basis for framing the hypotheses to be

[38] Although I still have latitude to do monetary research, as in the *EE* article and Cronin (2017) that have been undertaken, written up, and published in that period.

[39] My publications since 2013 in the sovereign markets-fiscal policy area include Cronin and Dowd (2013), Cronin (2014), Cronin and McQuinn (2014), Conefrey and Cronin (2015), Cronin et al. (2015), Cronin et al. (2016), and Cronin and McQuinn (2017).

investigated in a piece of research. Of the articles that I have written over the past five years or so, the *JMACRO* and *EE* publications are good examples of how this works. The former addressed a lacuna that exists in the literature (despite the progress made over the past fifteen years or so) of providing a rigorous quantitative assessment of the relationship between money and asset prices. A trawl of the literature (assisted by the arrival of Google Scholar and other search engines which I now use routinely in my research) helped assemble a set of related issues for investigation. My understanding of US money and financial databases and econometric skills combined to provide evidence on those that was sufficient to meet the standards of a high-ranking journal. The *EE* article also utilised those capabilities. It showed an ability to recollect and revisit a venerable theory and to give it new life. In summary, the experience of the research contained in this dissertation honed my skills in producing scholarly output to a peer-reviewed standard.

- <u>An improvement in my time-series econometrics skills</u>: Prior to the undertaking of the research that would result in the articles herein, I had spent the previous ten years or so writing papers that involved little or no econometrics. I was writing mainly in two areas: how fiscal policy should be conducted in EMU (in line with my duties as the Central Bank's designated "fiscal expert") and in the area of payments and monetary standards.[40] Part of the motivation in moving to the monetary policy function in 2003 was a desire to improve my empirical skills. Time-series-based econometrics are the predominant mechanism for assessing the various propositions and hypotheses being set out and investigated in monetary research. VAR-based econometrics (including Johansen cointegration) were of attraction to me, in particular the innovation accounting (impulse response functions and forecast-error-variance decompositions) that these estimation methods produce. The academic standing of the *EE*, *Empirica*, *JMACRO*, and *JEB* outlets for my research would indicate that I have mastered the application of these techniques to a high level. With this grounding, I have

[40] The fiscal policy articles include Cronin and McCoy (1999, 2000) and Cronin and Scally (2000, 2002). Among the articles on payments and monetary reform published in this period were Browne and Cronin (1995, 1997) and Cronin and Dowd (2001).

been able in recent years to extend my econometric knowledge to include threshold VAR (used in Cronin and McQuinn, 2014), multivariate GARCH (Cronin, 2014), Markov-switching VAR (Cronin et al., 2016), and autoregressive-distributed lag (ARDL) cointegration (Cronin and McQuinn, 2016).

- Writing and presentational skills: any research will have an impact and meet professional standards only if it is presented in a coherent and reader-friendly manner. The writer needs to be able to set out initially the hypotheses to be investigated, document the empirical results, and then marry them back to the economics hypotheses outlined initially. My ability to write and organise my research on paper has certainly benefitted from the research documented in the articles herein. Engaging with editors and referees and responding to their suggestions and requirements has not only sharpened how I present my findings but it has also made me more cognisant of their requirements before commencing new research. In short, I engage better with the undertaking and recording of research, as an economist engaged by my employer to do so and in satisfying my own curiosity.

The practical benefit of the research undertaken and documented in this dissertation then is that I am a better economist for it. This is illustrated, inter alia, by the number, and quality, of the scholarly articles that I have had accepted for publication in recent years. Alongside an enhanced research ability, my writing and editorial style has become more succinct as a result of contributing to various publication outlets, be they field journals, central bank periodicals or book chapters aimed at financial market professionals. My knowledge of monetary economics has also increased, particularly the monetarist and, to a lesser degree, the Austrian perspectives in the area. Beyond the practical benefit of improved skills, I also believe that I have engaged in a body of research that stands as a meaningful contribution to monetary economics and, in particular, to the understanding of the relationships between money, inflation, and asset markets.

Looking ahead, I would hope to continue to expand my knowledge of time series econometric methods to include principal components, canonical correlations, and structural VARs, and to gain at least some understanding of Bayesian methods. At something of a tangent to the material in this dissertation, I would hope to investigate developments in monetary economics relating to new technologies (for example, how and whether blockchain technology could have an effect on monetary arrangements in the years ahead). These technological advances could also blur the differences between money and financial assets, something that I argue for in a recent article (Cronin, 2017).

In concluding, the question that naturally arises is whether I am still of the view that "money matters" and has explanatory power over economic and financial market developments. The answer is in the affirmative. The research in this dissertation testifies to money's role in determining inflation along lines that have been described in the economics literature over many decades, something that always resurfaces to counter whatever inflation theory has recently been put forward and is in vogue. The relationship between money and financial markets is one that has not received as much attention and probably has a long way to go before being well understood, but on that path the research included in this dissertation points to money being a causative variable in financial market developments.

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Tranche 1

Recent Developments in Asset Prices and Liquidity in the Context of an Evolving Relationship*

by

Frank Browne, David Cronin and Edward J. O'Brien

Abstract

The prices of virtually all asset classes have seen substantial gains over the last two to three years, following on from the more mixed performances that occurred after the rapid succession of shocks in the early years of this decade. At the same time, liquidity conditions over this entire period can be broadly characterised as exceptionally easy. This was reflected in strong money growth and low short-term interest rates. This article examines the relationship between these liquidity conditions and asset price developments. Our graphical and highly tentative results indicate considerable monetary laxity as proxied by both excess money growth and the gap between the short-run real interest rate and its estimated equilibrium value (i.e., the natural rate of interest). The graphical evidence suggests that this lax liquidity situation began to impact positively on asset prices around the end of 2002 and the beginning of 2003. What is especially noteworthy is the escalation of prices across all asset classes since then. This suggests, subject to more rigorous econometric testing, that abundant liquidity has imparted significant momentum to asset prices across the board. This description seems to be broadly correct for the three economic regions examined, the US, the euro area and the UK.

*The views expressed in this article are those of the authors and not necessarily those of the CBFSAI or the ESCB.

August 2005

1. Introduction

Rising asset prices are a common feature of the current economic climate in many advanced industrial economies. They have increased substantially in nominal terms and relative to the prices of goods and services in recent years. A rise in asset prices can be symptomatic of a well-performing economy. There is always a concern, however, that the increase may exceed that warranted by economic fundamentals and be driven by speculative influences. The most worrying scenario is that asset prices become detached from their economically-justifiable values and that inevitably a correction takes place with a rapid decline in asset prices bringing a general economic malaise, including instability in the financial system, in its wake.

Among the factors usually considered to determine asset prices, liquidity conditions are typically given secondary importance in the general economic literature. Upside deviations of asset prices from fundamental values are, instead, more often than not attributed solely to “irrational” expectations, which drive asset prices higher and accordingly tend to become self-fulfilling. This article starts from the premise that liquidity conditions matter to the determination of asset prices. We look at recent liquidity and asset price developments and draw from the analysis some assessment, albeit quite tentative, of the current relationship between these variables.

In the past number of years, there has been a tendency for many asset prices (and here we include commodity prices in the definition of asset prices) to increase at the same time or in close temporal succession. A very high degree of overlap in the pace and timing of asset price acceleration seems to be in evidence. Alongside this, recent liquidity conditions can be broadly characterised as comprising exceptionally strong monetary growth and low short-term interest rates occurring in a period of general price stability and a varying degree of economic uncertainty. Liquidity has been growing at unaccountably fast rates, when reckoned in terms of the usual real economy determinants of the demand for liquidity or money. Almost by any measure, money stock growth has been excessive. Despite these rapid growth rates, there is little discernible evidence of any serious rekindling of goods and services inflation. The prices of virtually all asset classes, however, have seen substantial gains over the last two-to-three years from the more mixed performances that followed the rapid succession of shocks in the early years of the new century. This suggests some relationship between excess money and low short-term interest rates on the one hand and asset prices on the other.

The nature of this relationship, however, is far from straightforward. The apparent co-movement between monetary and credit aggregates on the one hand and asset prices on the other is amenable to a number of interpretations. One possibility is that asset prices are being driven by developments in the real economy and that credit and money are merely responding passively to accommodate the funding and payment requirements arising from these developments. Another is that autonomous movements in money and credit aggregates are driving asset prices. A third possibility is that both monetary aggregates and asset prices are both being driven by a common third influence, such as monetary policy or cyclical shocks. Similar model uncertainty surrounds the relationship between asset prices and our complementary measure of liquidity conditions, the real interest rate gap. It is not the purpose of this article to engage in rigorous econometric testing of these alternative hypotheses. It is much less ambitious. Rather, the aim is to conduct a graphical examination of the data with a view to seeing if there is some validity behind the idea that liquidity conditions impact on asset price behaviour. If there is, then it is possible that it will show up in the timing of events as revealed by the data. This may allow some tentative inferences about the likely consequences of any such relationship for prospects for financial stability.

In our view, the nature of the relationship between liquidity and financial assets is influenced heavily by the fact that liquidity, or more precisely money, provides two, separate functions to the public. First of all, money is a transactions medium and is used routinely to purchase goods, services and assets. At the same time, liquid balances do not need to be used immediately for this purpose; they can just as easily be held to buy goods or assets in the future. This gives money a second quality of providing a store of value over time, making it an asset for its holder and one whose fixed nominal value and saleable qualities make it an attractive and safe haven for holding one's wealth in times of uncertainty. Money then, uniquely, acts both as a medium of exchange (giving rise to a transactions demand) and as a store of value (giving rise to an asset demand for money).

The division of the money balance between these two functions depends in large part on the degree of uncertainty among the public concerning current and future economic/political conditions. Periods of heightened uncertainty, following, for example, a major shock to the economy, tend to see an increase in the asset demand for money, while in periods of declining uncertainty that source of demand for money tends to wane. This cycle in money demand (accumulation followed by de-accumulation) has, in the past, tended to impact on overall inflation. Since the liberalisation of financial systems, however, these cycles are, in the first instance, more likely to spill over into asset price gyrations. In this article, we provide only tentative graphical evidence in support of this and, therefore, our conclusions have likewise to be seen as tentative at this stage.

It is evident from a perusal of the data that liquidity conditions over the past five years or so could be appropriately described as "ample" in nature and that during the same timeframe asset price growth has also gathered momentum after uncertainties began to wane. This was especially the case after the start of 2003 when the prices for all asset classes began moving in the same upward direction at the same time. On the basis of our graphical examination of the data, we conclude tentatively that excess money and real short-term interest rates below equilibrium values have been important drivers of asset price developments in the last few years. It must be stressed, however, that this analysis is mainly suggestive and descriptive in nature and that a more thorough, quantitative examination of this area is being undertaken that might provide more definitive answers.

The link between asset price and monetary developments has been explored in recent years, most notably in papers emanating from the BIS.[41] These focus on financial liberalisation having strengthened the role of financial factors in the economic cycle and on excess demand showing up first in asset prices rather than consumer prices in the new price stability environment.

The rest of the article is structured as follows. Sections 2 and 3 show recent developments in liquidity and asset prices in the US, the euro area and the UK. Diagrammatic analysis suggests that there has been ample liquidity and historically low interest rates in these three areas over the past five years or so. We go on to analyse the uses to which this liquidity has been put in recent years. We take from this review the following observations. Firstly, general inflation has been quite low, both by historical standards and relative to the growth of money. Secondly, there is some evidence from developments in the velocity of money that there was significant hoarding of money in the early years of the current decade but that further hoarding has not since occurred. Thirdly, over the same five-year timeframe, asset prices initially behaved in a heterogeneous manner with some asset categories experiencing a decline and others rising. Since late 2002/early 2003, however, at about the same time that additional hoarding seems to have ceased, a more general rise in asset prices started to take place and has been maintained since. We suggest that this changed behaviour in asset prices over the past five years when assessed alongside contemporaneous developments in liquidity conditions is owing to a change in public confidence regarding economic and political risks and illustrates our basic contentions with regard to the asset price-liquidity relationship. In Section 4, we take stock of this analysis and consider its implications for financial stability. Section 5 concludes.

[41] This includes BIS papers written by Borio and Lowe (2002, 2004), Borio, English and Filardo (2003), Borio and White (2004), Filardo (2004) and speeches by Crockett (2000, 2003). It also includes contributions from non-BIS authors such as Clerc and Pfister (2003).

2. Recent Liquidity and Interest Rate Developments

2.1 Money Developments

The real growth rate of broadly-defined money stocks for the US, the euro area and the UK over at least the last twenty years are plotted in the first three panels of Chart 1.[42, 43] The full range of quarter-on-quarter growth rates is damped somewhat by the use of a backward-looking eight-quarter moving-average representation of the current and previous growth rates.[44] We see that each money stock has experienced a wide range of growth rates over their respective sample periods and that while not quite at the top of the historical range, real money growth rates have picked up gradually over the past ten years or so and have recently been close to historical highs.

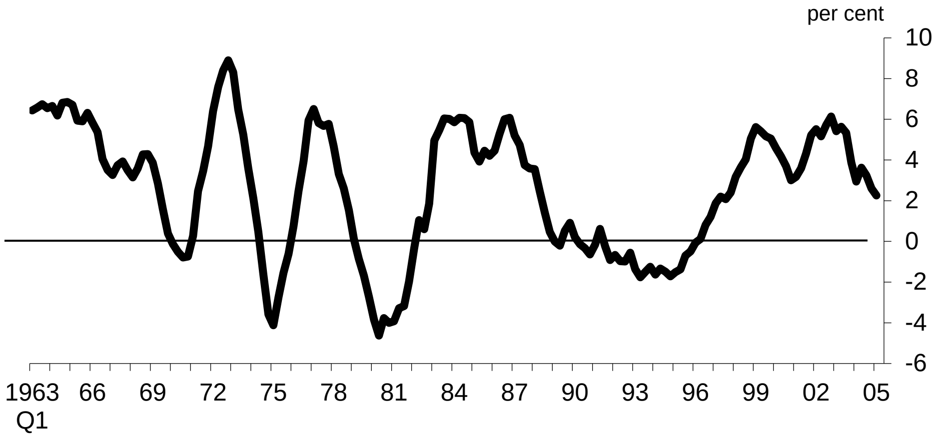
Headline money growth rates are not particularly illuminating on their own, however. One of the more important roles of money is as a transactions medium. To explore whether there is an excess supply of transaction balances, it makes sense, therefore, to relate money's growth rate to that of some measure of economic activity. Accordingly, Chart 2 links the nominal money growth rate to the growth rate of nominal GDP. The representation in Chart 2 involves subtracting the GDP growth rate from the money stock growth rate so that a positive value in the graphs (as scaled on the vertical axis) indicates that the backward-looking eight-quarter money growth rate exceeded that of GDP, and vice versa.[45] With regard to recent developments, Chart 2 adds to Chart 1 in saying that money growth has picked up strongly over the last ten years or so, in

[42] All data used in constructing the Charts are described in the accompanying appendix.
[43] Each nominal money stock is deflated by the consumer price index in calculating the real money growth rates. The growth rates shown for monetary and asset price data in Chart 1 and subsequent Charts are annualised quarter-on-quarter growth rates.
[44] They are "backward-looking" in the sense that the value reported for, say, the first quarter of 1990 is calculated as the unweighted average of the sum of that quarter's growth rate value and the previous seven quarters. This means that each growth rate is a function of current and historical data. The benefit of using a moving-average representation, as opposed to just a simple per-quarter value, is that it gives a better impression of medium-term growth rates.
[45] Negative values reflect, among other things, inflation following money growth with a lag.

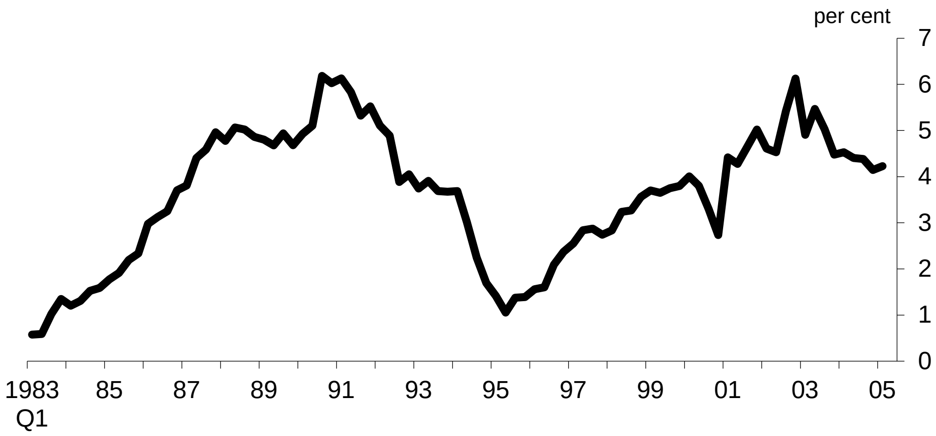
this case relative to economic activity, and that there may now be an excess of money balances outstanding.

Chart 1: Real Money Growth (Eight Quarter Lagged Moving Average, Percentages)

a) United States (1963Q1-2005Q1)



b) Euro Area (1983Q1-2005Q1)



c) United Kingdom (1985Q1-2005Q1)

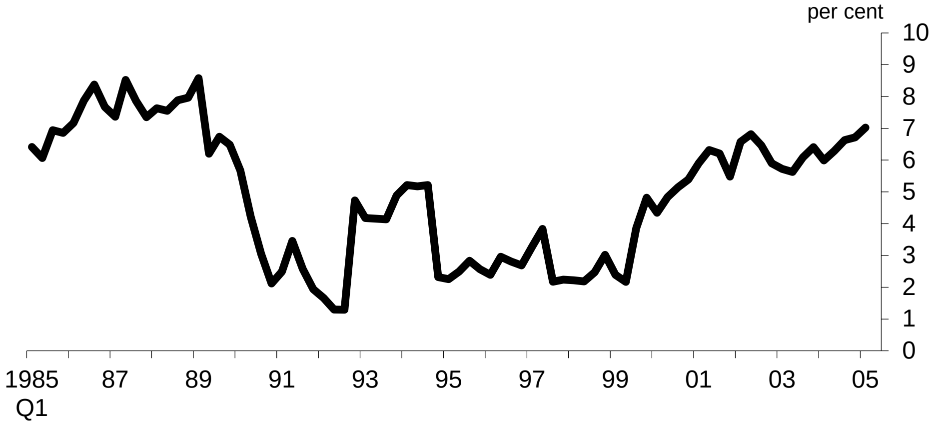
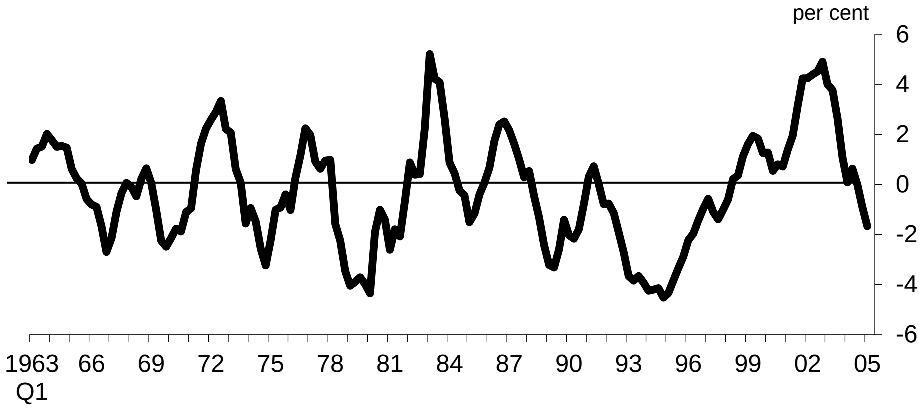
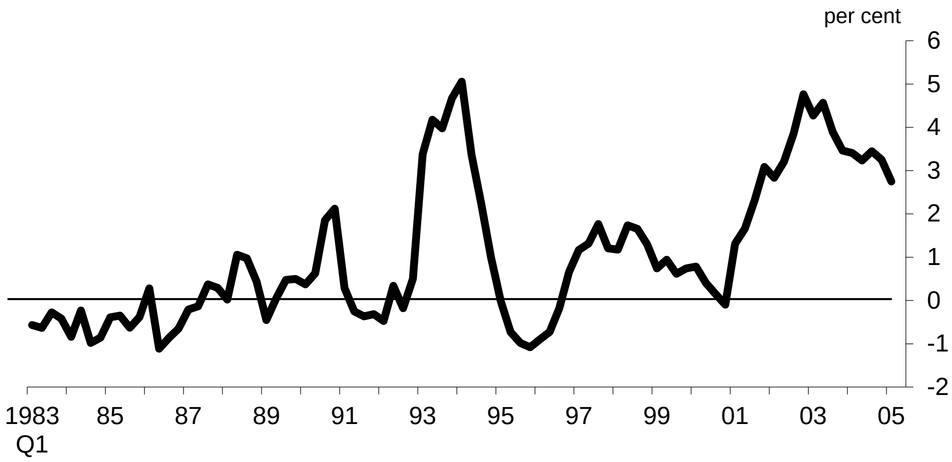

per cent
10
9
8
7
6
5
4
3
2
1
0
1985 Q1
87
89
91
93
95
97
99
01
03
05

Chart 2: Annualised Change in Money less Annualised Change in Nominal GDP (Eight Quarter Lagged Moving Average, Percentages)

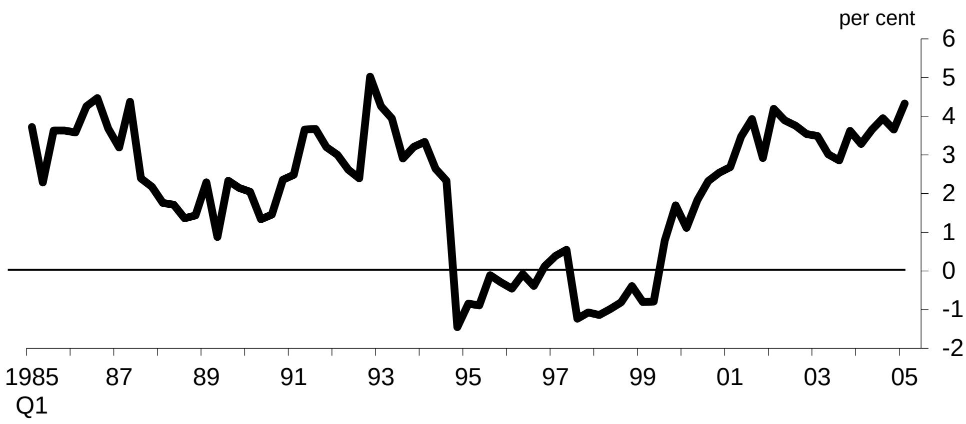
a) United States (1963Q1-2005Q1)



b) Euro Area (1983Q1-2005Q1)



c) United Kingdom (1985Q1-2005Q1)



2.2 Interest Rate Developments

Besides money-based measures, the other key variable used for assessing liquidity conditions is the short-term interest rate, which tends to be highly sensitive to the liquidity situation. In Chart 3, we see that the short-term nominal interest rate has dipped steeply in the US since about 2000 and has fallen more moderately in the euro area and the UK over the same timeframe. This follows a more sustained reduction since the early 1980s in the US, since about 1993 in the euro area and from the early 1990s in the UK. Indeed, short-term interest rates are now close to historically low values.

Lower inflation rates may explain in part this fall in nominal interest rates. To show that they do not account for the full amount of the decline, it is necessary to exclude the inflation rate component of the nominal interest rate giving a measure of the real interest rate. This inflation-adjusted rate is graphed in Chart 4.[46] We can see that real interest rates have, like their nominal counterpart, fallen from 1980s/early1990s levels and are also now close to historical lows. What does this signify? Real short-term interest rates are determined by the demand and supply of short-term loanable funds, where the supply of those funds can be inflated by excess liquidity. Low rates would, therefore, tend to indicate a large supply of funds relative to demand. According to this reasoning, these graphs would point to the economies in question being amply supplied with funds.

We can take this analysis of interest rates one step further and see how actual short-term real interest rates compare to their equilibrium values, which are determined by the sustainable rate of return in the economy. In the first column of Chart 5, we plot the actual real rate of return (as per Chart 4) and the estimated contemporaneous equilibrium values, while in the second column we plot the difference between them, which is termed the real interest rate gap.[47] The graphs

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[46] This interest rate is an ex post rate calculated as the actual nominal rate less realised inflation, which is a reasonable rate to use when examining trends over a long span of time.

[47] The actual and equilibrium real interest rate series for the euro area are taken from the article by Browne and Everett in this *Report*. We are grateful to Mary Everett for estimating and providing us with the interest rate series for the US and the UK.

in the first column can be broadly characterised as comprising an actual real interest rate (the solid line) moving around a less undulating equilibrium value. This reflects the excess supply or demand for funds varying more substantially than the rate of sustainable returns from productive activity. The difference between these two interest rates - the real interest rate gap – is plotted in the second column of Chart 5. It shows this gap to be now in negative territory in the US, the euro area and the UK, signifying an excess of funds being available relative to that justified by long-term returns.

3. Possible Causes and Consequences of Current Liquidity Conditions

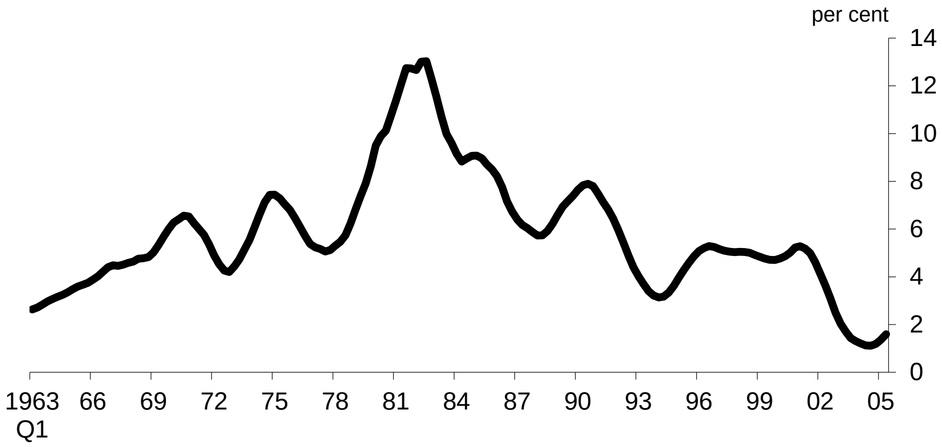
We conclude tentatively from our survey of indicators of liquidity conditions in the last section that there is an excess of liquid balances in all three economies being examined. There would also, therefore, appear to be an excess of liquidity at a global level. What are the reasons for and consequences of these current liquidity conditions? We seek to answer this in the subsequent subsections.

3.1 Changing Liquidity Preferences

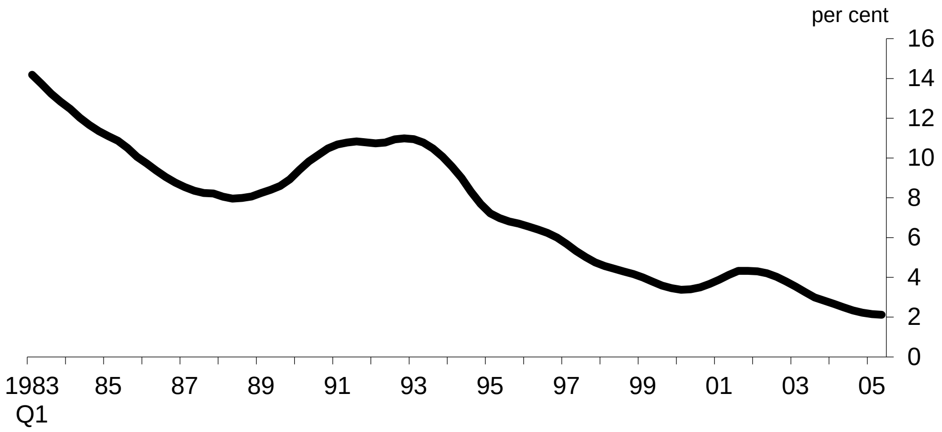
Besides being held for the purpose of purchasing goods and services, liquid balances are often simply held or hoarded. It is possible, therefore, that liquid balances have been built up in recent times as agents wish to hold money balances not for immediate transaction purposes but rather to use at some future date. This may seem a viable explanation for the features of the data in section 2 relating to the last five years or so. Rapid money growth may be symptomatic of a desire among the public to hoard larger holdings of money.

Chart 3: Short Term Nominal Interest Rates (Eight Quarter Lagged Moving Average, Percentages)

a) United States (1963Q1-2005Q2)



b) Euro Area (1983Q1-2005Q2)



c) United Kingdom (1985Q1-2005Q2)

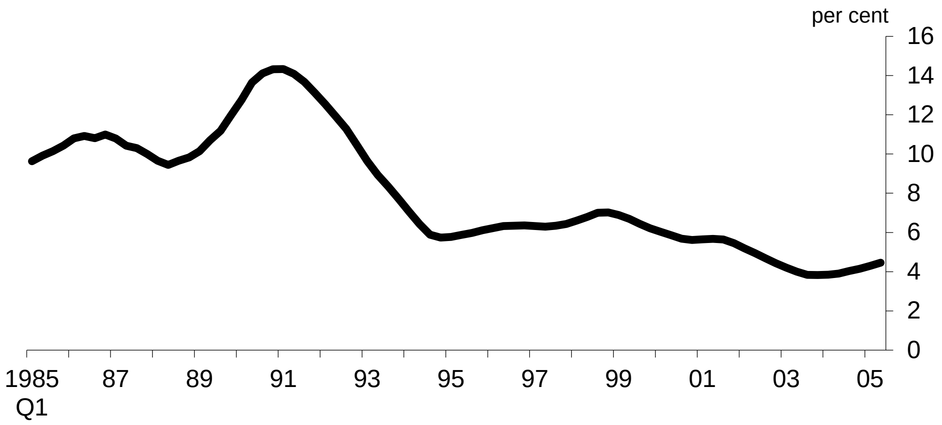
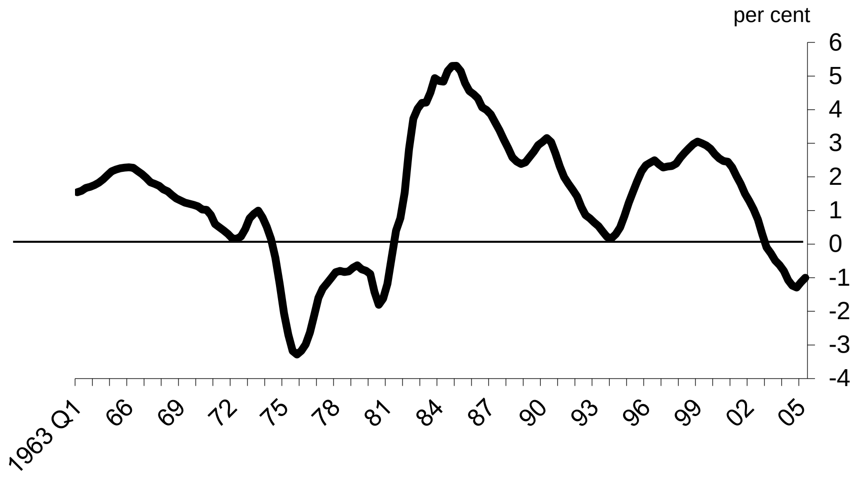
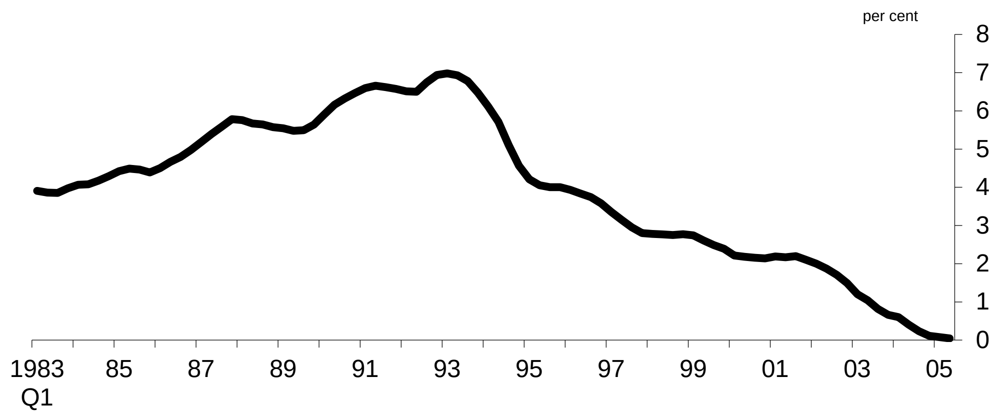


Chart 4: Real Interest Rates (Eight Quarter Lagged Moving Average, Percentages)

a) United States (1963Q1-2005Q2)



b) Euro Area (1983Q1-2005Q2)



c) United Kingdom (1985Q1-2005Q2)

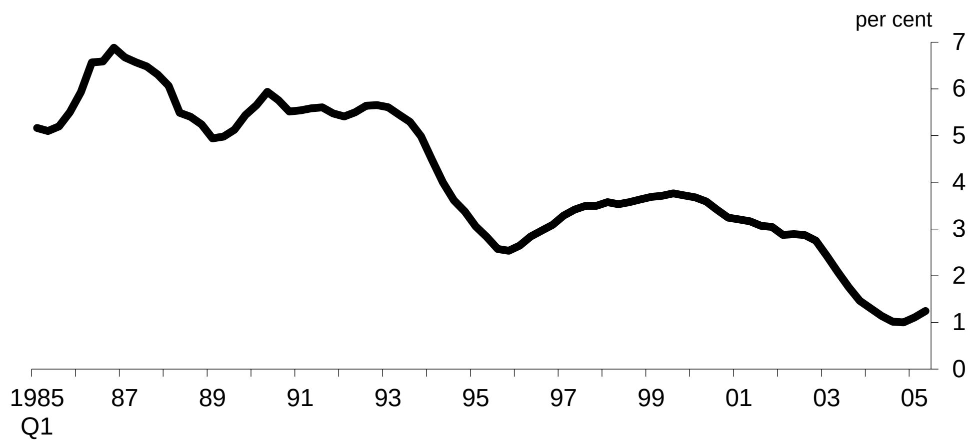
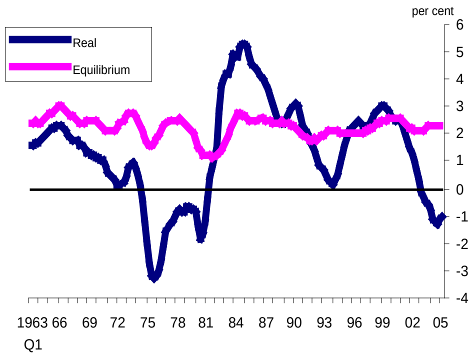
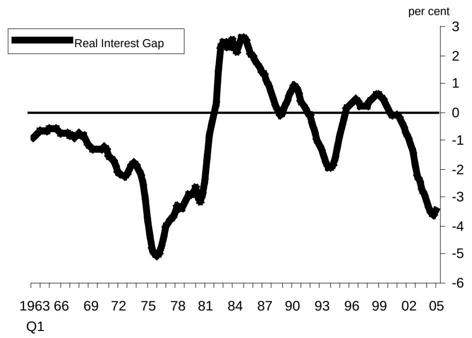


Chart 5: Real and Equilibrium Interest Rates and the Interest Rate Gap (Eight Quarter Lagged Moving Average, Percentages)

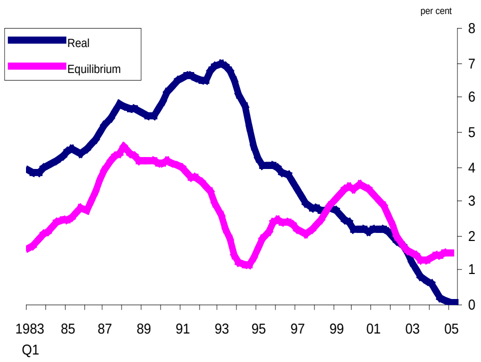
a) United States (1963Q1-2005 Q1)



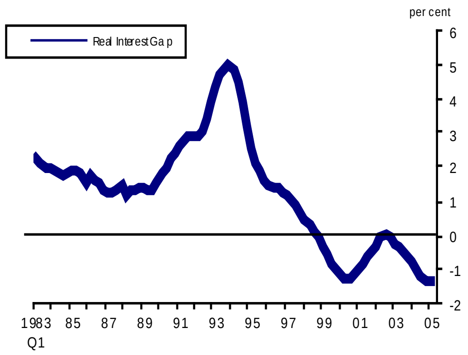
United States (1963Q1-2005 Q1)



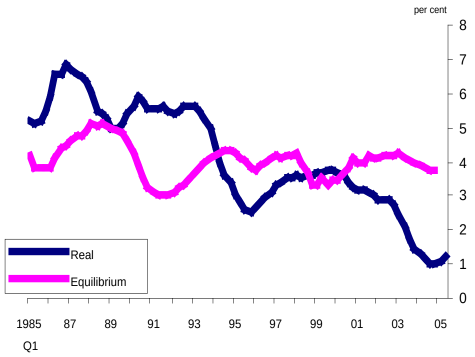
b) Euro Area (1983Q1-2005 Q2)



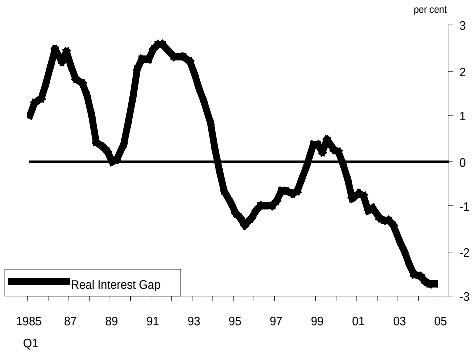
Euro Area (1983Q1-2005Q1)



c) United Kingdom (1985Q1-2005 Q2)



United Kingdom (1985 Q1 - 2004 Q4)



This may explain the sharp dips in the velocity of money for the US, the euro area and the UK in recent years, as shown in the left-hand column of Chart 6, where the velocity of money is defined as the nominal value of GDP divided by the money stock.[48] A sudden fall away in the velocity of money suggests a decision by consumers and firms to hoard money by holding more liquid balances than are needed for trade in goods and services.

Why hold more money? It is well recognised that cyclical movements in the velocity of money tend to be sensitive to the opportunity cost of holding money. When the opportunity cost is low, money is obviously less costly to hold and so money balances can be expected to increase relative to transactions demand. As can be seen in Chart 6, however, the recent declines in velocity for the euro area and the UK have occurred at a time when the opportunity cost of holding money (shown in the right-hand side column) has actually increased. For the US, the decline in velocity since about 1997 preceded the decline in the opportunity cost of holding money that started in 2001. An interest elasticity effect, therefore, does not seem to explain the rise in liquidity.

In suggesting that there is more than an interest rate effect impacting on the velocity of money in recent years, the next step is to examine some of the other non-transactions-based reasons why the public may want to hold more money. The principal factor in this regard will be the desire of the public to hold money for both precautionary and speculative reasons in a period of uncertainty. Money balances provide a safe haven for holding one's wealth at any time. Generally, they have fixed nominal value and can be easily mobilised and used in the future for acquiring other assets and goods. The early years of the current decade were evidently a time when there was much macroeconomic uncertainty following declines in stock markets and dips in economic performance and large-scale terrorist acts. We highlight 2001q3, to indicate the timing of the September 11 terrorist attacks, in Chart 6 through the use of a vertical line at that juncture. As

[48] We shorten the length of this Chart to start in 1995 to compare better the co-movement between the velocity of money and the opportunity costs of holding money in recent years.

we can see, the rate of decline in the velocity of money accelerated or was maintained subsequent to that time in all three areas, suggesting an increased hoarding of money. It is worth noting again from Chart 6, however, that the accentuated decline in the velocity of money preceded these events and was sustained after their effect may have been considered to be greatest. An increased desire to hoard money may, therefore, explain only part of the increase in liquidity in the economies being discussed.

3.2 A Rise in Demand for Goods and Services

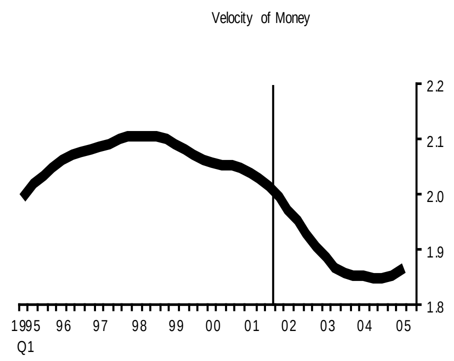
If more money is not being held entirely for hoarding purposes, the only alternative is that it is being used for transactions purposes. The normal expectation then would be that the recent build-up of liquid balances should coincide with a pick-up in the purchasing of goods and services in the economy and, should the supply of goods and services be inelastic relative to nominal expenditure, a rise in their prices should occur, albeit with some lag. The general inflation rate should then climb to higher levels. In Chart 7, we plot annualised growth rates for (nominal) broad money and the consumer price index (CPI), a suitable index of general goods and services prices, over the entire available sample periods. We can see that over time CPI inflation broadly tracks the rate of money growth, albeit usually at a lower rate and with some lag.[49] In other words, when the rate of money growth goes up so does the inflation rate, and vice versa. It is obvious, however, that while money growth has picked up substantially since the mid-to-late 1990s in all three countries/monetary zones, the rate of general inflation has either declined or effectively flattened out.

It could be suggested that perhaps real growth in goods and services bridges the gap between money and inflation growth rates. Referring back to Chart 2,

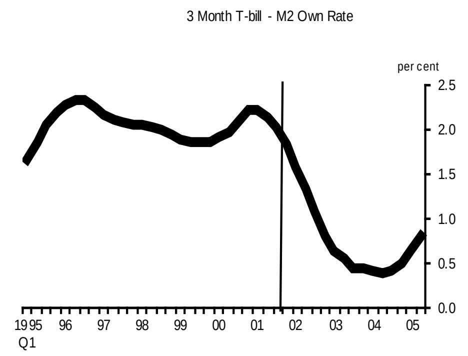
[49] The pick-up in the rate of inflation may not exactly match that of money growth because the supply of goods and services will also be changing over time. Most usually that supply is increasing resulting in some of the money growth being required to facilitate the extra amount of goods being transacted in the economy. Thus, part of money growth will not have an inflationary impact and the rate of money growth will then tend to exceed that of inflation.

Chart 6: Velocity and Opportunity Cost of Money (Eight Quarter Lagged Moving Average)

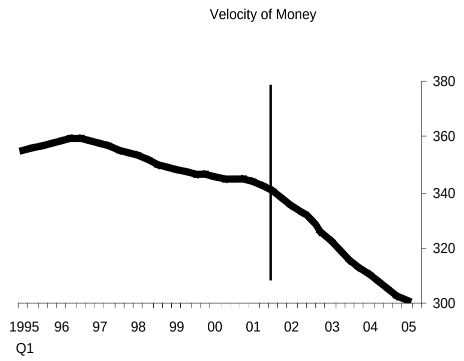
a) United States (1995Q1-2005Q1)



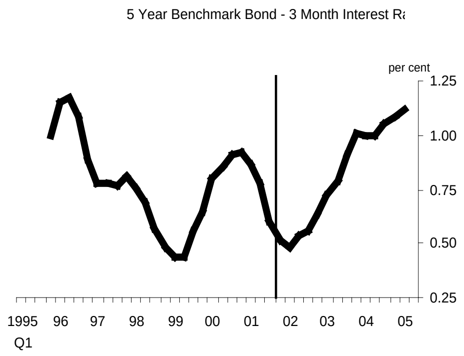
United States (1995Q1-2005Q2)



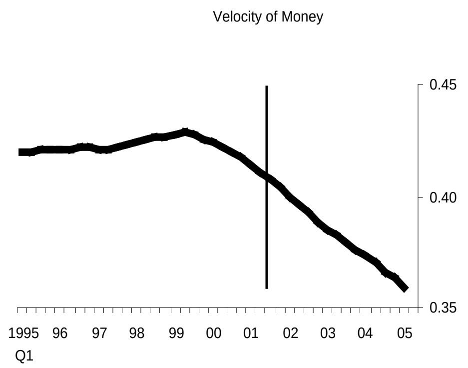
b) Euro Area (1995Q1-2005Q1)



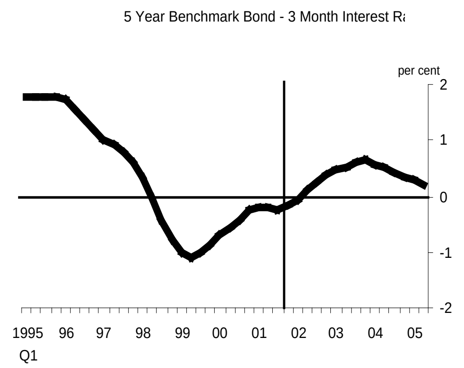
Euro Area (1995Q1-2005Q1)



c) United Kingdom (1995 Q1 - 2005 Q1)



United Kingdom (1995 Q1 - 2005 Q2)



however, we can see that the growth rate for nominal GDP, which accounts for both the changes in real activity and general prices, has been in almost all quarters less than that of money growth rates (as reflected in the positive gap values) during the current decade. It seems then that money growth is not currently having the expected effect on general inflation.

3.3 A Rise in Demand for Financial Assets

- *Asset price developments in recent years*

Having tentatively established a prima facie case for excess liquidity in all three economic areas, the next step is to examine graphically the relationship between these liquidity measures and a range of asset prices. We categorise across six asset types: government bonds, corporate bonds (across a range of default risk classes from AAA to Caa), equities, property, commodities, and emerging market (bond and/or equity) indices.[50] With the exception of commodities, which are represented by the price of oil, all other series are indices to capture broad market movements in the particular asset type. We undertake our analysis for asset prices for the shorter period of 2000 to the present. One reason for this is that asset prices tend to be particularly volatile and, therefore, patterns in the data are examined and digested better in a short-term context.[51] A second reason is that we expect the relationship between asset price and liquidity developments to be much stronger following the increased household participation in financial markets in the 1990s and subsequently. We focus on nominal rather than real asset price developments as general inflation has been so low in recent years that it is not unreasonable to study just one form of prices alone.

[50] The Caa category of corporate bonds is Moody's nomenclature for bonds that would be classified as CCC by other rating services such as Standard and Poor's. The asset price data utilised in Charts 8 to 13 for the three economic areas is, like all other data, described in the accompanying appendix.

[51] Given the shorter, five-year timeframe and a desire to capture the speed at which asset prices can change direction, all asset price entries in Chart 8 and subsequent Charts use a shorter, four-quarter backward-looking moving average representation of the underlying data while the eight-quarter moving average representation of the monetary and interest rate variables is maintained.

In the upper panels of Chart 8, 9 and 10, we plot the nominal levels of the aforementioned asset types over the past five years for, in turn, each of the three economic areas under consideration.[52] These and subsequent graphs include three vertical lines at a number of appropriate dates: 2001q1 (the start of the last recession in the US, as identified by the NBER), 2001q3 (the time of the terrorist attacks in the US) and end-2002 (which we will argue was a turning point in the perceived level of market uncertainty and risk aversion and, consequently, in asset price developments). This panelling allows the data to be read in a macroeconomic-political economy context.

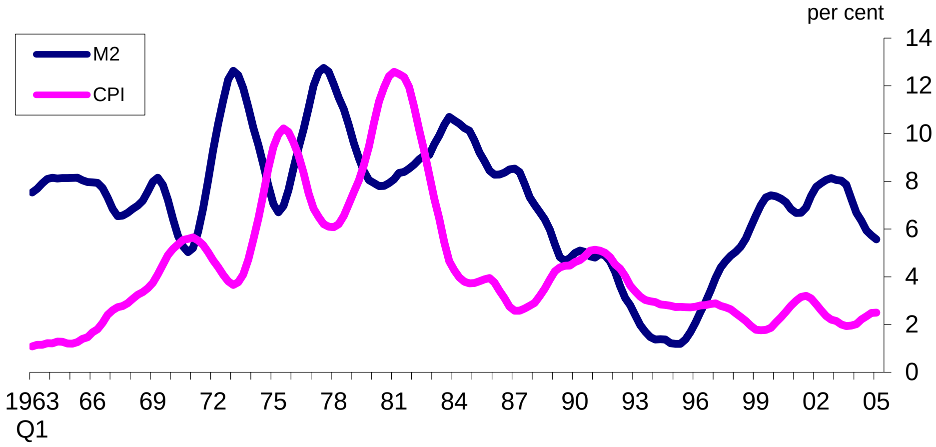
For the US, Chart 8a reflects a pattern of asset performance that is mirrored in the data for the euro area and the UK in Charts 9a and 10a. The sub-period from 2000q1 to 2002q4 was marked by diverse US asset price behaviour. Five of the asset types (the government bond index, the AAA and BBB bond indices, the property index, and the emerging markets bond index) experienced a trend increase in value; two more (the equity index and the emerging markets equity index) experienced broad declines; the Caa bond index's value declined sharply and steadily to end-2001 and maintained a firm rate of increase thereafter; and, finally, the price of oil oscillated around a range of values during the period. From end-2002 onwards, however, this directional diversity has disappeared with a trend rate of increase across all nine asset-types having been experienced.

In Chart 8b (and the lower panels of Charts 9 and 10), we provide an unweighted average of the indices available over the entire sample range of 2000q1 to 2005q2 to represent aggregate market behaviour.[53] The diversity of US asset performance to end-2002 is shown in an oscillating aggregate index measure.

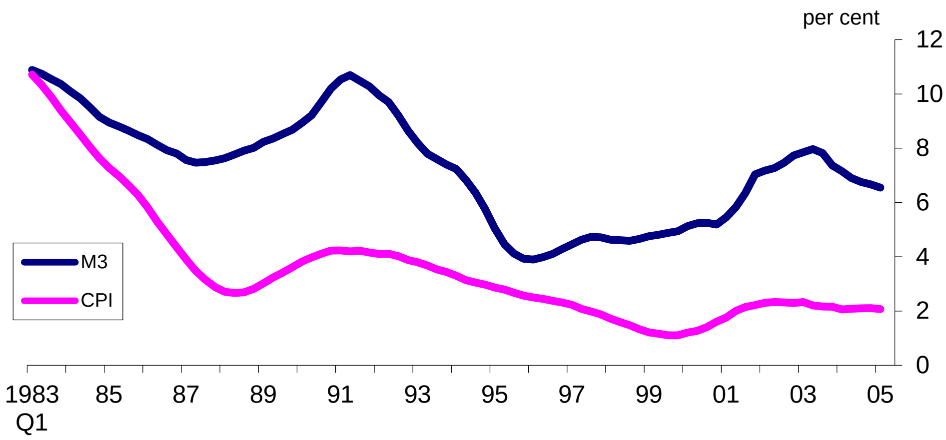
[52] For convenience, all are indexed to 100 at the start of the period.
[53] For the US, this includes eight of the nine asset types. The exception is the property index, which is only available up to 2004q3.

Chart 7: Monetary Aggregates and CPI Percentage Changes (Eight Quarter Lagged Moving Average, Percentages)

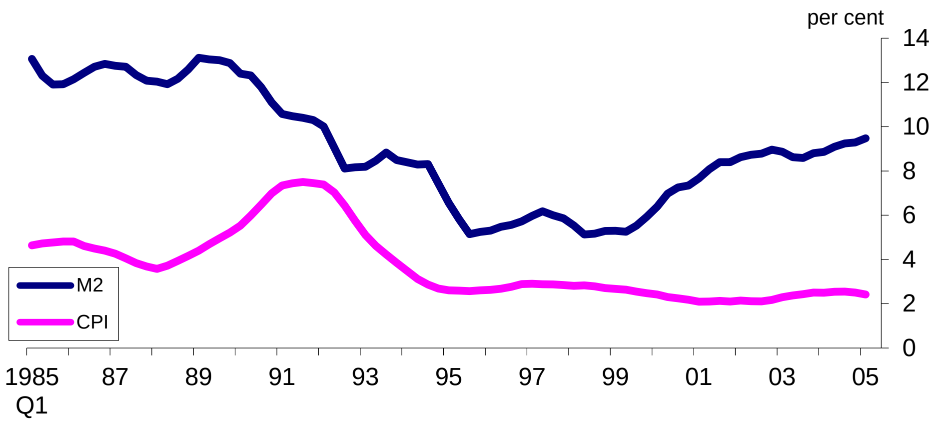
a) United States (1963Q1-2005Q1)



b) Euro Area (1983Q1-2005Q1)



c) United Kingdom (1985Q1-2005Q1)



There was initially a steady rise in 2000 followed by a flattening out and then a dip around the time of the recession turning point with that fall continuing in the aftermath of September 11. A moderate pick-up, however, started around early-to-mid 2002 which has followed by a more accentuated rate of increase from late-2002 onwards, reflecting all asset types experiencing positive and, in some cases, dramatic growth. It must be observed too that over the entire sample period, this aggregate index rose by some 50 percent, four-fifths of which occurred in the period after end-2002.

These patterns of asset price behaviour in the US are reflected in the euro area and UK data in Charts 9 and 10, albeit across somewhat different ranges and with some differences in timing. For the euro area, Chart 9a shows that the equity index declined to early 2003 but has mounted a partial recovery since then, while all three bond indices have increased steadily, if unspectacularly, over the sample period and oil's value experienced both periods of rise and decline (but increased, on balance, by over 60 percent for the entire period). In Chart 10a, we can see that UK government bonds, both types of corporate bonds and property have experienced little or only moderate rates of growth from 2000 to 2005 and so differ from the more robust US and euro area growth experience for these particular asset types. The UK equity and emerging market equity indices, however, shared the same decline-followed-by-a-rise experience of US and euro area equities while oil prices' behaviour was close to those of the other two areas for obvious reasons.

Looking at the aggregate indices in the lower panels of Charts 9 and 10, we can see a varying asset performance over the 2000 to 2005 period in the euro area and the UK that is broadly comparable to the US case. There was an initial rise in the aggregate indices through to early 2001 followed by a flattening out in both indices during 2001 and then a decline in their value to the start of 2003 before a sharp pick-up thereafter. Although the cumulative rates of increase for the aggregate indices in Charts 9b and 10b over the entire period are close to 30 percent for the euro area and just over 20 percent for the UK and are, like their US counterpart, well above the rate of increase in the prices of goods and services, it is the diverse performance of asset prices within the period that we find more interesting and which we analyse in the next subsection.[54]

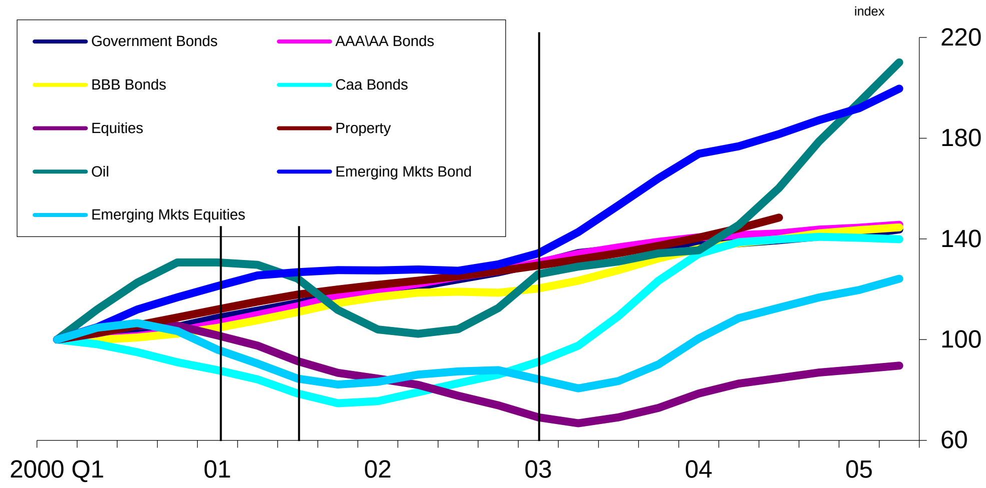
- ***Asset prices and monetary variables***

Asset prices in the US, the euro area and the UK in 2005 are now, in aggregate, substantially above their values in 2000. More interestingly, asset price behaviour over the past five years can be differentiated across two sub-periods. In the first sub-period, there were diverse performances across asset types up to end-2002 with some assets declining in value, others rising moderately and still more oscillating in value. This is exactly what we would expect in the environment of uncertainty that prevailed at the time in the wake of a succession of substantial shocks. In the second sub-period since end-2002, however, all asset prices have increased strongly and, indeed, most of the large overall increases in asset prices since 2000 occurred in this second sub-period. The entire 2000 to 2005 period has been characterised by a low short-term interest rate and strong money growth rate environment, as outlined in section 2, and low inflation, as discussed in a previous subsection. It remains then to try to tie together these developments into a coherent story and, in doing so, to provide an explanation of the asset price-liquidity relationship in recent years. We simplify the analysis by using the simple unweighted average of all asset-class index series which are plotted in the lower panels of Charts 8 to 10. These measures allow us to compare general asset price developments with general liquidity and interest rate conditions, all of which are plotted for the respective economic areas in Charts 11 to 13.

[54] The differing cumulative rates of increase in asset prices across the three economic areas reflect, in part, the differing composition of asset-types in the aggregate asset price indices for each area.

Chart 8: US Asset Price Nominal Levels 2000Q1-2005Q2 (Four Quarter Lagged Moving Average)

a) Asset Price Nominal Levels



b) Aggregate Asset Price Nominal Levels

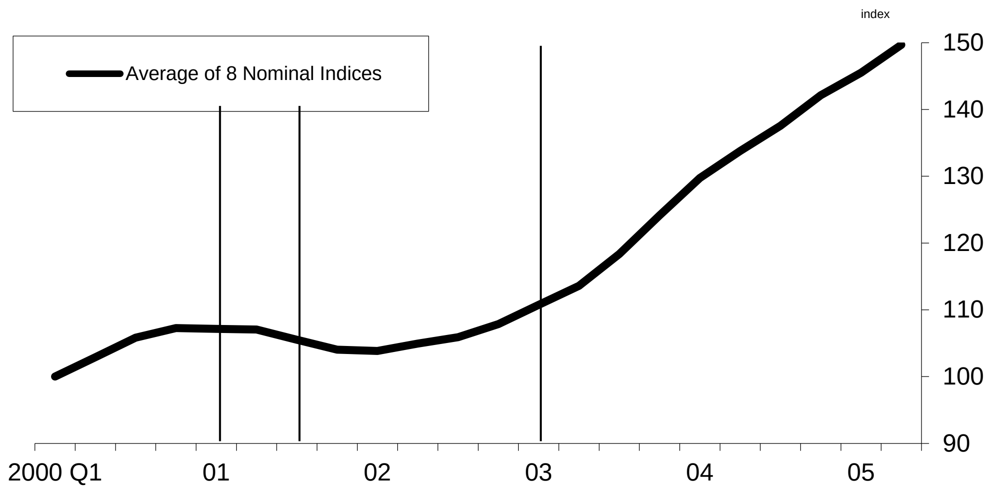
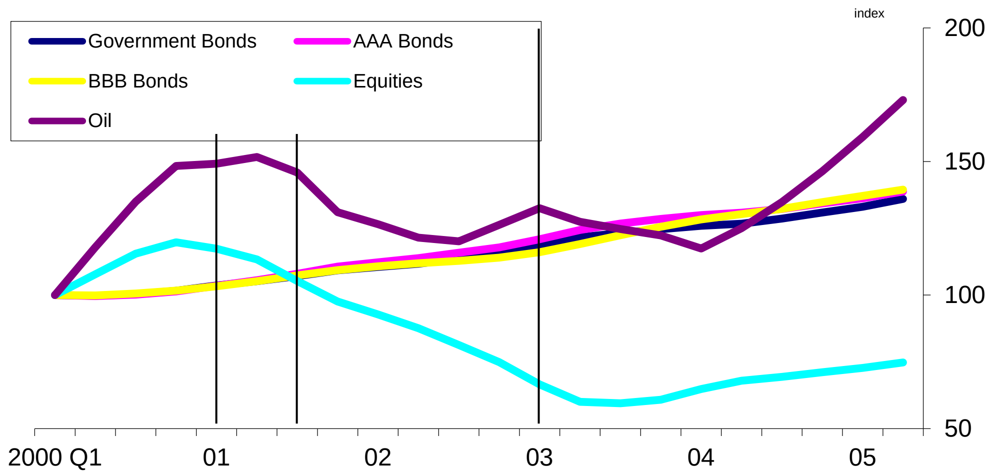


Chart 9: Euro Area Asset Price Nominal Levels 2000Q1-2005Q2 (Four Quarter Lagged Moving Average)

a) Asset Price Nominal Levels



b) Aggregate Asset Price Nominal Levels

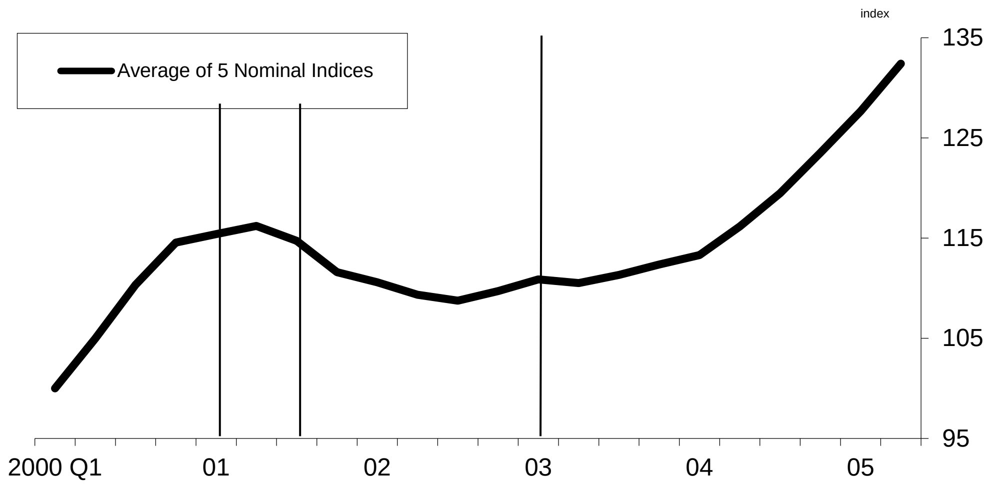
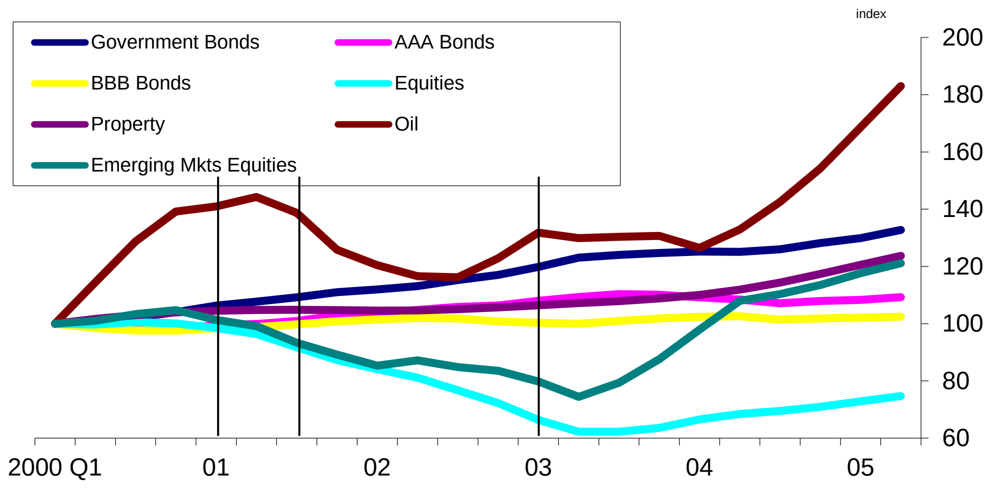
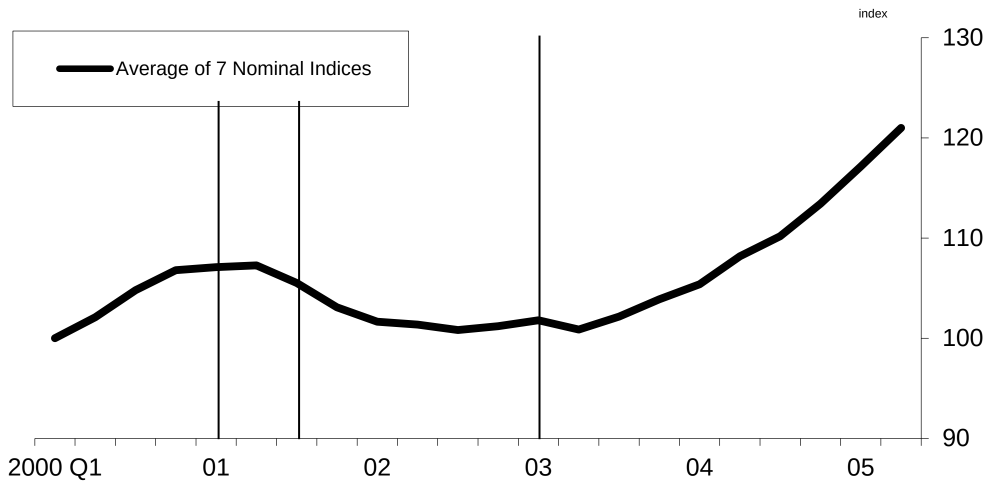


Chart 10: UK Asset Price Nominal Levels 2000Q1-2005Q2 (Four Quarter Lagged Moving Average)

a) Asset Price Nominal Levels



b) Aggregate Asset Price Nominal Levels



Looking in the first instance at the monetary conditions, the middle panels of Charts 11 to 13 point to a build-up of excess liquidity from 2000 through until early 2004 as the moving average values of money growth exceeded those of nominal GDP growth by one-half of one percent to about 4½ percent in all three areas. This excess money growth has been maintained in the euro area and the UK into 2005. For the US and the euro area, the excess growth rates reached maximum values in 2002 and 2003 while the UK's growth rate has been strongest in the most recent quarters. The interest rate gap has either declined steadily into negative values during the five-year period (in the case of the US and the UK) or has remained in negative territory throughout (as for the euro area), also reflecting the ample liquidity conditions.

As for asset prices, our aggregate measures in the upper panels of Charts 11 to 13 show that their behaviour could be broadly characterised in the following manner: they experienced some growth in 2000; this was reversed during 2001 and 2002; and since then, they have grown very strongly in the years 2003 to 2005. Why did asset prices not grow steadily throughout this period when money growth was high and interest rates were low? It may be that the initial growth in money occurred to satisfy a demand for money to hold at a time of political and economic uncertainty but that when that source of demand began to wane, the resulting excess money supply began to spill over into a demand for financial assets rather than a demand for goods and services, as reflected in the divergent patterns of consumer price inflation (which remained subdued) and asset price inflation (which took off for all main asset classes at about that time) already noted.

These charts then seem to provide a strong prima facie case for monetary conditions influencing asset price developments over the past five years or so. The entire period can be characterised as a time of low interest rates and ample liquidity. Initially, there was some diversity in performance across asset classes but there has been a more unified upward surge in asset prices since about the start of 2003. That this broadly-based rise in asset prices did not occur earlier at a time when monetary growth was already strong is likely owing to a more unstable macroeconomic environment and an aversion to equities and other more risky investments at that time. These two factors may, in fact, have contributed, through stronger money demand, to the pick-up in money growth. Once those uncertainties declined, as it is reasonable to argue has been the case for the past two years or so, that increased money stock would seem to have been used more as a transactions medium than as a store of value, with the transactions in question being in financial assets rather than in goods and services. The outcome was higher asset prices.

4. The Evolving Relationship between Liquidity and Asset Prices and Its Implications for Financial Stability

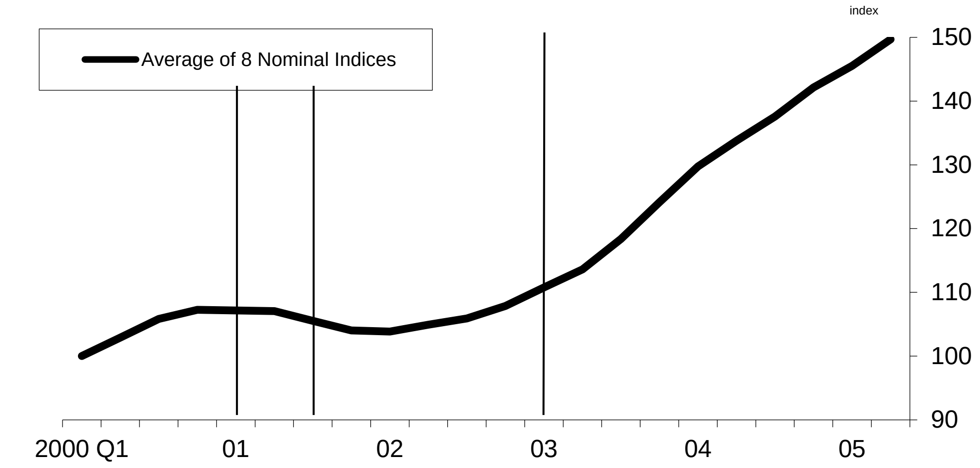
4.1 The Relationship between Liquidity and Asset Prices

The purpose of this article has been to look at recent experience in asset price developments alongside those in liquidity conditions in order to highlight features of the relationship between both sets of variables. For assets, the most salient of the stylised facts to emerge has been the tendency for prices in all asset classes to increase at the same time or in close temporal succession since, roughly, the end of 2002. This phenomenon is common to all three economic areas examined, the US, the euro area and the UK. This co-movement is no doubt reflective, in part at least, of the growing influence of the globalisation of financial markets.

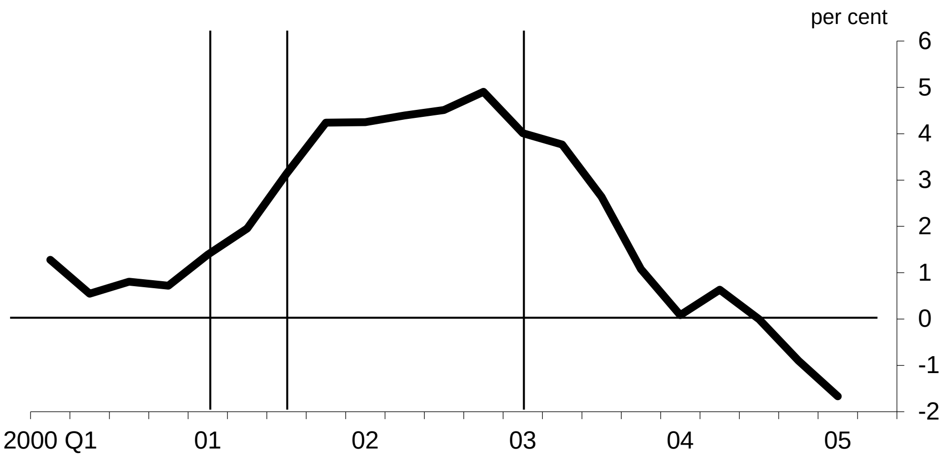
A prolonged period of ample liquidity has also been a feature of recent years. So far, this has failed to show up in consumer prices. This is quite puzzling when compared with similar circumstances in the past. It may be attributable, however, not to an absence of such inflationary pressures, but rather to the fact that it is now taking a longer period of time for easy liquidity conditions to show up in expenditure on final goods and services and, depending on the conjunctural state of the economy, in consumer prices.

Chart 11: Asset Prices and Liquidity Indicators for the US 2000Q1-2005Q2

a) Nominal Asset Price Index



b) Money - GDP



c) Interest Rate Gap

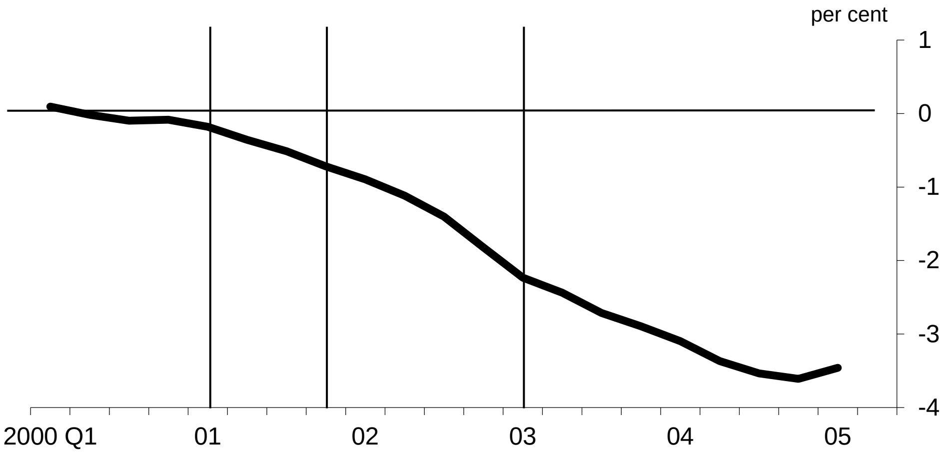
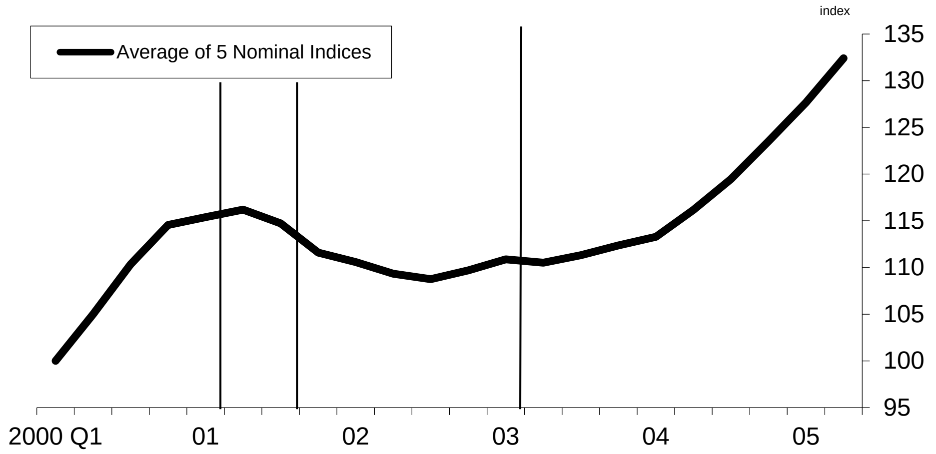
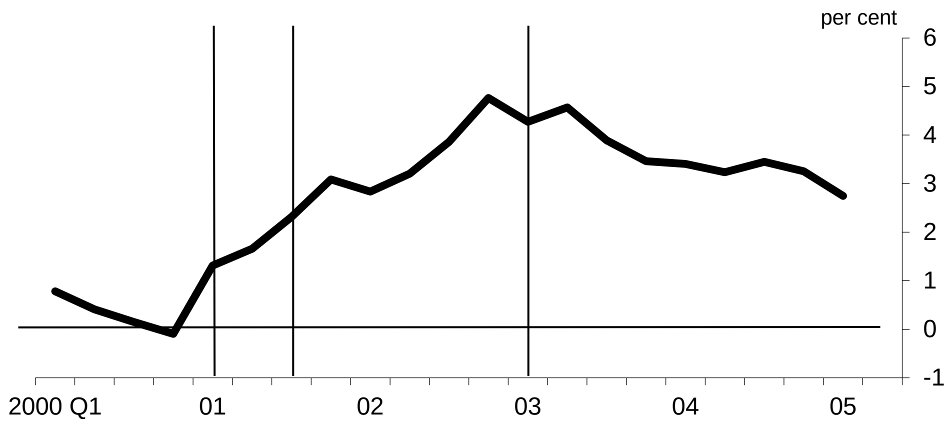


Chart 12: Asset Prices and Liquidity Indicators for the Euro Area 2000Q1-2005Q2

a) Nominal Asset Price Index



b) Money - GDP



c) Interest Rate Gap

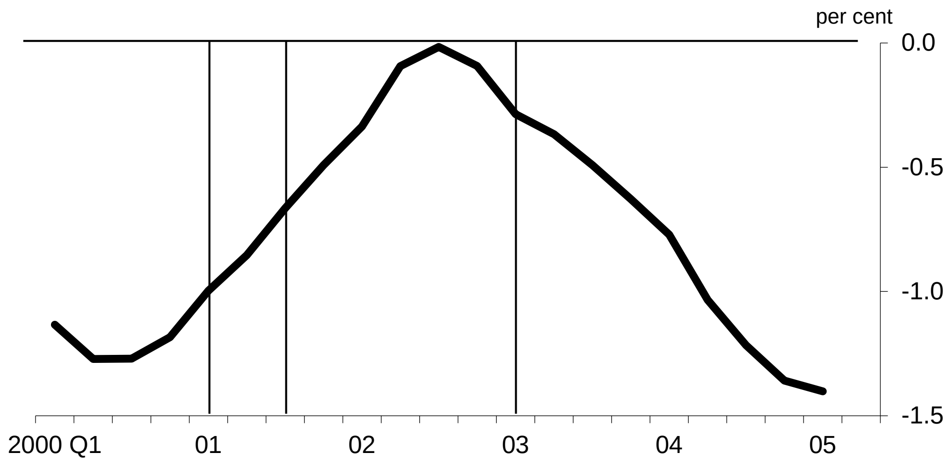
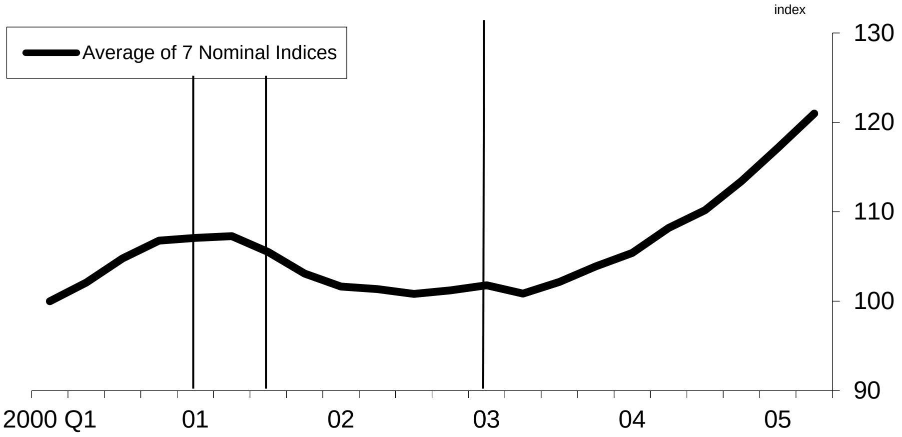
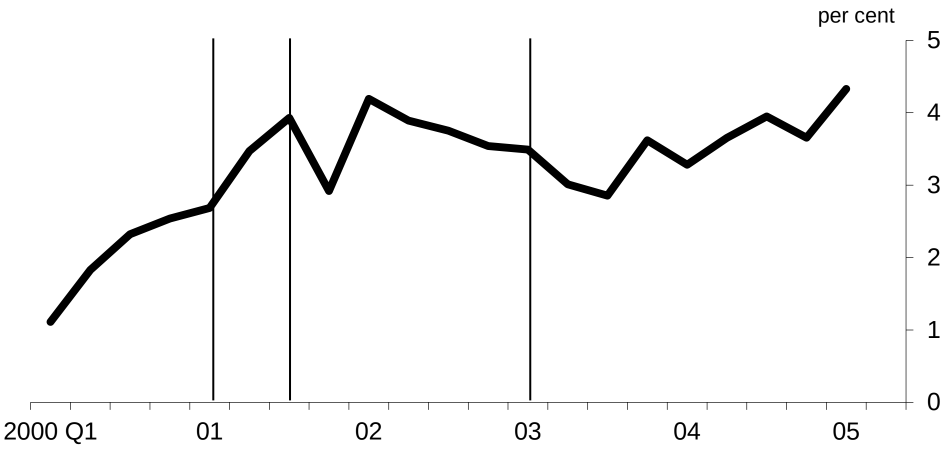


Chart 13: Asset Prices and Liquidity Indicators for the UK 2000Q1-2005Q2

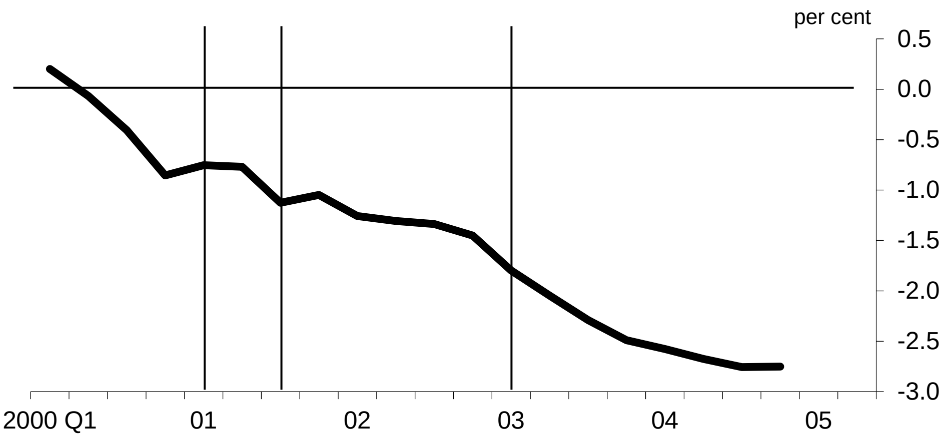
a) Nominal Asset Price Index



b) Money - GDP



c) Interest Rate Gap



Arguably, the reason for this may be that the transmission from ample liquidity to inflation is taking longer because it is following a more circuitous route to final expenditure and overall inflation than in the past and that that route is increasingly via financial markets.

Such a longer lag to inflation is not implausible if the transmission from ample liquidity and low short-term nominal interest rates is now occurring systematically via asset prices. In the relatively repressed financial market environment of the 1970s and some of the 1980s, much of the household and non-financial corporate sectors did not have the same easy and cheap access to financial markets that they enjoy today. This meant that monetary disequilibrium tended to be resolved relatively quickly in the market for goods and services. An element of the hypothesis being propounded here is that monetary disequilibrium is now being increasingly felt in asset price movements in the first instance owing to the improved access to financial markets available to the public. It will then tend to affect overall expenditure on goods and services and final consumer price inflation only much later and this will tend to happen predominantly through wealth effects arising from capital gains or losses on a range of marked-to-market assets but also via corporate investment spurred by cheap funding.

The graphical analysis in section 3 lends tentative support to this idea. The data, however, also show another key aspect to the money-asset price relationship, namely, that while money growth impacts on asset prices the two are not necessarily positively correlated at all times. This is because in periods of uncertainty excess money growth may actually reflect a change in the composition of wealth away from financial assets and so accelerating money growth can occur alongside static or even declining asset prices.

These two key features of the money-asset price relationship – firstly, excess money growth increasingly impacting on asset prices and, secondly, the exact timing and nature of the effect being dictated by the degree of uncertainty prevailing in the economy – allow us to interpret the patterns of asset and money market behaviour in recent years. The first year of the new millennium was marked by investor confidence, which saw financial markets continue to do well. A fall in the overall asset price index (the simple unweighted average of all available asset class price indices) started during 2001 and lasted until about the end of 2002 in all three areas. In 2001, each area also experienced a sharp pickup in the growth rate of the money stock as investors sought safety in the certain nominal value of money against the turmoil in financial markets (see middle panels of Charts 11 to 13). Another common feature around this time is the emergence of negative real interest rate gaps (see bottom panels of the same Charts) as short-term real interest rates fell relative to their corresponding equilibrium values. This is an additional indicator of the very liberal liquidity conditions that began to prevail at this time.

Also common to all three areas has been the positive response of the overall asset price index to these liquidity conditions as uncertainty began to fade towards the end of 2002 and the beginning of 2003. Not only did the overall asset price index start to escalate but so too did each of the individual asset price indices (which together comprise the overall index) covered in Charts 8 to 10. This may well be a unique event and is very likely to have been the result of the more-than-ample liquidity conditions prevailing in the global economy at this time as agents began to spend money balances hoarded during the period of uncertainty.

The rush to the safety of money in the 2001 to 2002 period following the heightened uncertainty generated by the collapsing dot-com bubble (and the many other substantial shocks which impacted the global economy during this period) was driven by both precautionary and speculative motives. The former was needed as a hedge against the prevailing financial market uncertainty and the latter by a desire to hold money in idle balance form until such time as confidence returned to the markets when those funds could then be released and used to take speculative positions on future asset price movements. It is likely that this began to happen in early 2003. Although uncertainty and heightened risk aversion seems to have lasted longer than might have been anticipated, much of the precautionary money holdings were no longer attractive in the light of the much reduced uncertainty moving into 2003. Both this and the speculative demand for holding money would have faded, thereby freeing up money holdings and starting a search for yield. This search for yield seems to have affected most, if not all, financial markets more or less simultaneously rather than sequentially, as has been suggested elsewhere.[55]

This description of asset price and liquidity developments in recent years shows the nature of the relationship between the two. It indicates that money growth will not necessarily coincide immediately with asset price rises if that money is hoarded – the timing of the increase is unknown and is dictated by the preferences of its holder, in particular his attitude towards risk. Once uncertainty abates and the demand for money as an asset wanes, however, much of the precautionary balances are likely to become transactions balances while balances held for speculative purposes begin to be used for that purpose. This is likely to increase the demand for financial assets and, with limited short-run asset supply, result in asset prices increasing rapidly. The temporal relationship between excess money holdings (relative to underlying transactions demand for goods and services) and asset prices then, being a function of uncertainty, is itself likely to be uncertain. Furthermore, as the actual behaviour of asset prices and excess money in recent years illustrates, these interactions between liquidity and assets have been made much easier by financial liberalisation and innovation.

4.2 Implications for Financial Stability

It is difficult to say what the dangers posed for financial stability from this relationship between liquidity and asset prices are. This is in part because, as argued, there may be some elements to this interaction that have always existed but are now coming more to the fore as financial liberalisation and innovation make it easier for the public to adjust their holdings of money and other assets. They, therefore, need deeper consideration. The most basic concern for financial

[55] The search for yield has received a good deal of attention especially in financial stability reports (see the ECB's Financial Stability Review and the Global Financial Stability Report of the IMF). The view in those publications, however, appears to be that there is a search for yield in particular asset classes with this search manifesting itself sequentially as funds move from one asset class to another.

stability, nevertheless, follows from the recognition that the money-asset relationship can alter and can do so relatively quickly, meaning that asset prices can experience rapid change. Sharp changes in asset prices are undesirable from a financial stability perspective. A rapid pick-up in asset prices may encourage speculation of further price increases driving asset prices into territory unwarranted by underlying economic conditions while a subsequent sudden fall in asset prices could weaken financial institutions' balance sheets substantially.

The danger is that excess liquidity will cause asset prices to become misaligned from their fundamental, real economy-based determinants. This, in itself, distorts the allocation of resources and may lead to subsequent economic weakness and financial fragility as projects signalled as being viable by financial markets prove not to be in the event. Another, more obvious risk arises from distorted asset prices collapsing, which, if accompanied by loan defaults on leveraged positions, could quickly erode the prudential buffers available to the banking system and threaten systemic collapse.

Monetary and asset price developments, therefore, seem to be interlinked. The changing relationship between money and asset prices provides authorities whose task it is to monitor financial stability risks with a number of practical difficulties. It seems possible also that this interlinkage may be becoming stronger and with the scope to be more variable over time as financial innovation and liberalisation enables the public to adjust its holdings of money and other assets more easily and cheaply and, therefore, also more rapidly. This is a feature of behaviour which we feel is tentatively confirmed by the recent developments in asset and money markets outlined in previous sections.

The financial stability implications of the relationship between liquidity and asset prices have received greater attention in recent years. The Bank for International Settlements (BIS) has been to the forefront of this area of research and has published a number of key papers on the subject.[56] Much of the BIS research

[56] Much of the literature emanating from the BIS has already been referenced in footnote 41.

seems to stress that while a stable monetary environment may not be sufficient to eliminate excess tendencies in financial markets, it does contribute to reducing those financial risks. As Borio and Lowe (2002) argue, however, it is the simultaneous build-up of imbalances in monetary variables, such as credit, and in asset prices that should be of most concern. Another thread running through BIS research is that greater financial liberalisation inherently encourages greater procyclicality in markets. The changes in financial markets that have occurred in recent decades may have potentially increased the scope for financial imbalances to occur and raised the vulnerability of the system to boom and bust cycles in asset prices.

5. Conclusions

Recent history has provided much evidence that asset price collapses from levels that were not consistent with their fundamental determinants has probably been the single most destructive influence on financial stability in a number of countries. Although liquidity is a nebulous variable and difficult to measure, the limited empirical evidence available would suggest that in the newly liberalised financial market environment, excess liquidity tends increasingly to be deflected into financial asset markets and inflates asset prices. Despite the measurement difficulties, liquidity is an issue to which those charged with financial stability should devote close and warranted attention.

If the recent and current excess liquidity does not show up in general inflation but instead distorts asset prices, this can be as damaging as higher general inflation (if not more so) to the overall performance of the real economy and hence to the systemic health of its financial sector as higher general inflation. Misaligned asset prices not only distort the allocation of resources, they also tend to collapse resulting in sharp increases in non-performing loans and insolvencies possibly leading to financial system weakness.

This article has focused on the connection between monetary variables and asset prices since 2000. The laxity of the liquidity situation was proxied by two measures, namely excess money and the gap between the short-run actual and (estimated) equilibrium real interest rates. A coherent story can be told about the relationship between the evolution of these two variables on the one hand and developments in asset prices on the other over approximately the last five years. It suggests that ample liquidity may be an important driver of the overall asset price increases that have taken place in recent years. A generalised search for yield across all asset classes that was prompted by the decline in financial market uncertainty and the consequent release of liquidity from its safe haven has indeed affected asset prices across the board. Furthermore, this process may not yet have run its course. The bottom line is that the recent and current ample global liquidity should be a source of concern for financial stability.

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Appendix. Data Description

Chart	Description
1a	United States, Broad money and components, M2 Monetary aggregate United States, Consumer Price Index, All items
1b	Euro Area, Monetary aggregate M3, All currencies combined Euro Area, Consumer Prices, All Items, Total (linked and re-based), Index
1c	United Kingdom, Broad money and components, M2 Monetary aggregate United Kingdom, Consumer Price Index, All items
2a	United States, Broad money and components, M2 Monetary aggregate United States, GDP by Expenditure, Gross domestic product, Current Prices
2b	Euro Area, Monetary aggregate M3, All currencies combined Euro Area, Gross Domestic Product, Current Prices
2c	United Kingdom, Broad money and components, M2 Monetary aggregate United Kingdom, GDP by Expenditure, Gross domestic product, Current Prices
3a	United States, Treasury Bills, 3 Month Yield Average
3b	Euro Area, Euribor 3 Month Average
3c	United Kingdom, Treasury Bills, 3 Month Average
6a	United States, GDP by Expenditure, Gross domestic product, Current Prices United States, Broad money and components, M2 Monetary aggregate United States, Treasury Bills, 3 Month Yield Average United States, Monetary Aggregate M2 Own Rate
6b	Euro Area, Gross Domestic Product, Current Prices Euro Area, Monetary aggregate M3, All currencies combined Euro Area, 5-year Euro area Government Benchmark Bond Yield Euro Area, Euribor 3 Month Average
6c	United Kingdom, GDP by Expenditure, Current Prices United Kingdom, Broad money and components, M2 Monetary aggregate United Kingdom, Government Benchmarks, 5 year Average Yield United Kingdom, 3 Month Deposit Rates
7a	United States, Broad money and components, M2 Monetary aggregate United States, Consumer Price Index, All items
7b	Euro Area, Monetary aggregate M3, All currencies combined Euro Area, Consumer Prices, All Items, Total (linked and re-based), Index

7c	United Kingdom, Broad money and components, M2 Monetary aggregate
	United Kingdom, Consumer Price Index, All items
8a	United States, J.P. Morgan, Government Bond Index, All Maturities, Total Return, Close
	United States, CGBI USBIG Corp. AAA/AA 1-10Y - Tot Return Index
	United States, CGBI USBIG Corp. BBB 1-10Y - Tot Return Index
	United States, Lehman High Yield, Caa
	United States, Dow Jones Wilshire, Broad, 5000 Index (Full Cap), Price Return, Close
	United States, NCREIF, National Index, Total Return
	United States, Spot Oil Price, West Texas Intermediate
	United States (World), J.P. Morgan, Emerging Markets Bond Index Plus (EMBI+), Total Return
	United States, Emerging Markets, MSCI, Index, Close
9a	Euro Area (Germany), J.P. Morgan, Government Bond Index, Average
	Euro Area, J.P. Morgan, Maggie Euro Credit, AAA Index, Total Return
	Euro Area, J.P. Morgan, Maggie Euro Credit, BBB Index, Total Return
	Euro Area, Standard & Poors, Euro Index, Price Return, Close
	Euro Area (World), Europe Brent Oil Spot Price, Close
10a	United Kingdom, J.P. Morgan, Government Bond Index, Average
	United Kingdom, IBOXX £ Coll. All Mats. AAA - Price Index
	United Kingdom, IBOXX £ Corp. All Mats. BBB - Price Index
	United Kingdom, FTSE 100, Index, Price Return, Close
	United Kingdom, IPD All Property Index, Capital Growth
	United Kingdom (World), Crude oil price, FOB spot Brent
	United Kingdom, UK-DS IT FTA Group Emerging Markets. - Price Index

Sources: Datastream, ECB, EcoWin, IFS, and Board of Governors of the Federal Reserve Board.
Note: Data for Charts 4, 5, 11, 12 and 13 are derived from the above series. See article for details.

The New Dynamic between US Stock Prices and Money Holdings

Frank Browne and David Cronin

Abstract

The financial crisis has had the effect of focusing attention on the role of liquidity, but more specifically excess liquidity, in driving asset prices to unsustainable bubble levels. We think this focus is fully warranted. However, we consider that, in this critical relationship between money and other financial assets, it is only half the story. Little attention has been devoted to date to examining whether this same money-financial asset interaction might also be responsible for the excess liquidity having been generated in the first place. We argue that it is. A new dynamic is at play in which newly liberalised and democratised financial markets, a hugely expanded role for (Keynesian) liquidity preference (driven by an asset demand for money), and a monetary policy constrained to respond to threats to financial stability play key roles. We present evidence, using the asset pairing, money and equities, which is supportive of our argument. These results have important implications for both monetary policy and financial stability.

Keywords: money hoarding and dishoarding; liberalised and democratised financial markets; asset price cycles; monetary policy; financial stability

The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Central Bank of Ireland or the European System of Central Banks.

Introduction

Financial markets in advanced industrial countries have been subject to a systematic evolution over recent decades that has left them radically altered relative to, say, the early 1970s. Ongoing financial market deregulation and innovation has enabled grass roots investors (such as households and small firms) to gain much easier and cheaper access to financial markets, both in their own home countries and abroad. It would not be inaccurate to say that, during this period, financial markets have been subject to a process of democratisation and that these markets are now, to all intents and purposes, fully democratised in that access to them is available to all. This description is particularly apt when applied to US financial markets, which is why we focus on that country in this paper.

The argument that we make here is that this new, democratised financial market setting has critical implications for patterns of substitution between money and financial assets. We illustrate this point by examining just one asset pairing, money and equities. The effect of the liberalised and democratised financial market environment has been to generate new and robust substitution patterns between these two assets over time according to the level of uncertainty in the economy. We think that these patterns pose tricky problems for monetary policy and a substantial danger to financial stability. These difficulties would be compounded if replicated between money and other risky asset classes, which we do not examine here.

The motives for holding money balances are well known - i.e. as a transactions and settlement medium on the one hand and as an asset which serves as a store of value on the other. In its relationship with equities, money can be used to buy and sell stock and as an alternative store of value to company shares. Friedman (1988, p. 221) notes a “close inverse relation between the level of the Dow Jones stock market index and the velocity of the monetary aggregate now designated M2 by the Federal Reserve System” over the period 1961 to 1986, where the velocity of money is nominal GDP divided by the money stock. He identifies four factors impacting on the nature of the relationship. The first three are the dominant factors for the period he was examining, as their effect was, individually and collectively, to determine the inverse relationship he observed. The first factor relies on a wealth effect and, although not stated explicitly, the idea that money is a luxury good (a view espoused by Friedman in other publications). A rise in stock prices increases the wealth to income ratio, which, because money is a luxury good, results in a higher money to income ratio (i.e., a fall in income velocity). The second factor also rationalises an inverse relationship by arguing that a rise in stock prices implies an increase in the dollar volume of financial transactions, which leads to a greater demand for money to facilitate these transactions. The third effect suggested by Friedman is that, as their prices increase, stocks are assumed to become riskier and, with an unchanged level of investor risk aversion, investors want to acquire additional holdings of safer assets of which money will probably be the most attractive. This type of behaviour also serves to reduce income velocity.

The fourth and final factor identified by Friedman is a substitution effect. It operates on the interaction between the variables in the opposite direction to the other three factors just noted. An expected rise in the return on equities (proxied by the share price index) leads to substitution out of money resulting in an increase in the velocity of circulation.

We contend that the relative strength of the motives for holding money balances has been transformed radically by the democratisation of financial markets and that Friedman's fourth factor in the money-stocks relationship, the substitution effect, is now much stronger as a result. So whereas Friedman is of the view that there is a "close inverse relation" between stock prices and the velocity of money, we believe that there is now a "close positive relation" between them. In our view, in the pre-liberalised-pre-democratisation period, the relationship between money and the stock market was dominated by the demand for money as a transactions and settlement medium for completed share trades. In the post-liberalised-post-democratised period, this transactions demand has been displaced by an asset/store of value demand as the dominant motive for holding money balances with a view to participation in the stock market. This heightened asset demand for money derives from stronger precautionary and speculative motives for holding it in a situation in which retail investors are now much more exposed to the vicissitudes of the stock market.

Observers such as Congdon (2005) argue that general movements in asset prices are strongly influenced by the money supply and that ignoring monetary aggregates could have destabilising effects on the economy. Economists at the Bank for International Settlements (e.g., Borio and Lowe (2002) and Borio and White (2004)) have been persistent in flagging the role of "ample liquidity" in instigating the search-for-yield episode of the mid-2000s. This, ultimately, may have sent asset prices shooting upwards during those years and may have contributed to the 2007/8 financial crisis. There has been little attention, however, devoted to examining the possibility that this "ample liquidity" itself might have been the product of the interaction between money and financial markets, along the lines we are suggesting here, i.e. that strong substitution effects are now at work in the money-financial asset relationship. We would agree with the view that an excessively loose monetary policy pursued by central banks during the 2000s facilitated and drove the search-for-yield phenomenon. Yet, was that loose stance itself forced on central banks by the dynamics of the interaction between money and financial markets? We would say yes and will explain why later.

The empirical focus in this paper is on the relationship between the real Standard and Poors 500 (S&P 500) price index and US M2 money holdings and how it has evolved over time.[57] We demonstrate how the behaviour of the income velocity of money (nominal GDP divided by the M2 money stock) in response to uncertainty appears to have changed in the transition between two periods that correspond to periods of pre- and post-democratisation of financial markets, respectively. We also show how the correlation between S&P 500 price changes and changes in the velocity of money has become strongly positive in recent times, having previously been negative. We argue that these developments are attributable to the improved ability of the public to manage its wealth holdings, and in its enhanced ability to shift wealth between money and other assets in response to the level of uncertainty in the economy.

[57] The S&P 500 Price Index data used in this paper are inflation-adjusted, i.e. the Index has been deflated using the Consumer Price Index. Description and sources of all data used are included in the appendix.

New correlation patterns in the data – a case to be addressed?

Financial market democratisation is a fairly amorphous process which makes it difficult to pinpoint a starting date and a completion date. There is, likewise, no easily identifiable chronological demarcation line dividing pre- and post-democratisation periods. The collapse of the Bretton Woods system of fixed exchange rates, the creation of money market mutual funds, the removal of Regulation Q interest rate ceilings, and, in the specific case of US stock trading, the ending of NYSE fixed commissions, were among the key events that liberalised US financial markets and enhanced household participation in those markets. Bertaut and Starr-McCluer (2001) report that the share of US households holding risky assets (either directly held or indirectly held though mutual funds and other accounts) rose from 31.9 percent in 1989 to 49.2 percent in 1998, a substantial rise in a short period. One could reasonably expect this share to have increased further since 1998.

The interplay between money variables and the stock market in the United States has received some, if not adequate, attention in the literature. Dow and Elmendorf (1998) and Carlson and Schwartz (1999) find US M2 and its components acting as a "gateway" for redirecting and rebalancing funds in household portfolios. The gateway effect will be triggered by both rises and falls in stock prices, and it would appear to have become more important between the 1980s and the mid-1990s as households gained easier and cheaper access to financial markets with practical recourse to these markets being provided by mutual funds in particular.

We would think that the early 1990s constituted the time when US financial markets were substantially democratised and when the new dynamic between stock markets and money came into noticeable effect. The data examined here cover the period 1967Q2 to 2010Q2. To assist the analysis below, we will exclude the interim hybrid period between the mid-1980s and the early-1990s from our empirical analysis so as to be able to draw a stronger contrast in behaviour between a period of financial market repression (before the mid-1980s) and a period of virtually full liberalisation and democratisation (after the early-to-mid 1990s).

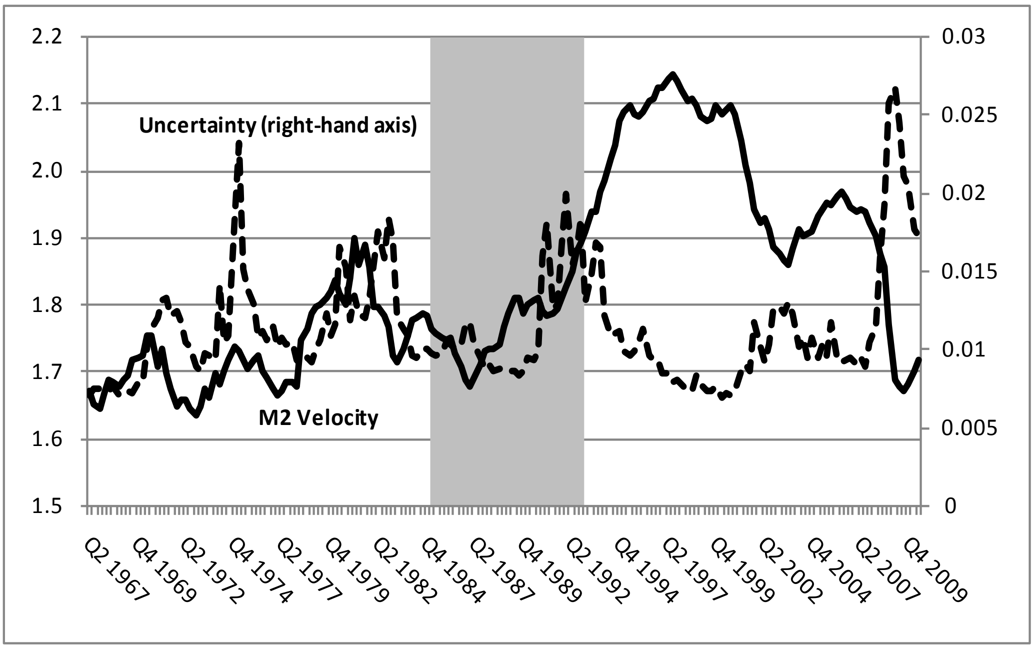
The periodicity of the data used is quarterly. Our preferred velocity variable is US nominal GDP divided by the US M2 money stock. A decrease in the velocity measure indicates a rise in money holdings relative to economy-wide transactions needs, all other things being equal, and vice versa. The starting date (1967Q2) is determined by the earliest available data on the Consumer Confidence Index (CCI). It is a consumer sentiment indicator calculated from survey data by The Conference Board. The inverse of this is used here as a measure of uncertainty.

The CCI-based measure of uncertainty and the velocity of the US M2 money stock are graphed in Figure 1 below. The interim hybrid period observations are plotted against a shaded background, covering the period 1985Q1 to 1992Q4. In the era of financial repression, before 1985Q1, the simple contemporaneous correlation between the uncertainty variable and M2 velocity was positive at 0.36 - the velocity of money and the level of uncertainty tended, broadly speaking, to rise and fall together. The reason why this positive correlation arises for that period can be explained as follows. An increase in uncertainty (a deterioration in consumer sentiment) would probably have likely led to a reduced need for money as a transaction medium, not only in the overall economy, but also because a fall in share values associated with greater uncertainty would have caused a decline in the volume of financial transactions requiring less money as a transactions and settlement medium (a fall in M2 demand and an increase in velocity).

For the later, financially liberalised and democratised period (1993Q1-2010Q2), the contemporaneous correlation value between the two series changes sign to -0.81. This is a dramatic change in value, with Figure 1 testifying to the changed correlation between the two series. Our view is that this is due to the changing role of money for stock market participants between the pre- and post-democratised periods. Nowadays, an increase in uncertainty is associated with a decrease in velocity as investors substitute out of equities and into the safe haven of money, and vice versa. An increase in liquidity preference (i.e., increase in the demand for money to hold) has to be accommodated by the central bank – otherwise interest rates will rise, at an inappropriate juncture in the economic cycle. The actual money stock, therefore, also increases in response to this demand. The greater precautionary demand for money as an asset dominates the overall demand for money even as the transactions demand probably falls off as the economy slows under the sway of deteriorating consumer sentiment and declining stock prices.

This type of conjuncture could also see an increase in the asset demand for money driven by speculative considerations. Speculators will want to be in a position to purchase assets when they believe profitable investment opportunities arise from asset values having fallen to bargain basement levels. The only way they can be sure that they will be in such a favourable position is to hold (hoard) liquidity. These two sources of asset demand for money come to the fore in periods of heightened uncertainty when the equity market is increasingly populated by grass roots investors as it has become in the post-democratised period.

Figure 1: The velocity of money and uncertainty, 1967Q2-2010Q2

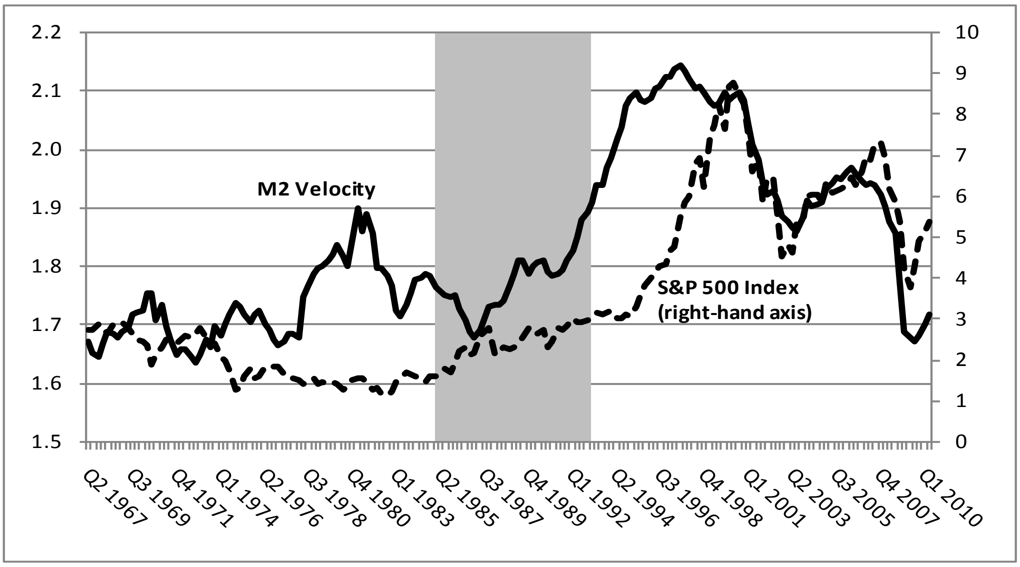


Note: Shaded area represents period from 1985Q1 to 1992Q4.

We would expect the contemporaneous correlation between M2 velocity and the S&P 500 price index to be consistent with this broad narrative. It is, as we can see from Figure 2. The period of financial market repression (1967Q2-1984Q4) was characterised by a negative correlation (-0.70 over the period) between money velocity and share prices. This switched to a positive, if low, correlation for the democratisation period (0.16). When the initial phase of this later period (i.e., 1993Q1 to 1999Q4) is dropped from this correlation calculation (because it is clear from Figure 1 that equity prices were lagging velocity and the correlation, although remaining strong, is not contemporaneous) then the contemporaneous correlation goes to 0.85 – a dramatic change from the 1967Q2-1984Q4 period and mirroring the change in the contemporaneous correlation value between uncertainty and velocity already noted.

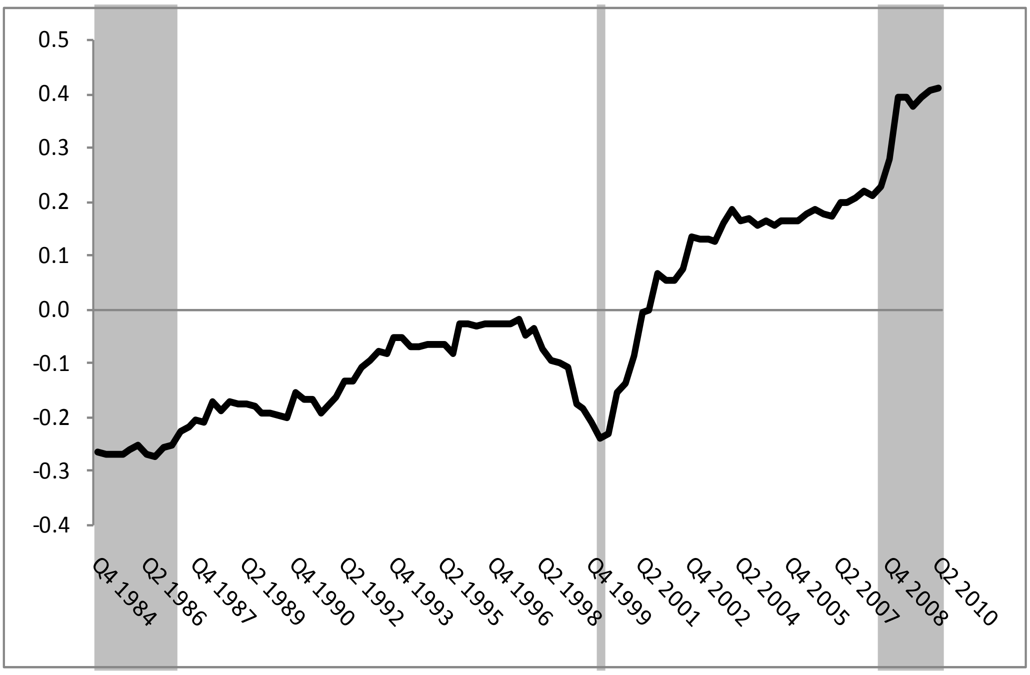
Figure 3 follows on from Figure 2 by showing that there has been an increasing correlation between S&P 500 price changes and changes in M2 velocity over time. In that chart, the correlation values are calculated on a rolling 70-quarter basis so that the first correlation value plotted is for the period 1967Q3-1984Q4, in the pre-democratisation period, and the last value for 1993Q1-2010Q2, in the post-democratisation period. The correlation between the two variables rises from an initial value of -0.26 to a final value of 0.41.

Figure 2: The velocity of money and the S&P 500 price index, 1967Q2-2010Q2



Note: Shaded area represents period from 1985Q1 to 1992Q4.

Figure 3: Rolling correlation values of S&P 500 price changes and changes in the velocity of money, 1984Q4-2010Q2



Note: Shaded areas represent correlation values that are statistically significant at the 5 percent level.

A rationale for the new dynamic

Our perspective in this area stems from the greater scope for rapid and substantial substitution between equities and money in modern, democratised financial markets, affording investors great latitude in managing their portfolios. This brings money's dual role as both a transactions and settlement medium on the one hand and as a store of value on the other to the fore. Money is an extremely good store of value and this feature generates both precautionary and speculative motives for holding it. A short-term increase in the money stock relative to trade needs (as reflected in a decline in money velocity) should mainly reflect precautionary and speculative behaviour at work.[58] In effect, this reflects the public's desire to hoard money as a store of value but with the knowledge that it is available to purchase assets (or goods) in the future if so required.

In the new world of democratised finance, asset prices are increasingly affected by substitution out of money and into financial assets in periods of growing

[58] It is also possible that some of the quarter-to-quarter change in the income velocity of money represents a response to changes in the net opportunity cost of money and/or an ongoing technological shift in the amount of real money balances required to fulfil transaction needs. The latter effect is likely to be a negligible influence in the short or medium term.

confidence (or even irrational exuberance), and out of financial assets and into money in periods of waning confidence or market uncertainty. We believe that in financial markets with substantial grass roots participation, Keynesian liquidity preference is now a much more powerful force than it was in the time of Keynes, which was long before financial markets were democratised according to our characterisation.

The relative motives for holding money have been transformed by the democratisation process. In the pre-democratisation period, the need to transact and settle equity market transactions was the dominant motive for stock market participants to hold money. With the greater involvement of retail investors in the stock market in the post-democratisation era, the demand for money as an asset has come to play a much greater role than it did previously. More democratised financial markets give households greater latitude in reconfiguring the composition of their wealth holdings in response to extraneous events.

Among the key influences on asset management is likely to be the level of uncertainty in the economy. The broader participation in financial markets that is implied by democratisation also means greater exposure of households to economic and financial market uncertainty. A rise in uncertainty can be expected to see households attempt to change the composition of their wealth holdings away from risky asset categories, such as stocks, in favour of money. Likewise, they will be inclined to invest (or re-invest) in riskier assets in a search for yield when uncertainty fades.

This behavioural change is necessary to explain the new dynamic between money and equities but so also is the role of money, created to excess, in driving up asset prices, and into bubble territory in extreme cases. We argue that the role of the interaction between money and financial markets goes much further than excess money creation and its repercussions for asset prices – it also contributes to the excess liquidity in the first place. This is because an asset price bust raises the demand for money as an asset (safe haven), especially in the new democratised environment. This increased demand must be accommodated by the central bank to avoid interest rates rising in circumstances where financial markets and the real economy are under strain.

As a result, there is a large increase in the money stock as the central bank is forced to accommodate the shift of investments out of the stock market. The central bank is not likely to meet with much success in attempting to sterilise this injection of money at a later stage. When confidence returns to financial markets, there will be a substantial monetary overhang. The improvement in investor sentiment combined with ready purchasing power is then likely to kick off a new asset price cycle and may even ratchet up its amplitude in comparison with earlier cycles.

Figures 4 and 5 show how both the S&P 500 price change and the change-in-velocity respond to a positive innovation or shock in the other variable for the 1967Q2-1984Q4 and 1993Q1-2010Q2 periods, respectively.[59] The responses in the earlier period (Figures 4a and 4b) see a significant negative effect for each variable being registered in the same quarter that the innovation in the other variable takes place, but no significant effect occurs in subsequent quarters. The interpretation of the S&P 500 price change shock's effect on the velocity variable in this period is that it was dominated by a rise in equity prices, generating same-period increases in the transactions demand for money from stock market participants. Likewise, a positive shock to M2 velocity at that time led to a contemporaneous fall in S&P 500 prices as a lower transactions demand for money by stock market participants was associated with fewer stock trades and a decline in stock prices.

In contrast, in the later, post-democratisation period, there are significant and prolonged positive responses to shocks from either variable (stock price or velocity) to the other variable (Figures 5a and 5b). So, in this period, a positive velocity shock causes a relatively long-lasting, though still transient, rise in equity prices. This reaction is consistent with the view that a dishoarding (hoarding) of money balances is associated with an increase (decrease) in the price of a risky asset, such as equities. Similarly, a positive shock to equity prices causes a

[59] The plots in Figures 4 and 5 are based on generalised impulse responses based on a vector autoregression (VAR methodology). The S&P price change, change-in velocity, and CCI series (measured in log-natural first-difference form) used heretofore are included in the VAR estimations. The VAR lag length chosen is one, based on an examination of various test statistics across both sample periods, and a constant term is included in all VAR equations.

positive change in the velocity of money. We interpret this evidence as saying that good returns in equity markets prompts investors to dishoard their idle money holdings and substitute in favour of stocks. These results back up our view that the role of money in its interaction with stock markets has shifted from being predominantly one of a transactions medium to being mainly one of an asset or store of value between the pre- and post-democratisation periods.

In other research on this general topic conducted at the Central Bank of Ireland, Browne and Kelly (2009) undertake an econometric assessment of US money demand and, specifically, the influence of uncertainty on it. Employing also a pre-democratisation/democratisation split in the time series, they find that an increase in uncertainty (also measured using the inverse of the CCI) in the pre-democratisation era would have resulted in a decline in the transactions demand for money owing to pessimism regarding income and employment prospects. In the post-democratised era, they find the precautionary/store-of-value function of money dominating the transactions demand such that a rise in uncertainty results in a net increase in the demand for money.

Figure 4a: Impulse response of the S&P 500 price change to a change-in-velocity shock, 1967Q2-1984Q4

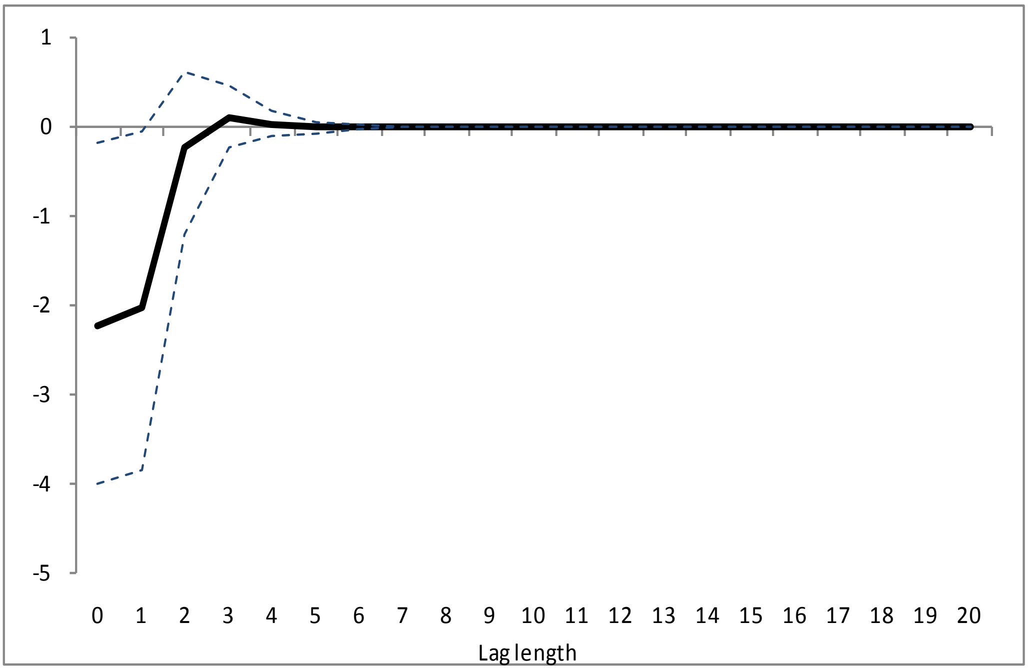
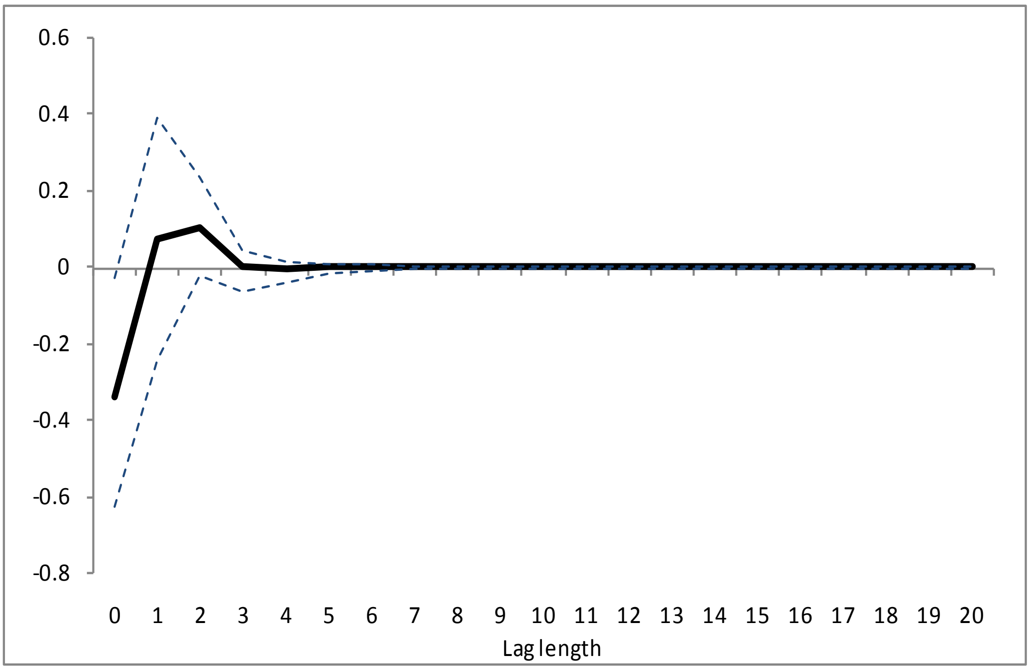


Figure 4b: Impulse response of the change-in-velocity to a S&P 500 price change shock, 1967Q2-1984Q4



Note: The solid lines indicate the impulse response and the jagged lines the related bootstrapped error bounds at the 95 percent confidence level.

Figure 5a: Impulse response of the S&P 500 price change to a change-in-velocity shock, 1993Q1-2010Q2

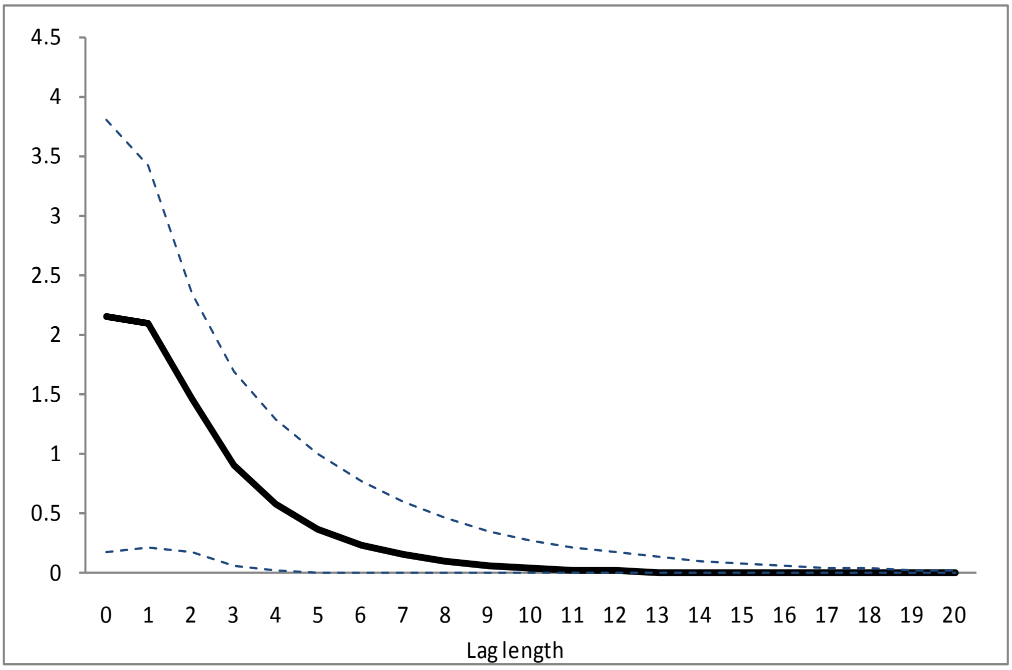
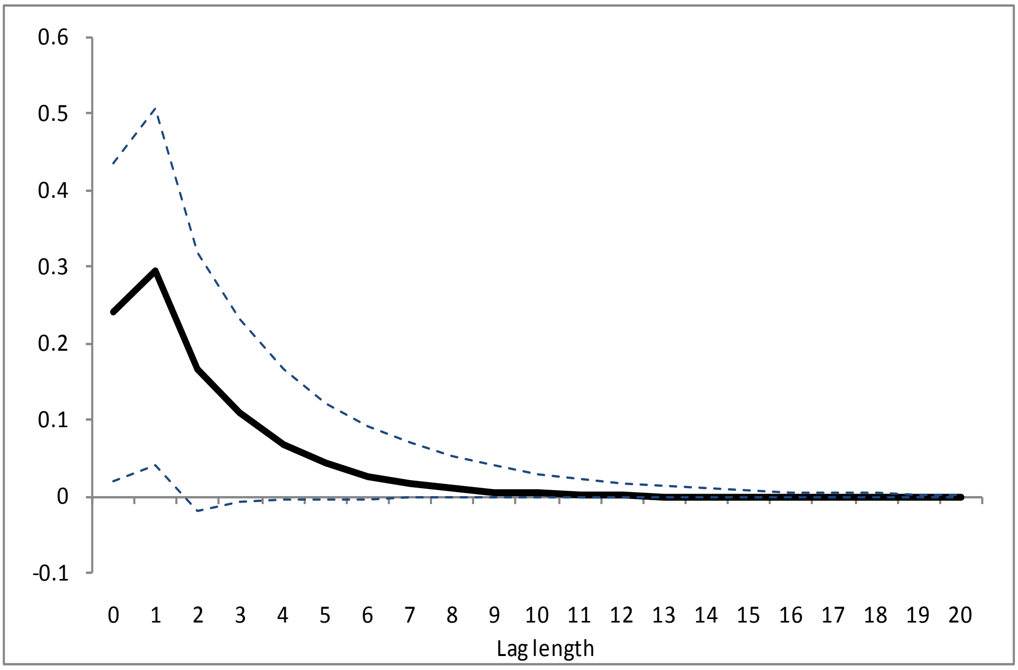


Figure 5b: Impulse response of the change-in-velocity to a S&P 500 price change shock, 1993Q1-2010q2

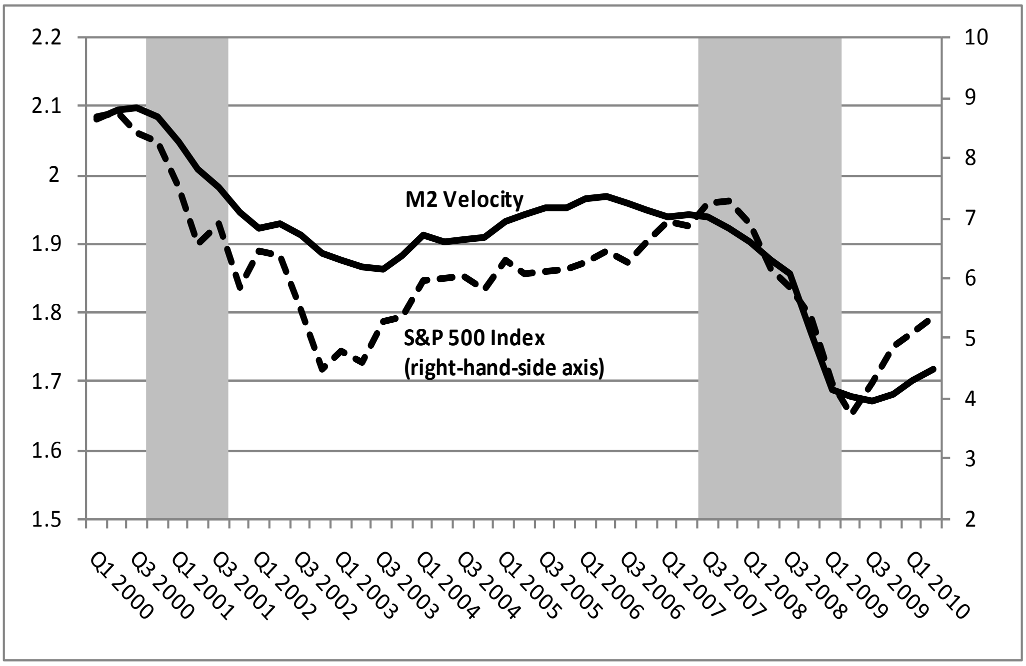


Note: The solid lines indicate the impulse response and the jagged lines the related bootstrapped error bounds at the 95 percent confidence level.

The equity price-velocity relationship in the new millennium

If we restrict attention to the part of the post-democratisation period beginning at the start of the new millennium then the close co-movement between the income velocity of money and stock market prices is particularly evident. The performance of the S&P 500 price index from 2000Q1 to 2010Q2 is plotted in Figure 6, alongside the velocity of M2 money stock for the same period. It can be seen that the two series track each other closely during those years – the contemporaneous correlation between them for the period is 0.85.

Figure 6: The velocity of money and the S&P 500 price index, 2000Q1-2010Q2.



Note: Shaded areas represent periods of recession, as identified by the NBER.

The narrative for the 2000s can be told as a sequence of phases of the economic cycle. In terms of exposition, this is helped by the inclusion of shaded areas representing the 2001Q1-2001Q4 and 2007Q4-2009Q2 US recessions, as identified by the NBER, in Figure 6. Another feature of the decade was the loose stance of monetary policy at critical parts of the economic cycle. The short-term real interest rate was extremely low in particular in the 2000s relative to its level at similar points in previous business cycles. We illustrate this through Figure 7a which shows how the real effective Federal Funds rate behaved through the 2001Q1 and 2007Q4 cyclical peaks, as identified by the NBER, relative to the average of the five cyclical peaks prior to those two.[60] The real interest rate was rising prior and subsequent to the cyclical peak, on average, in the pre-2000s, while it dipped and was at a relatively low level after the 2001 and 2007 peaks.

It can also be seen in Figure 7b that real money growth at the 2001 and 2007 cyclical peaks was much higher than through the previous peaks' average. Moreover, real money growth increased subsequent to the peaks of the 2000s whereas it declined, on average, in earlier post-peak periods. These data then point to a much looser monetary policy stance in the two most recent US economic cycles than occurred in those phases in earlier decades. Such a stance would have helped feed the search-for-yield behaviour of financial market participants in the 2000s by providing them with cheap access to funding balances, as well as accommodating their desire for money holdings when financial market performance started to deteriorate.

Figure 6 shows that the early 2000s saw a decline in both M2 velocity and the S&P 500 index. As well as the defined 2001 recession, uncertainty was at elevated levels at that time relative to late 1990s values (see Figure 1). It is unsurprising then, given our previous discussion, that the S&P price index declined during this time. There would, as a result, have been a greater demand to hold wealth in the form of money balances. The extremely loose stance of monetary policy in the early 2000s (the tinted lines in Figures 7a and 7b have already illustrated this) would have accommodated such hoarding behaviour.

When confidence returned (around mid-2003), the excess liquidity arising from the monetary policy stance of that era would be expected to have driven a search for yield, thereby raising equity returns. This is what can be seen to have transpired (Figure 6). The S&P 500 price index increased, in real terms, by 62 percent between 2003Q2 and 2007Q3. Over the same period, the velocity of the M2 money stock rose also**.**

[60] The five earlier peaks occurred in 1969Q4, 1973Q4, 1980Q1, 1981Q3 and 1990Q3. The plotted series in both Figures 7a and 7b are each eight-quarter moving averages, with the variable plotted at the last quarter of those eight.

Figure 7a: Real interest rate through the cyclical peak, 1967Q1-2010Q2

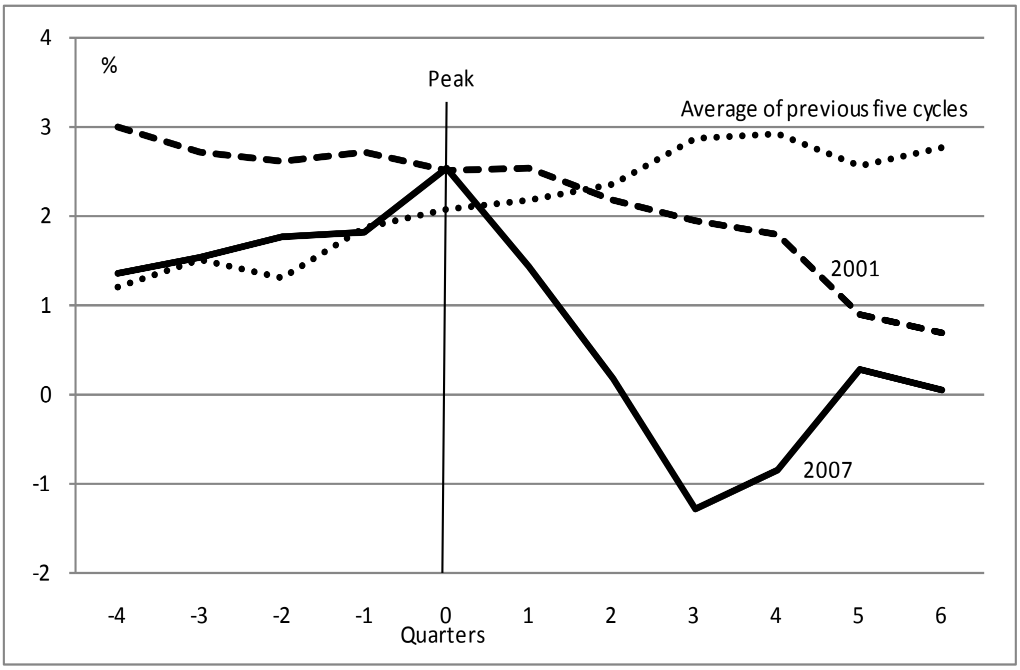
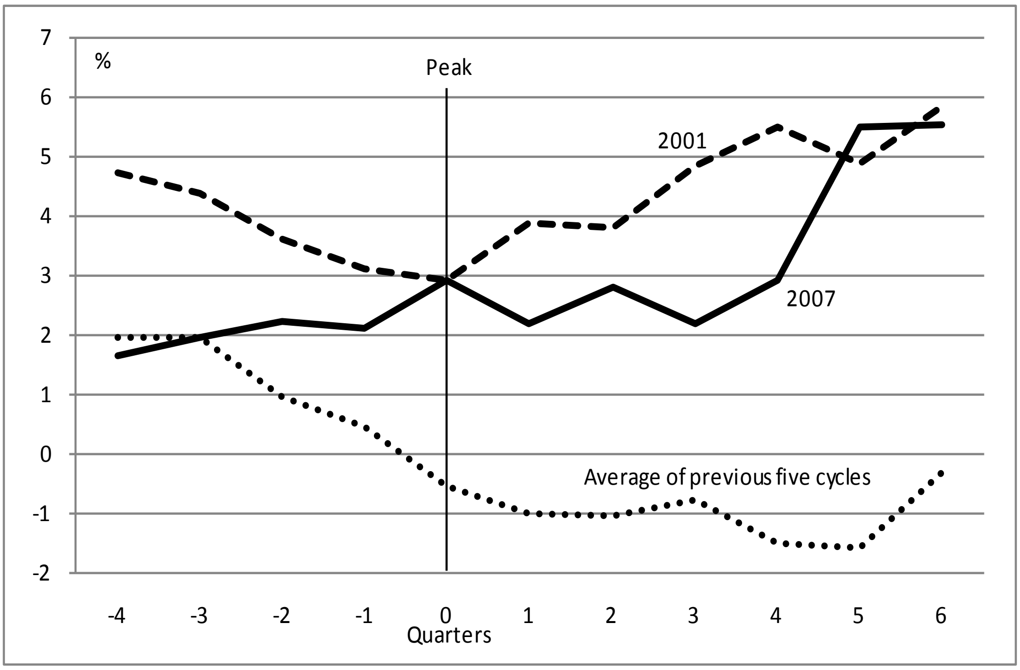


Figure 7b: Real money growth rate through the cyclical peak, 1967Q1-2010Q2



The next identifiable phase in the development of the two variables occurs between 2007Q4 and 2009Q2. The deteriorating economic and financial environment of late 2007 to early 2008 triggered a flight-to-safety response from investors. They offloaded financial assets in general and built up their money stocks as the financial crisis of 2007/8 took hold. This behaviour is illustrated in Figure 6 where the S&P 500 index can be seen to fall by almost one-half, in real terms, between 2007Q3 and 2009Q2. Over the same period, the velocity of the M2 money stock also declined, reflecting both a preference among the public for holding money as liquid balances and an unavoidably loose monetary policy stance (as shown by the solid lines in Figures 7a and 7b).

Finally, from early 2009 onwards, both money velocity and the S&P 500 index have started to rise. As can be seen in Figure 1, this was a time when uncertainty started to recede after a particularly turbulent year, 2008. It is unsurprising, then, that both the velocity and equity price variables have started to increase in tandem.

Implications for policy

The new financial market environment ushered in by the prolonged process of liberalisation and democratisation of financial markets would be expected to evoke behavioural changes in these markets especially in the wake of large shocks. The greater involvement of retail investors in stock markets means that the natural ebb and flow of uncertainty in the economic environment now throws up quite different patterns of interaction between stock prices and money than occurred in the past. These are not just an academic curiosity: they have implications for both monetary policy and financial stability.

Monetary policy, in particular, would seem to be in something of a bind when it comes to addressing the effects of democratisation, in particular in having to facilitate a safe-haven demand for money in a downturn while realising that money creation at that time is not easily sterilised later. The central bank is not likely to be able "to sit on its hands" in such a situation. The liquidity preference theory of the rate of interest says that a failure to meet an increasing demand for money arising from the efforts of investors to substitute out of financial assets and into money will drive up the market rate of interest according to the standard Keynesian theory of liquidity preference. The extent of the increase will be directly proportional to the strength of the public's preference for liquidity. It is likely to be intense in the kind of situation investors found themselves in during 2007 and, in particular, 2008.

In these circumstances, a sharp increase in the interest rate would be harmful to the real economy. It would have already been hit by a steep decline in most asset prices, which, in itself, impacts negatively on banks' loan losses and causes primary issuance on securities markets to dry up. The resulting credit crunch would be expected to have a powerful deflationary effect. The central bank has little option in such conditions but to accommodate the much greater preference for liquidity among the public. Banks and investors need money created by the central bank as a safe haven against the turmoil in financial markets. Inflated money stock holdings are then held by them as idle balances as insurance during the period of uncertainty.

When confidence returns, excess money balances can drive a search-for-yield and rising asset prices in excess of those warranted by fundamentals. While a central bank is likely to be aware of the difficulties that a loosening of monetary policy can create in subsequent years, its broad mandates of maintaining price stability and contributing to financial stability mean that it is effectively constrained to respond to a systemic threat by adopting such a loose policy stance when a generalised asset price collapse occurs. If the central bank does not react in that way, it might face the prospect of an even steeper meltdown in asset prices, which could leave widespread corporate and household bankruptcies in its wake. Initial financial weakness could easily become systemic in such circumstances. An accumulation of bad debts could result in a credit crunch and drive the economy into an overall deflation, with the emergence of a debt deflation then making the situation progressively worse, with the central bank in danger of missing both its price stability and financial stability objectives at the same time. Experience suggests (most recently in the case of Japan) that it is extremely difficult to extricate the economy from a debt deflation. Equally, it would probably be particularly difficult to do so for the US economy now in light of the way in which debt ratios have trended upwards there over time as indeed they have in other advanced industrial countries.

Conclusion

We have sought to shed new light on the relationship between money and equities. The results point to a substitution effect, governed by the level of uncertainty in the economy, now being the dominant force in that relationship. This state of affairs is, in our view, owing to the transformation of financial markets in recent decades.

The democratisation of financial markets is likely irreversible. In itself, this is to be welcomed as it provides the public with greater control and influence over its financial affairs. It does, however, bring with it particular macroeconomic dangers that we have sought to relate here. Monetary policy would seem to be in something of a bind when it comes to addressing these issues, in particular in having to facilitate a safe-haven demand for money in a downturn while realising that money creation at that time can drive a search-for-yield and an asset price spiral subsequently. It can threaten financial stability later when those prices collapse. It remains to be seen whether and how central banks will address such issues.

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Data Appendix

Consumer Price Index for All Urban Consumers: All Items, 1982-84=100, Seasonally Adjusted.
Source: U.S. Department of Labor: Bureau of Labor Statistics.

M2 Money Stock, Seasonally Adjusted.
Source: Board of Governors of the Federal Reserve System.

Gross Domestic Product, Seasonally Adjusted Annual Rate.
Source: U.S. Department of Commerce, Bureau of Economic Analysis.

Effective Federal Funds Rate, Non-Adjusted
Source: Board of Governors of the Federal Reserve System.

The Conference Board Consumer Confidence Index.
Source: The Conference Board.

S&P 500 Stock Composite- Price Index.
Source: Standard and Poors.

The Interaction Between Money and Asset Markets: A Spillover Index Approach

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Abstract

We employ Diebold and Yilmaz's (2009, 2012) spillover approach to study the relationship between US money and financial assets since 2000. We find that sizeable spillovers arise during periods of economic and financial turbulence (after the 11 September 2001 terrorist attacks, the post-Lehman Brothers bankruptcy period, and in the second half of 2011 when there were concerns about sovereign market developments). Households readjusting their portfolios between holdings of risky financial assets and nominal-certain money may have been the dominant factor at play in explaining this. The interaction of the monetary base with the financial assets in recent years is less than that of M2 with them, a perhaps surprising feature given the balance sheet policies pursued by the Federal Reserve during this time.

JEL Classification: E44, E51, E52
Keywords: Money supply; Asset price behaviour; Spillover index

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1. Introduction

Following the collapse of Lehman Brothers in September 2008 and the ensuing turbulence experienced in financial markets, the Federal Reserve and other central banks chose to pursue what Borio and Disyatat (2010) refer to as "balance sheet policies" alongside standard monetary policy, which focuses on the setting of short-term interest rates. These unconventional policies essentially involve central banks using their balance sheets to influence market prices and conditions directly rather than through the indirect interest rate channel. Such actions affect the composition of private sector balance sheets as well as those of the central banks. This approach appears to be in keeping with Brainard and Tobin's (1968) view that monetary policy works through a "portfolio balance effect" which sees changes in the relative supply of assets held by the private sector leading to changes in their relative yields.

The Federal Reserve initially chose to undertake sizeable purchases of financial assets in late 2008. This involved it acquiring, inter alia, government bonds from banks in exchange for reserve balances at the Reserve. The monetary base has expanded considerably since then following various rounds of so-called quantitative easing. The immediate price effect of the policies on government securities was to alter the yield on them but its effect was expected, and intended, to work beyond that asset market alone and may have had the desired effect. The reduction in the yield on government securities could, for example, have forced fund managers to invest in commodities in a search for yield (Koo, 2011) and to have altered prices in that market. A similar effect might be expected to be at play in stock and currency markets.

As well as the interaction between the monetary base and financial assets, the financial and economic turbulence of recent years may also have affected the dynamic between broad money, specifically M2, and assets. The economics literature in this area has mainly focussed on the broad money-equities relationship. Friedman (1988) argues that there are two conflicting influences on the nature of that relationship. The first is a wealth effect - that is a rise in stock prices increases demand for money both as a transaction medium and as a store of value.[61] The other factor is a substitution effect and works in the opposite direction to the wealth effect with an expected rise in the return

[61] In a cross-country assessment, Caruso (2001) finds that wealth effects in stock markets do impact the demand for money.

in equities leading to a substitution out of money and into stocks. Friedman acknowledges that which factor dominates the other is an empirical issue. His own assessment is that the wealth effect dictates the money-stocks relationship. More recently, Dow and Elmendorf (1998) and Carlson and Schwarz (1999) have found evidence of a link between stocks and money (specifically, M2) in the United States in households' management of their wealth portfolios over time. M2 acts as a gateway for redirecting and rebalancing funds in household portfolios. The gateway will tend to be utilised when there are both rises and falls in stock prices. Browne and Cronin (2012) argue that financial innovation over the last twenty years or so has led to the substitution effect now dominating the wealth effect among the two broad factors identified by Friedman as dictating the relationship between stocks and money. Households will re-orientate their wealth holdings from stocks to money when uncertainty in the economy rises and will reverse this flow when the economic climate is perceived to have improved. If modern financial markets allow agents to switch their wealth holdings more easily between nominal-certain money and risky financial assets in response to the level of uncertainty in the economy then the period since 2008 seems likely to have been one when such substitution would have been quite substantial.

While the literature may have focussed primarily on the money-stock price relationship, linkages between money and other asset classes also arise. Friedman acknowledges that the public will undertake general portfolio adjustment, affecting money, stock and other asset holdings. The link between money growth and commodity prices has received renewed attention in recent years. Commodity prices have been shown to overshoot new equilibrium values in response to money shocks as a result of sluggishness in consumer prices (Frankel (2008), Browne and Cronin (2010)). Variability in money growth rates then may effect considerable volatility in commodity markets due to the overshooting dynamic.

A link between bond markets and monetary base is a standard feature of the monetary policy transmission mechanism. It has been brought back into the spotlight of late by central banks pursuing policies that alter the composition of government debt held by the private sector. These can alter the yield on government securities and can also have effects on returns in other asset classes. A feature of monetary policy in recent years (from 2008) has been the practice of the Federal Reserve announcing details of its programs of quantitative easing, outlining specific asset purchase targets. Announcements on money supply targets in the past (following the 1979 decision by the Federal Reserve to target money growth) had effect on both foreign exchange futures and spot prices. Mussa (1979) indicates that the efficient markets hypothesis would lead one to expect exchange rate movements in response to any such announcements or "news". Sheehan and Wohar (1995) find that expected money growth leads to a depreciation of the US dollar, but that unexpected changes in money supply have insignificant effect. Neely and Dey (2010) conclude from a survey of the literature that macroeconomic announcements in general have effect on exchange rate returns.

This paper then uses an econometric method owing to Diebold and Yilmaz (2009, 2012) to examine, in the first instance, the interaction between money (both monetary base and M2) and the returns on four classes of financial asset (stocks, commodities, currency index, and government bonds) since 2000. This approach allows the user to quantify the extent to which shocks in different variables spill over to one another. It may then shed some light on whether the particular monetary policy of recent years has a noticeable impact on financial asset return behaviour. A successful balance sheet policy would be expected to see greater spillover between the monetary base and asset returns. Likewise, if the gateway/substitution effect is active then one should see greater spillover between broad money (M2) and financial asset returns occurring during periods of financial and economic uncertainty.[62]

The relationship between money and asset market volatility is addressed in a second set of econometric estimations herein where the changes in the two money aggregates used in the first set of estimations are combined with measures of the volatility in stock, commodity, currency and government bond markets. This is a natural extension of the study as money growth on asset returns could also affect the variability of the asset price, as already alluded to above. Bailey (1988) finds that unanticipated changes in money supply affects the volatility of asset prices, including the four asset classes being considered in this study. Roley (1983) notes the increased responsiveness of asset prices to money surprises after the Federal Reserve's policy of targeting monetary aggregates,

[62] The focus in this paper is on the relationship between the financial and money variables, and between the money aggregates themselves. We do, however, pass brief comment on the bilateral spillover relationships between the four asset classes.

adopted in October 1979. In particular, it explains a large fraction of the increase in the average volatility of interest rates following that policy change. It remains to be seen whether the adoption of unconventional monetary policies in recent years may also have resulted in money having greater effect on asset volatility through increased spillover.

Asset price volatility can also affect money aggregates. Slovin and Sushka (1983), for instance, show that greater interest rate variability increases money demand. Tatom (1984) notes the two-way causal effects between money growth and interest rate variability. Among the possible effects that might be observed in recent times, and with the particular policies being utilised by the Federal Reserve, is that when there is a volatility shock in a financial market, a substantial change in the monetary base, but not in M2, will be observed. This would occur because the Federal Reserve has responded to such a financial event by altering the monetary base, with little impact on M2.[63] This effect, if correct, could be expected to manifest itself in a noticeable rise in the spillover between financial markets and the monetary base.

Finally, the Diebold-Yilmaz approach can also provide information on how the monetary base and broad money, M2, have themselves interacted with one another. The increase in the size of the monetary base following the balance-sheet programs of recent years would normally be expected to raise the size of the M2 money stock via a money multiplier effect, although it might also not be unexpected in an uncertain economic environment if the monetary base was hoarded by the banking sector and not used to pursue a larger retail deposit stock. Lothian (2009) points out that in spite of the monetary base more than doubling from August 2008 to April 2009, its growth did not spill over in any major way to M2. An absence of spillover from the monetary base to M2 may then transpire in the econometric results.

2. Methodology

Diebold and Yilmaz (2009) provide a spillover measure based on vector autoregressive (VAR) models in the tradition of Engle et al. (1990). Construction of the index relies on forecast error variance decompositions, which show the proportion of the movement in a variable's development over time due to its own shocks and that due to shocks in

[63] This hypothesis was suggested by a referee.

other variables in the vector autoregression by quantifying how much of the total variance forecast is attributed to each. The spillover index provides a measure of interdependence among variables with a higher index value implying that a larger proportion of the shocks in markets as a whole can be accounted for by cross-variable shocks rather than own-variable shocks.[64]

Whereas their earlier paper utilised orthogonalised variance decompositions, Diebold and Yilmaz (2012) uses the generalised VAR framework of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998). The advantage of this form of VAR is that variance decompositions are invariant to the ordering of the variables in it. Net spillover values between variables can also be calculated, if desired. Given these features, we utilise this VAR approach rather than that in the earlier Diebold-Yilmaz paper. In the remainder of this section, we outline in summary form the VAR framework and construction of the spillover index, while referring the interested reader to the greater detail found in section 2 of Diebold and Yilmaz (2012).

The N-variable VAR (p) specification is given by

$$x_t = \sum_{t=1}^{p} \Phi_i \, x_{t-i} + \varepsilon_t \qquad (1)$$

Where $\varepsilon \sim (0, \Sigma)$ is a vector of independently and identically distributed disturbances.

Assuming covariance stationarity, this specification can be rewritten in moving average form as:

$$x_t = \sum_{t=1}^{\infty} A_i \, \varepsilon_{t-i} \qquad (2)$$

Where the $N \times N$ coefficient matrices A_i observe the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \ldots + \Phi_p A_{i-p}$, with A_0 an $N \times N$ identity matrix and $A_i = 0$ for $i < 0$. Variance decompositions allow the fraction of the H–step-ahead error variance in forecasting x_i owing to shocks to x_j, $\forall \, j \neq i$, for each i to be measured.

[64] Diebold and Yilmaz (2009, p. 170) point out that spillover measures "have the appealing virtue of conveying important and useful information while nevertheless sidestepping the contentious issue of definition and existence of episodes of "contagion" so vigorously debated in recent literature such as Forbes and Rigobon (2002)".

Cross-variance spillovers are the fractions of the H–step-ahead error variance in forecasting x_i owing to shocks to x_j, for i, j = 1, 2,...,N, such that $i \neq j$, while own variance spillovers are the fractions of the H–step-ahead error variance in forecasting x_i owing to shocks to x_i, for i = 1, 2,...,N. With the H–step-ahead forecast error variance decompositions denoted as $\theta_{ij}^{g}(H)$ for $H = 1, 2, \ldots$, we get

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (e_j' A_h \Sigma e_i)^2}{\sum_{h=0}^{H-1} (e_j' A_h \Sigma A_h' e_j)} \qquad (3)$$

Where Σ is the variance matrix for the error vector ε, σ_{ii} is the standard deviation of the error term for the ith equation and e_i is the selection vector with one as the ith element and zeros otherwise.

Each entry of the variance decomposition matrix is then normalised by the sum of the elements of each row of the variance decomposition table as:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\Sigma_{j=1}^{N} \theta_{ij}^{g}(H)} \quad (4)$$

By construction, $\sum_{j-1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j-1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$.

The total spillover index, which measures the contribution of spillovers of shocks across the variables to the total forecast error variance, is then defined as:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} . 100 \qquad (5)$$

The directional spillover imparted by all other variables j to variable i is measured as:

$$S_{i.}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} . 100 \qquad (6)$$

In a similar vein, the directional spillover from market i to all other markets j is calculated as:

$$S^{g}_{.i}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}^{g}_{ji}(H)}{\sum_{j=1}^{N} \tilde{\theta}^{g}_{ji}(H)} . 100 \qquad (7)$$

Given these directional spillovers, net volatility spillovers from market i to all markets j can be calculated as the difference between gross volatility shocks transmitted to and gross volatility shocks received from all other markets:

$$S^{g}_{i}(H) = S^{g}_{.i}(H) - S^{g}_{i.}(H) \qquad (8)$$

3. Data and Full-Sample Results

3.1 Data

We use weekly financial market data from four US asset classes: stocks (represented by the S&P 500 index), commodities (DJ-UBS commodity index), currency index (the ICE US dollar index futures contract) and government bonds (US Generic Government 10-year bonds).[65] The basic data for the stocks, commodities and US dollar contract are index levels and that for the government bonds are nominal yields. The sample size covers the period 24 May 2000 to 28 November 2012.

Two money supply variables are used: the US M2 money stock and US monetary base. Weekly data for these aggregates are reported on the Federal Reserve Bank of St. Louis's FRED database on a Monday reporting date for M2 and on a Wednesday for the monetary base. In constructing first-difference datasets for the money aggregates, we are then required to use the Wednesday-to-Wednesday changes for the monetary base and to match them to the preceding Monday-to-Monday changes in the M2 stock. There are then two business days between the reporting days for the monetary base and for M2. Real rates of weekly change in these money variables are included in the two datasets that we utilise in the VAR estimations that follow. The first dataset is completed by including real return series for each of the four asset series. Those rates of return series use Wednesday closing values for the assets. The second dataset includes volatility measures for the four financial assets and, again, the two money aggregate first-differences series. The asset return/volatility series then are contemporaneously matched

[65] All data series used are detailed in Appendix A.

to the monetary base series, while the M2 series is separated from them by two business days. This is an unavoidable consequence of the differing reporting dates for the money aggregates but, particularly in the context of the sample sizes in the regression analysis that follows, this seems to be a sensible and low cost means of dealing with the issue.

The nominal rates of change in the stock, commodity and currency indices, the government bond yield, and in the money aggregates are adjusted for inflation using the following formula:

$$\frac{1 + n_t}{1 + \pi_t}$$

Where n_t is the nominal rate of change in money aggregate/asset value over the week and the measure of π_t is estimated as follows: the rate of change in the CPI between start- and end-month is divided by four or five depending on the number of Wednesdays in the month.[66]

The first dataset utilised in the regression analysis then comprises the real rate of changes in the four asset variables and in the two money aggregates. The latter two are also used in the second dataset which is completed by the inclusion of volatility measures for the four asset classes. Following Garman and Klass (1980) and Alizadeh, Brandt and Diebold (2002), volatility for each asset class is calculated as follows:

$$\tilde{\sigma}^2 = 0.511(H_t - L_t)^2 - 0.19[(C_t - O_t)(H_t + L_t - 2O_t) - 2(H_t - O_t)(L_t - O_t)] - 0.383(C_t - O_t)^2$$

Where H is the high index/yield value in the Thursday-opening to Wednesday-close week, L is the Thursday-Wednesday low value, O is the Thursday opening value and C is the closing Wednesday value (all in natural logarithms with the exception of the government bond).[67]

[66] If all weekly data were deflated by a quarter of the monthly inflation rate, the rate of deflation of asset returns and nominal money growth over time would exceed that warranted by the actual path of the CPI. Deflating the nominal data according to the method outlined then provides a more accurate measure of real returns or rates of change.

[67] Our choice of the Garman-Klass estimate of volatility follows that of Diebold and Yilmaz (2009) and its standing as an efficient measure of volatility (Shu and Zhang (2006)). Alternative measures of volatility could also be used. Generalised autoregressive conditional heteroskedasicity (GARCH) and stochastic volatility models are two means of estimating and modelling time-varying conditional financial market

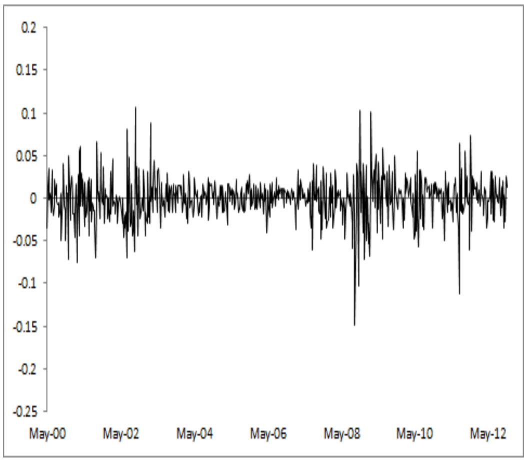
The data are graphed in Fig.s 1 and 2. In Fig. 1, the four asset return series are relatively volatile during the period extending from September 2008 to mid-2009. Their range of values was also high in the early 2000s, with the exception of commodities. There is a pickup in the variation of weekly returns for stocks and, more noticeably, for the government bond series in the second half of 2011. The M2 money stock experiences large, positive changes in the weeks ending 19 September 2001, 24 September 2008 and 3 August 2011. The positive spike in 19 September 2001 was followed by a large negative change in the week ending 26 September 2001. A similar pair of changes occurred for the monetary base at that time. Large weekly changes in the monetary base, mainly of a positive value, occur between the period 24 September 2008 and 24 June 2009.

The four intra-week asset volatility series in Fig. 2 reveal a number of periods and particular weeks when there was high volatility. For stocks, there was a sharp, temporary pickup in volatility in July 2002. Volatility also rose in the weeks after 17 September 2008 and relatively high values were maintained into early 2009. Intra-week volatility values in commodities rose in the second half of 2008 and persisted at higher values into the spring of 2009, while earlier in the decade there was a noticeable spike in volatility in September 2001. The volatility series for government bonds sees large values being recorded in three sub-periods: from December 2001 to August 2003, from September 2008 to June 2009, and in the second half of 2011. Finally, unlike the other three assets, the currency index exhibited relatively high volatility only in the late 2000s and not earlier in the decade. The largest volatility value was recorded in the week ending 23 April 2008, while volatility values were usually high from September 2008 to early-2009. More recently, high volatility values were recorded in November 2010 and November 2011.

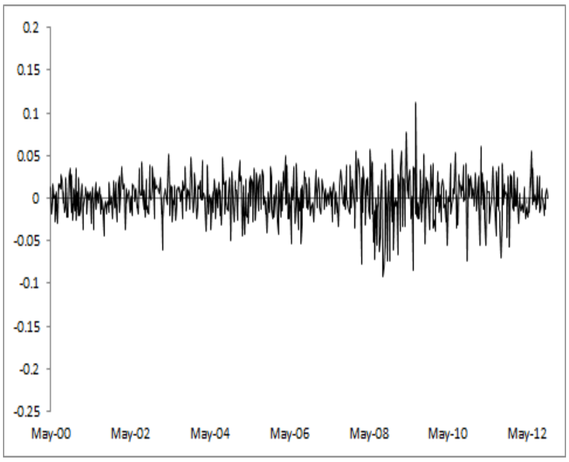
volatility. Both, however, have been criticised as being inaccurate and inefficient as they use closing prices and fail to take account of price information within the period (in this case, a week) (Alizadeh, Brandt and Diebold (2002), Brandt and Diebold (2006)). The Garman-Klass estimator uses price range information to improve volatility estimation. Both it and the Parkinson (1980) estimator of volatility (used below in assessing the sensitivity of the spillover index to volatility choice) are also robust to market microstructure noise (Alizadeh, Brandt and Diebold, 2002).

Fig. 1. Weekly return series for four asset classes and weekly changes in M2 and Monetary Base

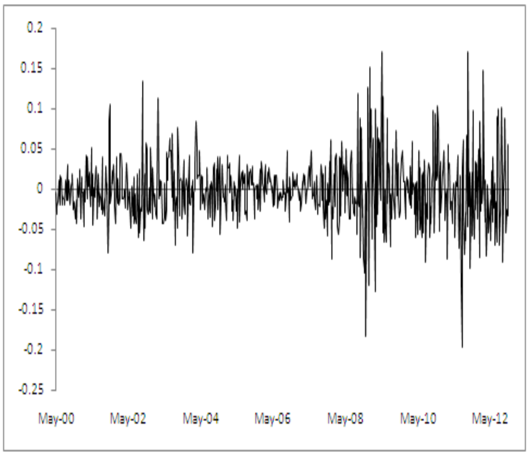
i. Stocks



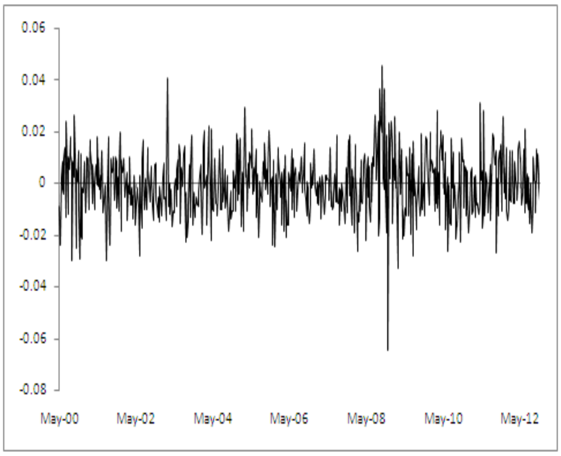
ii. Commodities



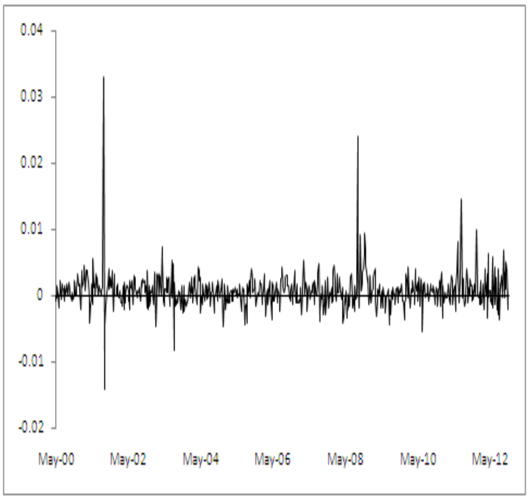
iii. 10-year Government Bond



iv. US Dollar Index



v. M2 money stock



vi. Monetary Base

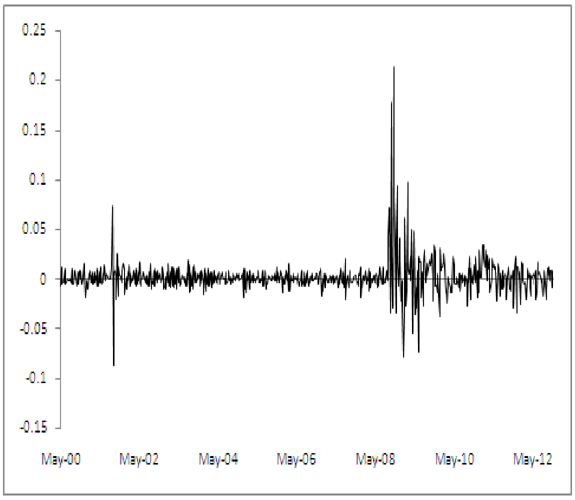
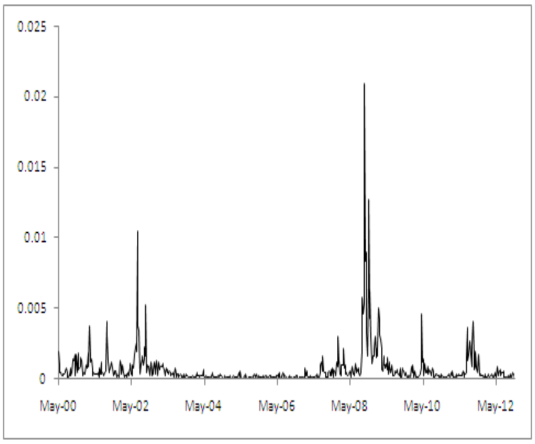
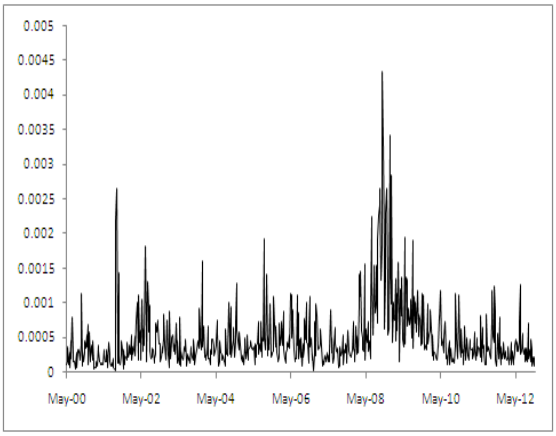


Fig. 2. Weekly volatility series for four asset classes

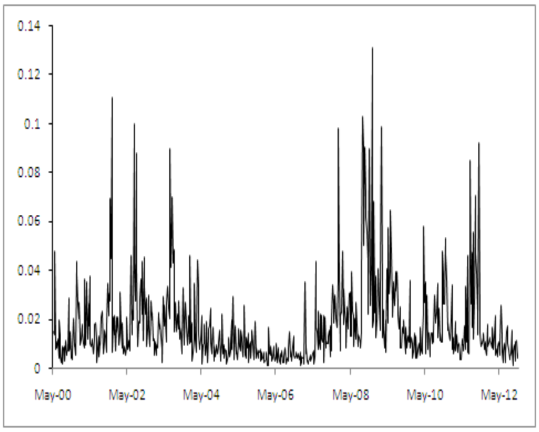
i. Stocks



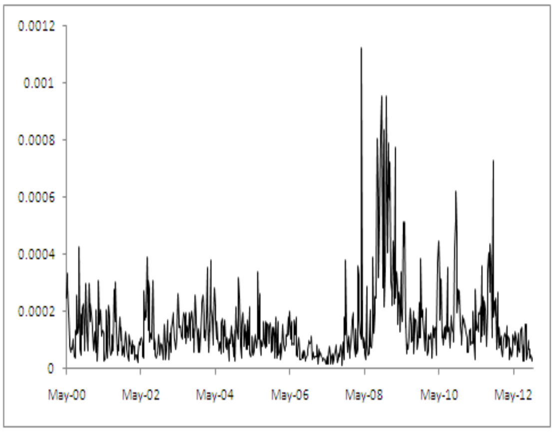
ii. Commodities



iii. 10-year Government Bond



iv. US Dollar Index



3.2 Full-sample analysis

The initial vector autoregression (VAR) undertaken involves a full-sample estimation of the total spillover index and its constituent parts. As well as giving an indication of spillover behaviour over the entire May 2000 to November 2012 sample period, it may also help the reader in following the graphical representations in the rolling-sample analysis that follows. All decompositions are based on ten-week ahead forecast errors and the aforementioned generalised forecast error variance method.[68] The lag order of the VAR is three and a constant term is included in the regression equations.

Table 1 then shows the decompositions where the financial asset variables are the weekly returns, illustrated in Fig. 1. In Table 2, the financial variables are the volatility measures in Fig. 2. The two money variables outlined above make up the six variables in each VAR. For convenience, we refer hereafter to the decompositions involving the return series as the return spillovers and those containing the volatility series as the volatility spillovers.

A measure of the estimated contribution to the forecast error variance of market i coming from innovations to market j is given by the off-diagonal elements in the main body of each table. The sum of off-diagonal column entries (contributions/directional to others) and the sum of the off-diagonal rows (contributions/directional from others) then give, respectively, the "to" and "from" directional entries for each variable in the "Directional to others" row and "Directional from others" column of Tables 1 and 2. The total spillover index is calculated by dividing either the sum of the "to" or "from" measures (they will each add up to the same numerical value) by the sum of the six columns (in this case, 600). The difference between the "Directional to others" and "Directional from others" values for each variable gives its net spillover to/from other variables.

The value of the total return spillover index in Table 1 is 21.4 percent. For the two money variables, M2 can be seen to impart greater spillover to (14.9 percent) and from (20.3 percent) the other five variables relative to the corresponding values for the monetary base (12.6 percent and 16.4 percent, respectively). When one looks at the bidirectional spillovers between each money variable and the four financial asset return

[68] The insensitivity of the total spillover indices to the forecast horizon is shown in Appendix B using the 52-week rolling windows employed in section 4.

series, the individual values reported in Table 1 are low, having values of less than five percent. With regard to the spillover between the money variables, the spillover from M2 to the monetary base is 10.6 percent and that from the monetary base to M2 is 8.2 percent. Bidirectional spillovers amongst the asset classes are relatively strong between stocks and commodities, stocks and government bonds, and commodities and the currency index.

Turing to Table 2, it can be seen that the total volatility spillover index value is higher, at 34.4 percent, than that reported in Table 1. The directional-from and directional-to values for the money variables are also higher in this table. M2 imparts 35.6 percent spillover to the other five variables and receives 21.1 percent from them. It, therefore, has a net spillover flow to the other variables of 14.4 percent. In contrast, monetary base is a net spillover recipient from the other variables, albeit of only 0.5 percent. Its spillover from the other five variables is 29.4 percent while its spillover to them is 28.9 percent.

With regard to the bidirectional spillover values, it is noteworthy that M2's spillover value to stocks is 11.1 percent, higher than that imparted to stocks by two of the other three financial asset variables. The spillover M2 receives from stocks is 7.3 percent, and from the monetary base is 8.1 percent. The spillover from the other three asset classes is low. For the monetary base, there is a spillover from it to stocks of 9.6 percent and a spillover of 13.2 percent in the opposite direction. The interaction between the money aggregates and stocks then exceeds that between the other financial assets and the money aggregates. The spillovers between M2 and the monetary base reported in Table 2 are not too different from those reported in Table 1. Stock market volatility imparts relatively strong shocks to the other three asset markets (see first column of Table 2). Other relatively large spillover values are from government bonds to stocks (11.7 percent) and from government bonds to the dollar index (10.5 percent).

Table 1. Returns spillover index and components: full sample estimation

	Stocks	*Commodities*	*Govt. Bond*	*Dollar Index*	*M2*	*Monetary Base*	*Directional from others*	*Net spillover (+: to; -: from)*
Stocks	73	9.2	10.2	3.9	1.2	2.5	27	2.3
Commodities	8.5	72.8	2.6	13.5	1.3	1.3	27.2	6.5
Govt. Bond	11.3	3	83.7	0.7	0.9	0.4	16.3	0.2
Dollar Index	4.2	15.1	0.7	79	0.9	0.2	21	0.3
M2	4.1	4.4	1	2.6	79.7	8.2	20.3	-5.4
Mty. Base	1.2	2	2	0.6	10.6	83.6	16.4	-3.8
Directional to others	29.3	33.7	16.5	21.3	14.9	12.6	128.3	***Total Spillover Index:***
Directional incl. own	102.3	106.5	100.2	100.3	94.6	96.2		21.4

Table 2. Volatility spillover index and components: full sample estimation

	Stocks	*Commodities*	*Govt. Bond*	*Dollar Index*	*M2*	*Monetary Base*	*Direction-al from others*	*Net spillover (+: to; -: from)*
Stocks	56.2	6.6	11.7	4.8	11.1	9.6	43.8	19
Commodities	13.6	62.5	5.5	7.9	5.5	5.1	37.5	-15.8
Govt. Bond	13.7	2.6	69.5	9.2	4.1	1	30.5	1.5
Dollar Index	15	8.2	10.5	55.8	5.4	5.1	44.2	-18.6
M2	7.3	1.5	2.8	1.4	78.9	8.1	21.1	14.4
Mty. Base	13.2	2.8	1.5	2.3	9.5	70.6	29.4	-0.5
Directional to others	62.8	21.7	32	25.6	35.6	28.9	206.6	***Total Spillover Index:***
Directional incl. own	119	84.2	101.5	81.4	114.5	99.5		34.4

4. Rolling Sample Analysis

4.1 Total Spillover Indices

Examining how spillover relationships have evolved over time should prove more informative than the full-sample assessments garnered from Tables 1 and 2. It allows us observe, for example, whether spillover patterns changed markedly during periods of acute financial market turbulence or policy intervention. Estimating and plotting components of each of the two spillover indices, as well as the total spillover index values themselves, on a rolling-sample basis allows such an analysis to be undertaken. We estimated the VAR on a 52-week (approximately one year) rolling sample basis, beginning with a sample from 24 May 2000 to 16 May 2001 and concluding with a sample from 7 December 2011 to 28 November 2012. In what follows, we plot the series of total spillover index values generated from these rolling sample estimations, along with charts of components of that index. The dates on the horizontal axis of each chart correspond to the end-week of each rolling regression.[69]

In Fig.s 3 and 4, two rolling total spillover indices are plotted. The first represents the VAR containing the two money variables and the four asset return series (the returns spillover index), while the second comprises the same two money variables and the four asset volatility series (the volatility spillover index). The returns spillover index (Fig. 3) attains values of 60 percent and above in sample periods ending on 26 September 2001 and on 3 October 2001 and in samples ending between 29 October 2008 and 17 December 2008.[70]

While the evolution of the returns spillover index remains relatively steady and uneventful after 2008, there is noticeable variation in the volatility index in later years (Fig. 4). It experiences sharp pickups in value in the rolling window ending 10 October

[69] No value of the total spillover index is reported for a rolling window when one, or more, of the individual data series exhibits an explosive root within that window. The incidence of no value being reported is low with only 10 occurrences among the 603 rolling window estimates for the returns spillover index and 24 instances among the 603 estimates for the volatility spillover index.

[70] The plotted values in Fig.s 3 and 4 correspond to the total spillover index values in the bottom right-hand corner of Tables 1 and 2. In other words, they are rolling samples measures of average spillover across all six variables included in each VAR. The reader will notice that total spillover values in the two figures are well in excess of those in the tables (where values of 21.4 percent and 34.4 percent are recorded, respectively). This likely reflects the differing sizes of the rolling samples (52 weeks) versus that of the sample size of the tables (654 weeks).

2001, and after the sample period ending 10 September 2008. Interaction remains high for some time after those dates. Spillover values are also elevated from early August 2011 through until early 2012.[71] [72]

The index values indicate a number of periods common to both spillover indices when there was a visible rise in general interaction. The first was around September 2001. The terrorist attacks on 11 September 2001 caused considerable disruption to the operation of financial markets at that time. The Federal Reserve responded by providing large quantities of liquidity to financial markets and the target federal fund rate was lowered over a number of months.

A second period when there was a marked rise in spillover was during late 2008 with spillover declining only gradually in the ensuing months. This period was one when there was a sharp deterioration in financial market conditions, most notably associated with Lehman Brothers filing for Chapter 11 bankruptcy protection on 15 September 2008. This event not only instigated considerable disruption in financial markets but elicited a series of policy responses from both the Federal Reserve and the US Treasury over the following weeks and months. The policy initiatives were expansionary in nature and included programs of quantitative easing.

The third period of note (although involving milder rises in spillover than the two former periods) occurs from late-summer 2011 to the end of that year, with the returns spillover index rising sharply in the week ending 10 August 2011 and the volatility spillover index rising steadily in the following months. There was renewed turbulence in US financial markets at that time with international factors such as the European sovereign debt crisis at play. Standard and Poor's chose to downgrade the rating of US Treasury bonds on 5

[71] The spike in volatility spillover in the week ending 12 May 2010 appears to be attributable to a "flash crash" of the stock market on 6 May resulting in a particularly large difference between the high and low values for the week ending 12 May and thus generating a large stock volatility value for that week.

[72] We tested the sensitivity of the volatility spillover index to the choice of volatility measure by estimating the volatility of all four asset categories using the measure proposed by Parkinson (1980), which, like the Garman-Klass measure, is recognised as an efficient measure of volatility. Volatility in this case is measured as $\tilde{\sigma}^2 = 0.361[H_t - L_t]^2$ where H is the high index/yield value and L is the weekly low value (both measured in natural logs with the exception of the government bond). Fig. A.3 in Appendix B indicates that the volatility spillover index is not notably sensitive to the choice of volatility measure. There is a spike in the Parkinson-based index in the sample ending 24 August 2011, a period when no value was returned for the Garman-Klass-based index.

August 2011. The Federal Reserve responded to these developments, as it had to events earlier in the crisis, by providing additional policy

Fig. 3. Total returns spillover index (percent)

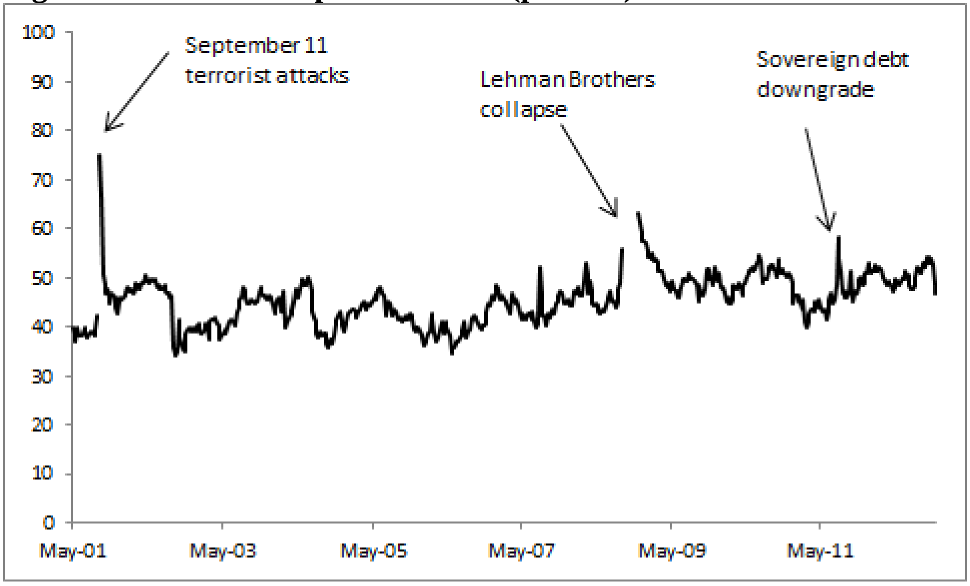
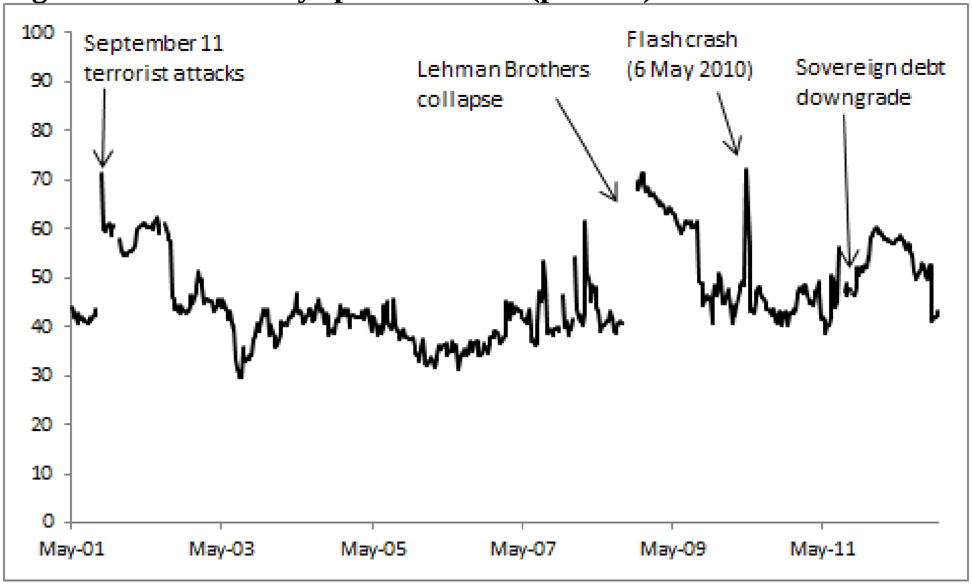


Fig. 4. Total volatility spillover index (percent)



accommodation. The higher spillover values around September 2001, September-October 2008 and late 2011 then point to spillover, or interaction, rising between money and financial markets and within financial markets at times of increased uncertainty and pronounced monetary intervention.

Beyond these brief summaries of these particular periods, we choose to go into greater detail on them and other periods when analysing the components of the spillover indices in the next four subsections. This allows us identify, where possible, particular events with the information contained in charts and to highlight how money and financial asset variables, in particular, interacted at those times.

4.2 Interaction between monetary aggregates and asset returns

Fig.s 5 and 6 are organised in a way whereby the bidirectional spillovers between M2 and individual/total financial assets are plotted in the left-hand side column and that between the monetary base (marked "MB" in those graphs) and individual/total financial assets in the right-hand side column. In each panel, the spillover from the money variable to-and-from the financial asset(s) are graphed. Panels (i) and (ii) of the figures show the cumulative spillover totals from each money variable to the four individual assets' returns, and in the opposite direction.

The largest spillovers from the two money aggregates to asset returns (Fig.s 5 (i) and (ii)) occur on the sample periods ending 26 September 2001 and 3 October 2001 in the wake of the 11 September terrorist attacks (the spillover indices fail to converge on the week ending 19 September 2001). This effect is noticeable for all four asset classes (panels (iii) to (x)). Not only was there monetary accommodation by the Federal Reserve at that time but the M2 money stock was volatile in the second half of September 2001. At the same time, returns on all asset classes experienced sharp weekly changes. One would expect that portfolio adjustment away from risky assets to the "safe" haven of money was at play and, consequently, one would not be surprised to see increased interaction taking place at that time.

Throughout the mid-2000s bilateral spillovers between the money aggregates and asset returns were of similar magnitudes. Spillovers in both directions, however, picked up suddenly in late 2008 before falling slowly afterwards. One could surmise that these heightened gross spillover values reflected a substitution from risky financial assets to the "safe haven" of money balances during this period of considerable economic and financial uncertainty. Bordo (2012) notes that M2 did not collapse during the 2007-2009 recession, as occurred in the 1930s. There were no runs on commercial banks as deposit insurance protected money balances. M2's attraction as a store of value then would have been strong and would have acted as a spur to households adjusting their portfolio wealth in favour of money. This adjustment might be expected to be particularly strong between stocks and M2 because of the emphasis that wealth movements between them has received. Panels (iii), (v), (vii) and (ix) of Fig. 5 indicate that bidirectional spillovers between stocks and M2 were usually at higher values among the four asset classes during late 2008 and up to end-2009. A similar phenomenon occurred in the wake of the September 11 terrorist attacks. Indeed, substantial spillover from M2 to all four asset returns is evident in Fig. 5 at that time.

Aspects of this interaction are repeated between the monetary base and the asset returns (panel (ii) of Fig. 5). Spillover from the monetary base to all four asset returns is quite high at the time of the September 11 terrorist attacks, although less than from M2 to those assets. During the financial market turmoil of mid-2008 to end-2009, spillover from asset returns to the monetary base is well above that in the opposite direction. In contrast to M2 (where spillover from stocks is strongest), government bonds tend to explain the largest proportion of the other-variable shocks to the monetary base during the post-Lehman Brothers period (panel viii). Given the importance of the bond market to monetary policy operations generally and the undertaking of programs of quantitative easing from September 2008 onwards specifically, this feature of Fig. 5 should not be unexpected.

Turning towards the later rolling sample estimates, panel (i) of Fig. 5 shows a sizeable rise in spillover from M2 to asset returns in early August 2011, which is maintained through that month. This is not replicated between the asset returns and the other money aggregate, the monetary base. Retail investor sentiment appears to have taken a turn for the worse around this time. As noted by the Board of Governors (2012), US equity markets fell sharply in response to concerns about the European sovereign debt crisis, the US debt ceiling debate and a possible slowdown in global growth. The Board also notes that US M2 increased at an annualised 12 percent rate in the second half of 2011, which it indicates "appears to be the result of the increased demand for safe and liquid assets" (2012, p. 28). This flight-to-safety effect then may have been occurring in a similar way to that which arose in late 2008 and thus shows up in the spillover values in Fig. 5. The largest spillover from M2 during the second half of 2011 was to stocks, although it was closely followed by its spillover to government bonds. The latter may reflect the downgrading of the US long-term sovereign credit rating by S&P on 5 August 2011 and an associated investor preference for holding money rather than bonds.

Spillover from government bond markets to the monetary base (panel (viii)) started to decline from mid-2010 onwards at a time when the second phase of quantitative easing was specifically focussing on purchases of US Treasury securities. Fratzscher et al. (2012) find a fundamental difference between the first and second phases of US quantitative easing with the first phase (QE1) being highly effective in lowering long term bond yields and in supporting US equity phases but the second phase (QE2, commencing mid-2010) not having this outcome. They claim that QE2 policies induced a portfolio rebalancing out of US equities and bonds and into foreign equities. This may contribute to the diminished bidirectional spillovers after 2010 in panels (iv) and (viii) of Fig. 5. What QE2 succeeded in doing, Fratzscher et al. indicate, was to bring about a marked depreciation in the US dollar. This may explain the increased spillover from the monetary base to the dollar index in the later part of the sample (panel (x) of Fig. 5).

For commodities, besides September 2001, spillovers between it and the two money stocks are generally at relatively low values through most of the rolling sample estimations. The year 2007 is an exception with spillovers from the monetary base to commodities of close to 20 percent being recorded at that time. Commodity prices rose by over 11 percent in that calendar year. The surprise is that given the aforementioned overshooting theories on the relationship between broad money and commodity prices, and strong M2 growth during 2007, that spillover effects arise from the monetary base and not from M2 during that period.

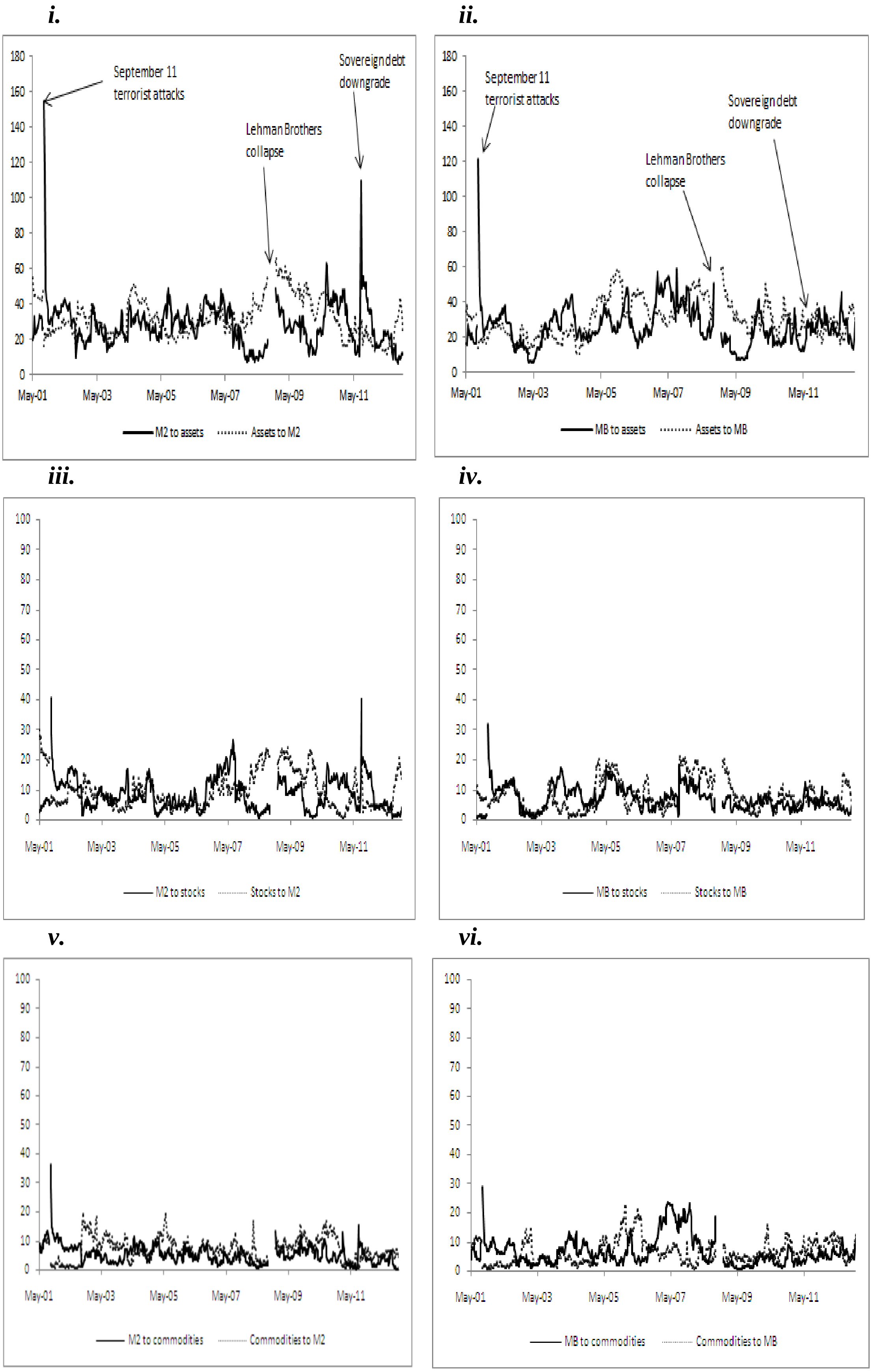
4.3 Interaction between monetary aggregates and asset volatility

The spillover from M2 to asset price volatilities in Fig. 6 (panel (i)) is particularly pronounced through late-2008 and 2009 and between mid-2010 and mid-2011. The view that there was a flight-to-safety at work in asset markets at these times may be appropriate here. The greater volatility in markets evident during these periods (Fig. 2) was matched by strong M2 growth (see Fig. 1). It may then be that portfolio allocation away from assets to M2 brought with it higher volatility in asset values and, thus, by way of econometric effect, a large spillover from M2 to those volatility values is evident. Among the spillovers to individual assets, that from M2 to stocks exceeds that to the other three financial assets in 2008-2009, while sizeable M2 spillover to both stocks and the currency index is apparent in the mid-2010 to mid-2011 phase.

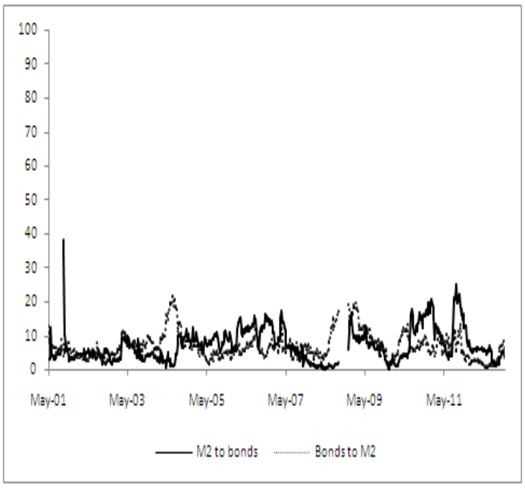
Turning to the right-hand-side panels of Fig. 6, large spillover effects from the monetary base to asset price volatilities are evident in September-October 2001, in late 2008, and in the sample periods ending 16 and 23 February 2011. In the other direction, volatility in asset markets has substantial net directional-to effects on the monetary base in 2004-5, 2008-9 and also in 2012. The latter occurrences may reflect the Federal Reserve responding to asset price volatility by increasing the monetary base. Nevertheless, in general, the influence of the monetary base on volatility in the four asset markets is less than that arising from M2 and is substantially less than the broad money stock after the onset of the financial crisis.

Stock market volatility has only sporadically sharp influence on the monetary base (panel (iv)). The spillovers between the monetary base and government bond volatility are relatively low throughout (panel (viii)) and are noticeably so during later years when a link between quantitative easing and bond market volatility might have been expected. In general, the level of bidirectional interaction between the monetary base and asset market volatility in the era of unconventional monetary policies has not been notably different from what passed before.

Fig. 5. Return spillovers: bidirectional and multidirectional (percent)



vii.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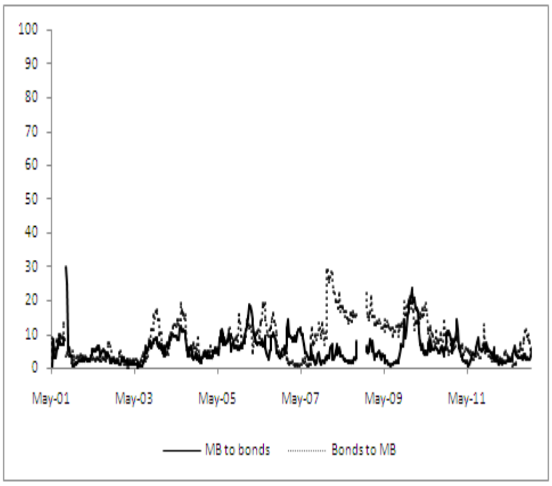
M2 to bonds
Bonds to M2

viii.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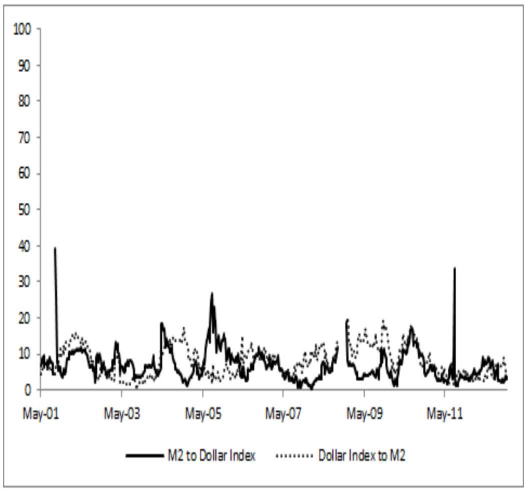
ix.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M2 to Dollar Index
Dollar Index to M2

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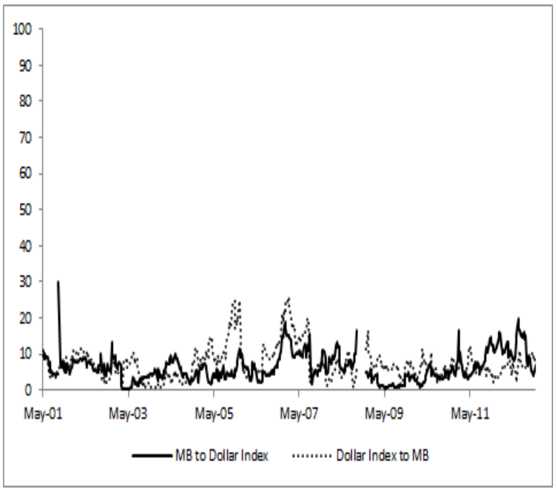
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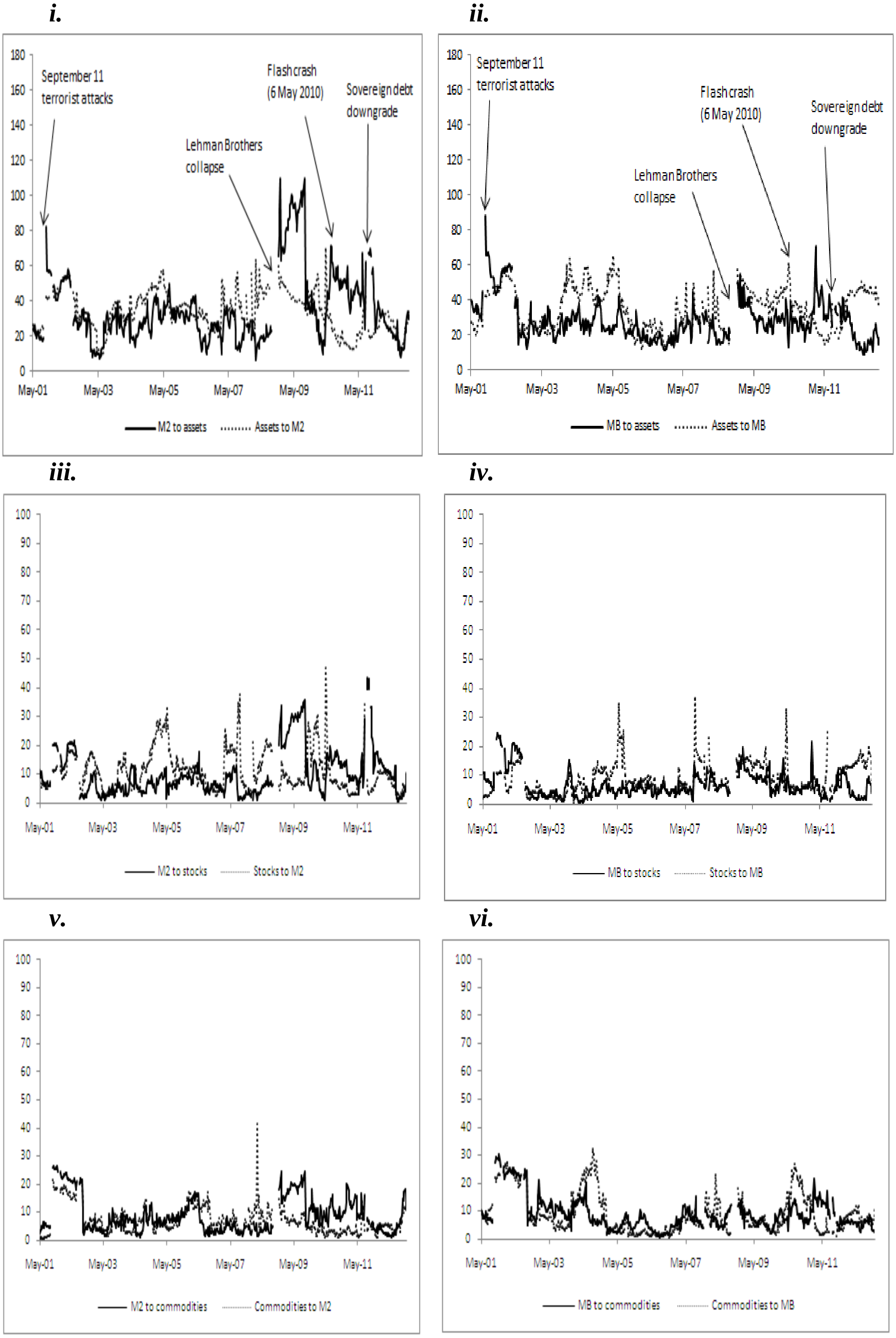
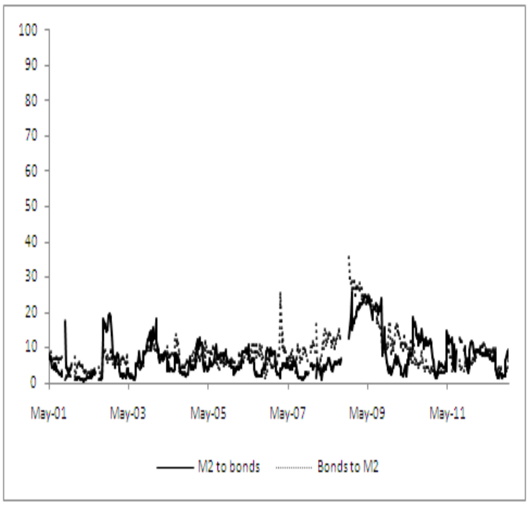
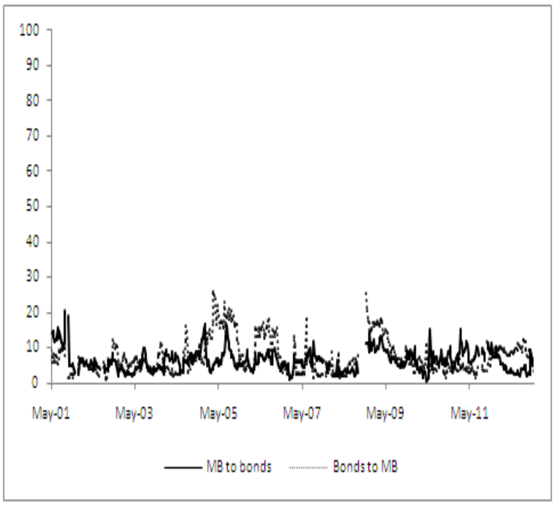
MB to Dollar Index
Dollar Index to MB

Fig. 6. Volatility spillovers: bidirectional and multidirectional (percent)



vii. *viii.*





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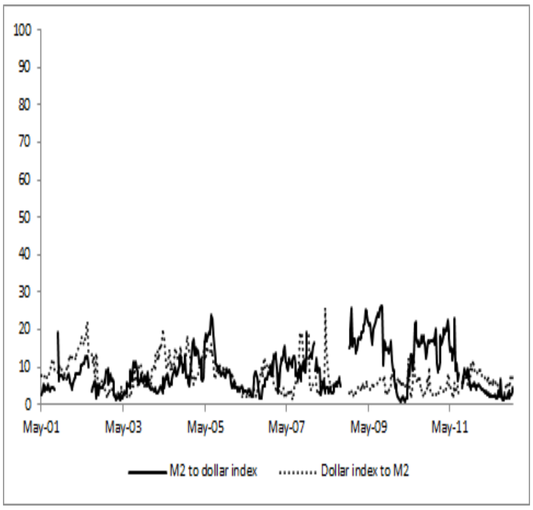

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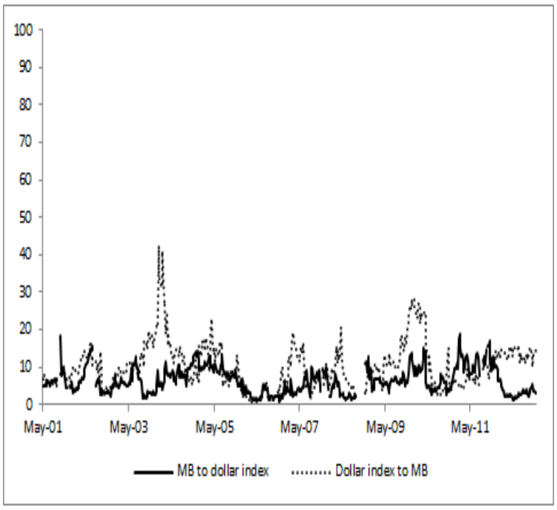


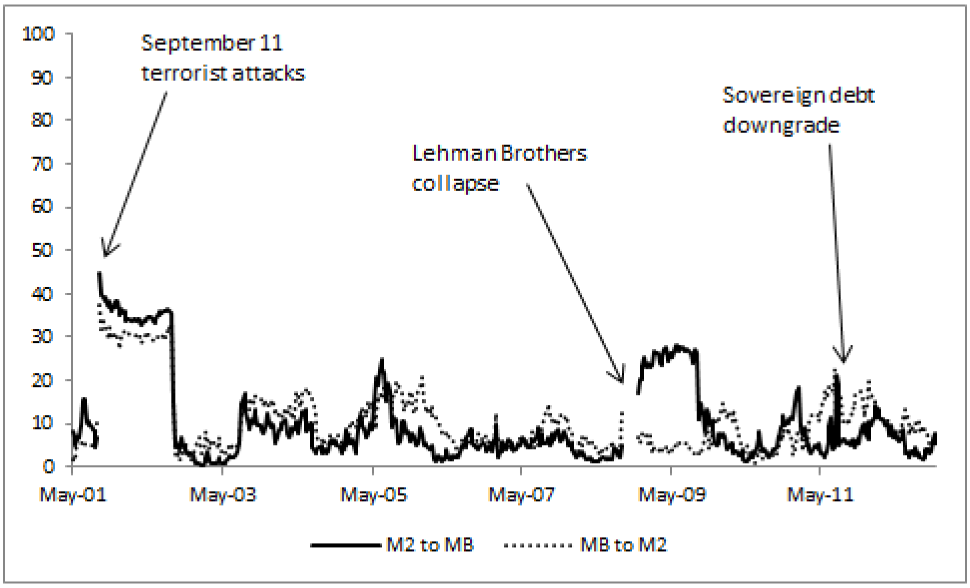
4.4 Spillover between the money aggregates

The two charts in Fig. 7 show the bidirectional spillovers between the two money aggregates from the return spillover estimates (panel (i)) and volatility spillover estimates (panel (ii)). Qualitatively, the patterns of interaction are not substantially different between both sets of VAR estimations, particularly after the mid-2000s.

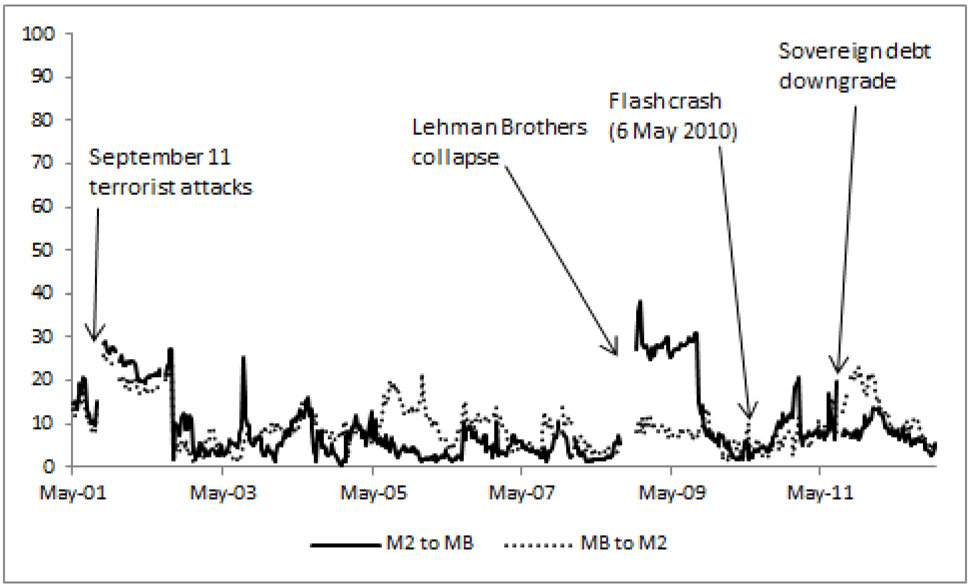
Both panels show strong bidirectional spillovers during the twelve months after the September 11 terrorist attacks. Monetary accommodation by the Federal Reserve at that time (including through reductions in official interest rates) may have facilitated a demand for broad money, increasing interaction between the two money stocks. Asset prices started to recover in late 2002-early 2003 and the relative strength of the dynamic between the money aggregates declined substantially.

Fig. 7. Bidirectional spillovers between M2 money stock and monetary base (percent)

i. Returns spillover estimation



ii. Volatility spillover estimation



The largest net spillover between the two variables occurs during the period after the collapse of Lehman Brothers up to mid-2009 when spillover from M2 to the monetary base was at values over 25 percent and that from the monetary base to M2 was usually in single percentage point values. As discussed in the previous two subsections, shocks in M2 had large effects on financial asset markets as well around this time and Fig. 7 points to them having marked influence on the monetary base as well. We would again suggest that this may follow from a process of portfolio adjustment during this period.

Not only was spillover from M2 to financial markets occurring but the Federal Reserve may have chosen to increase the monetary base, at least in part, in response to this development. Thus, while the monetary base would have expanded substantially more than M2, driving down the money multiplier, it would seem that this was in response to both broad money and asset market developments.

4.5 Spillover between asset classes

Fig.s 8 and 9 show the bidirectional spillovers between asset returns and asset volatilities, respectively. We comment only briefly on them. Fig. 8 shows the spillover flows to be broadly matched in value for each pair of assets. Those between commodities and stocks (panel (i)), stocks and the dollar index (panel (iii)), and commodities and the dollar index (panel (v)) have tended to rise over time. Gorton and Rouwenhorst (2006) highlighted the diversification benefits of adding commodities to a portfolio of financial assets. Perhaps as a result of this finding, greater interaction between returns in commodities and those in the other two asset classes might not be a surprise. Spillovers between commodity and bond returns are relatively low and unchanged throughout the 2000s (panel (iv)). The interaction between stock returns and government bond returns (panel (ii)) tends to fluctuate over time but tends to be strong at times of marked uncertainty, such as subsequent to the September 2011 terrorist attacks and after the sub-prime crisis started to manifest itself in 2007. Substitution between these two asset classes with differing risk characteristics could be expected at times of uncertainty and, consequently, large spillover values occur.

Volatility spillovers across the four asset classes used in this paper are also those studied in Diebold and Yilmaz (2012), in that case using daily volatility values. They note "particularly important" spillovers from the stock market to the other markets after the collapse of Lehman Brothers. This is notable in Fig. 9 between stock and bond market volatilities only (panel (ii)).

Fig. 8. Return spillovers: between asset classes (percent)

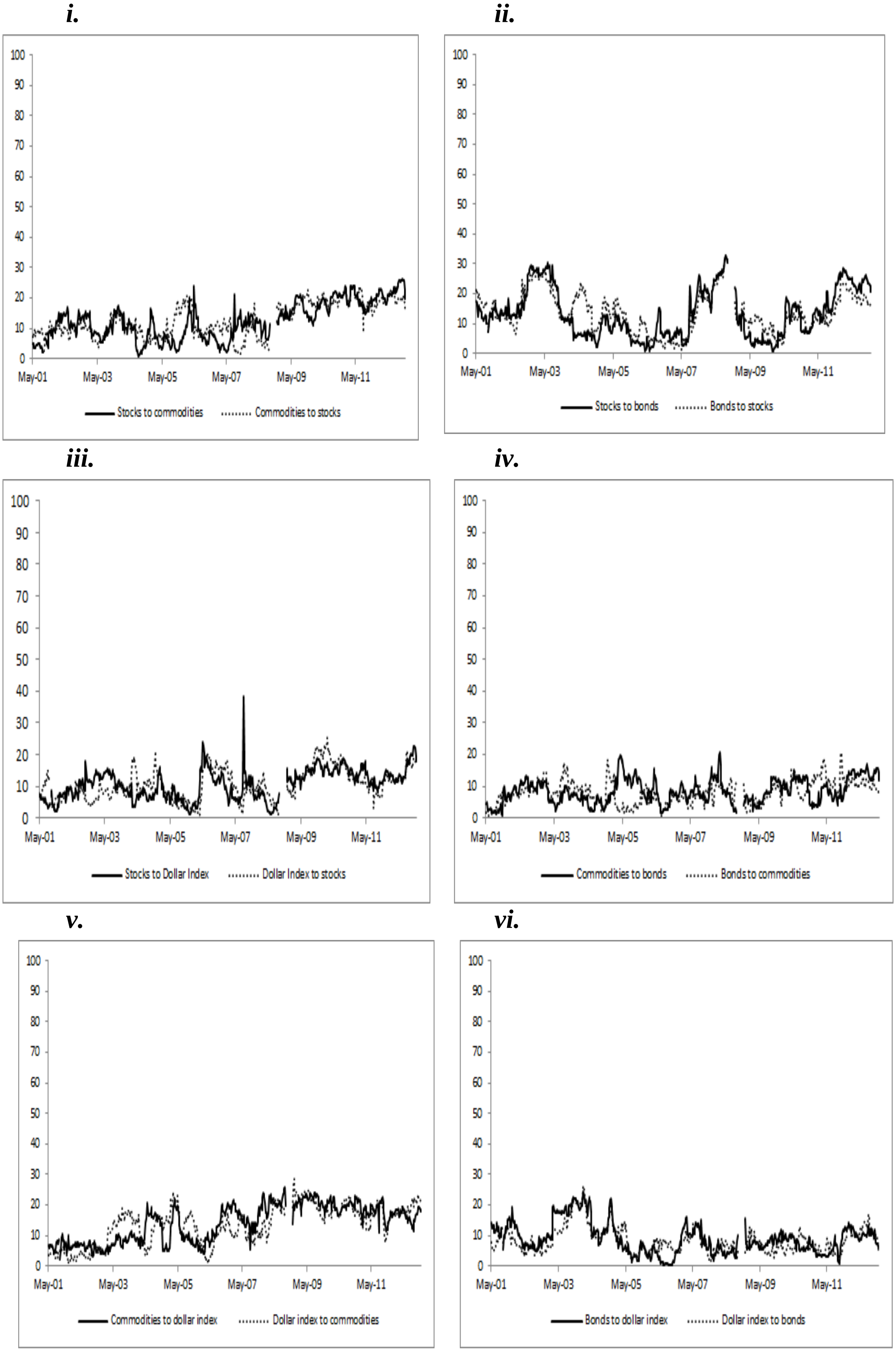
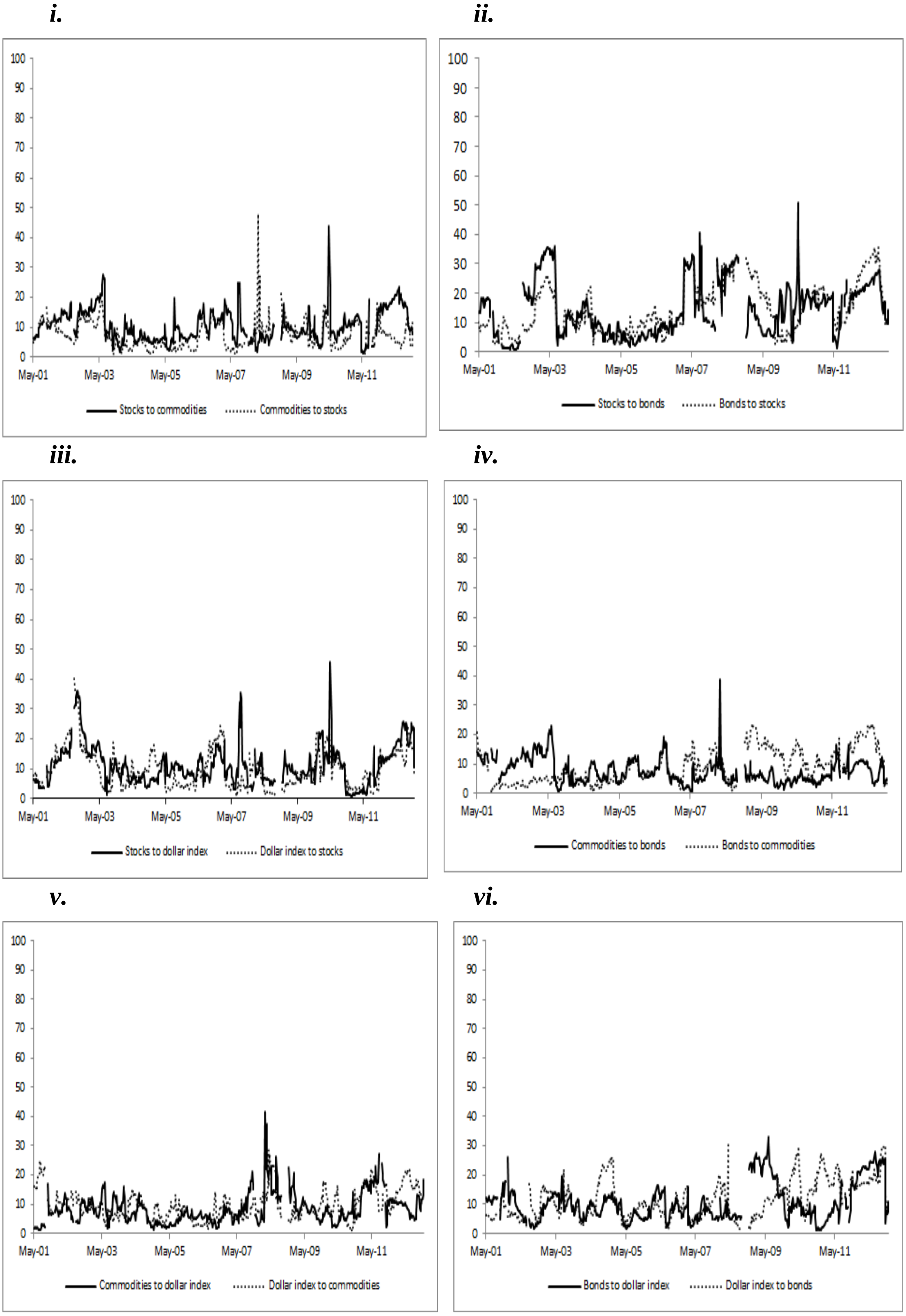


Fig. 9. Volatility spillovers: between asset classes (percent)



5. Conclusion

We have used an econometric method devised by Diebold and Yilmaz (2009, 2012) to examine the relationship between money and financial assets since 2000, where alternative asset market measures (returns and volatilities) have been used to capture behaviour in stock, commodity, government bond, and currency markets. Two money aggregates were considered: M2, representing broad money, and the monetary base. Given the reporting and discussion of the econometric results in the previous sections, we draw the following conclusions:

(i) It is evident that the interaction between money and financial assets, in both returns and volatility measures, tend to be much stronger during periods of financial market turbulence than in calmer times. Spillover effects were robust after the September 11 terrorist attacks, during the early stages of the financial crisis (2008-9), and in the second half of 2011. We would expect that the nominal-certain property of money balances versus the lack of such a quality in financial assets to be an important contributor to such a dynamic in periods of financial and economic stress.

(ii) The interaction between M2 and financial assets tends to be greater than between the monetary base and those assets. The relatively high amount of spillover that arises at times between M2 and stocks is particularly notable. The effects of quantitative easing may then be less important than portfolio adjustment between broad money and financial assets by households in explaining the nexus between money and financial markets, although it is possible that quantitative easing facilitates portfolio adjustment. A flight-to-M2 by households engaged in portfolio adjustment may have been at play during the two aforementioned crises, as well as in the second half of 2011, a period when there was diminished investor confidence and particular concerns about sovereign bond markets. There was less spillover from the monetary base to government bond markets, and in the opposite direction, in recent years than might have been expected a priori given the programs of quantitative easing pursued during this time.

(iii) In the relationship between the two money aggregates, M2 also had strong influence over the monetary base during the post-Lehman Brothers bankruptcy period between September 2008 and August 2009. While the monetary base was not having its expected influence on M2 via the money multiplier, it seems that M2 had explanatory power for developments in the monetary base. We would posit that this was owing to the key role M2 was playing in portfolio adjustment and the decision by the Federal Reserve to respond to financial market developments in an accommodating manner.

With regard to the implications for policy arising from our analysis, the at-times quite high spillovers between broad money (M2) and financial variables observed in the econometric results serve as a reminder of the importance of that money aggregate to financial market developments, something which, like the role of money in economic performance more generally, has been neglected of late. Borio (2006) indicates that changes taking place in the economic, monetary and financial environment in recent years require vigilant central banks to heed the shifting dynamics between policy and economic performance. Our results back up these perspectives and stress the need for central banks not to view financial markets in isolation from monetary developments and, in particular, to heed the interplay between financial assets and money held by the public.

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Appendix A. Data description

Standard and Poor's 500 - Price Index.
Source: Standard and Poor's

Dow Jones-UBS Commodity Index
Source: Standard and Poor's

US Generic Government 10 year Yield
Source: Bloomberg

ICE US Dollar Futures Index
Source: Bloomberg

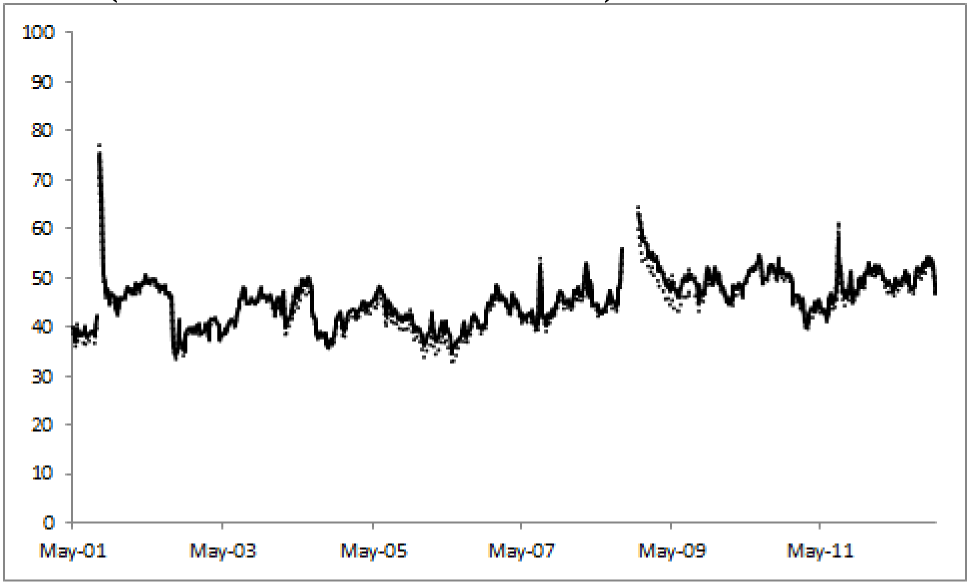
US M2 Money Stock (seasonally-adjusted)
Source: Federal Reserve Bank of St. Louis FRED database

St. Louis Source Base (seasonally-adjusted)
Source: Federal Reserve Bank of St. Louis FRED database

Consumer Price Index for All Urban Consumers: All Items (seasonally-adjusted)
Source: US Department of Labor: Bureau of Labor Statistics

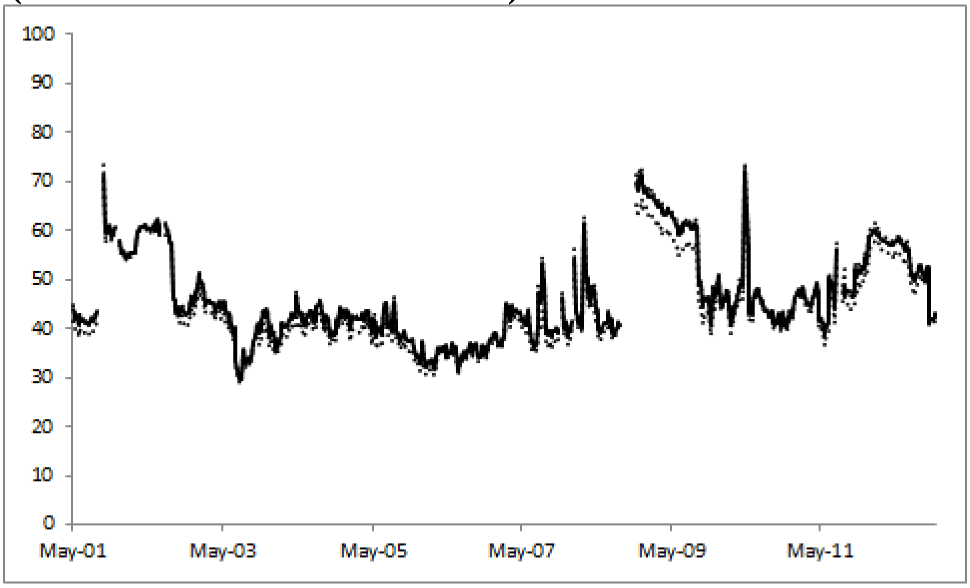
Appendix B. Sensitivity analysis

Fig. A.1 Sensitivity of the returns spillover index to forecast horizon (Six-week to fourteen-week horizons)



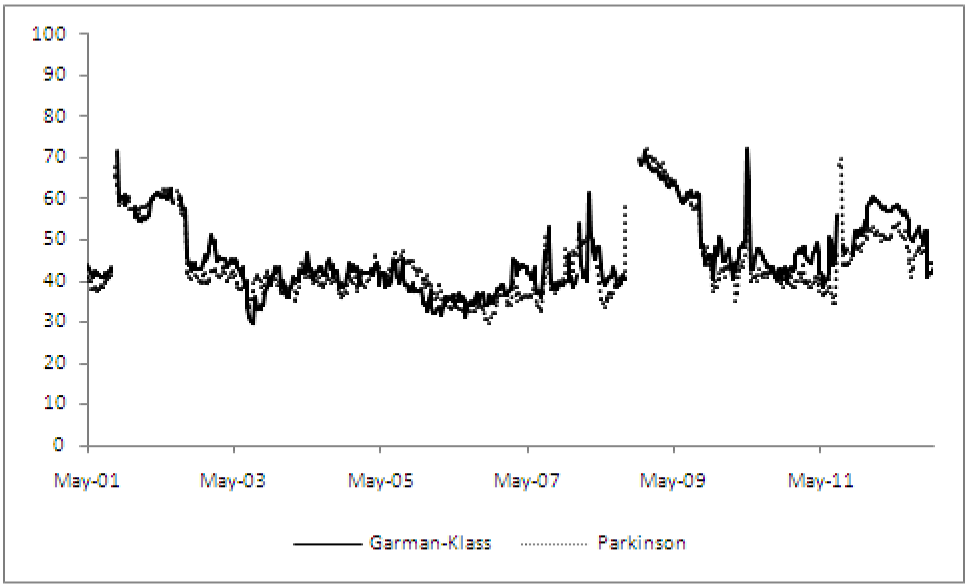
Note: median value – solid line; minimum and maximum values – dashed lines

Fig. A.2 Sensitivity of the volatility spillover index to forecast horizon (Six-week to fourteen-week horizons)



Note: median value – solid line; minimum and maximum values – dashed lines

Fig. A.3 Sensitivity of the volatility spillover index to choice of volatility measure



Money Growth, Uncertainty and Macroeconomic Activity
– A Multivariate GARCH Analysis

David Cronin*, Robert Kelly and Bernard Kennedy

Abstract

The impact uncertainty has on money growth has received much attention in recent years and is an issue of critical importance to central banks, particularly for those, such as the European Central Bank (ECB), which place a strong emphasis on monetary analysis in monetary policy formulation. Some recent papers examining this issue, however, use ad hoc estimates and measure variability rather than uncertainty. We employ a multivariate GARCH model, which measures uncertainty by the conditional variance of the data series, to investigate whether macroeconomic uncertainty and monetary uncertainty Granger-cause changes in real money. The estimated model also allows us to investigate how monetary uncertainty impacts economic activity. We find that macroeconomic uncertainty impacts positively on US real M2 growth over a two-year horizon but that monetary uncertainty does not cause changes in real M2. Instead, our results indicate that real money growth causes monetary uncertainty. Monetary uncertainty is found to have a negative effect on real economic activity and on macroeconomic uncertainty. We conclude by discussing the implications of these results and the methodological approach used for institutions such as the ECB that give monetary analysis a prominent role in their monetary policy strategy.

Keywords Money growth – Uncertainty – MV GARCH – Monetary Analysis

The authors are, respectively, Senior Economist, Economist, and Economist at the Central Bank and Financial Services Authority of Ireland, Dame Street, Dublin 2, Ireland. The views expressed herein are the authors' own. They are not necessarily held by the CBFSAI or the ESCB. The authors would like to thank Don Bredin, Frank Browne, Gerard O'Reilly and Karl Whelan and two anonymous referees for helpful comments and suggestions. Any remaining errors, however, are their own.
* Email: dave.cronin@centralbank.ie

Money Growth, Uncertainty and Macroeconomic Activity – A Multivariate GARCH Analysis

1. Introduction

The impact uncertainty has on money growth has received much attention in policy analysis in recent years. The European Central Bank (ECB), in particular, has identified "portfolio shifts" as a critical factor in the development of the euro area M3 aggregate between 2000 and 2003, attributing those shifts to global shocks which "have had a profound impact … on the dynamics of monetary aggregates" (ECB, 2005, p.57). According to the ECB, heightened geopolitical, economic and financial uncertainties led to increased money holdings in the euro area during the early years of this decade. The impact uncertainty has on monetary developments, therefore, is of critical importance to central banks such as the ECB which give money a prominent role in their monetary policy strategy.

In the economics literature, discussions of uncertainty and money growth have often been broadened out to encompass their interaction with economic activity as well. Two sources of uncertainty have been highlighted: that associated with economic activity (macroeconomic uncertainty) and that associated with money growth (monetary uncertainty). Bornoff (1983), Friedman (1983, 1984) and Mascaro and Meltzer (1983) consider how these various variables should interact. Belongia (1984), referencing those papers, outlines a set of causal links between the variables. It is rooted in an initial change in monetary behaviour. A pickup in monetary volatility generates, or adds to, perceived uncertainty within the economy and, thereof, will increase the demand for, and lower the velocity of, money. In other words, more volatile money growth will induce agents to increase their real money holdings. Those real balances will be held for precautionary, as opposed to spending, purposes, which means that greater monetary uncertainty has the effect of lowering output growth within the economy.

This committed view on how these variables should impact on each other contrasts with a recent contribution by Choi and Oh (2003), which has a narrower focus on the effect of uncertainty on money holdings. They employ a general equilibrium framework where output and money growth are determined by independent stochastic processes and a monetary policy parameter, with the representative agent's preferences being captured by a money-in-the-utility function. They derive both output uncertainty and monetary uncertainty coefficients and incorporate them in a money demand function. They point out that those coefficients' influence on money holdings is *a priori* ambiguous as they depend on the curvature of the utility function and the policy rule parameter. An increase in either form of uncertainty generates both substitution and precautionary effects that have opposing consequences for money holdings.[73] Monetary volatility is assumed in Choi and Oh's model to occur from the money supply side. The implication of their model is that with the influence of uncertainty on money holdings seemingly ambiguous on theoretical grounds, the relationship between the two can only be determined empirically.

Against this background, the challenge for econometricians is to quantify the interaction between the four variables identified in the discussion above: the two forms of uncertainty, money growth and changes in economic activity. In section 2, we initially undertake a brief review of empirical analyses in this area. Many papers, including some recent contributions, address this topic using ad hoc estimates and employ measures of variability rather than uncertainty. In contrast, a generalized autoregressive conditional heteroskedasticity (GARCH) model measures uncertainty as the conditional variance of shocks to the data series and is more appropriate for analyzing the impact of uncertainty on other variables. A multivariate GARCH model can be employed to investigate more rigorously the relationship between the variables concerned.

In section 3, using US data, we successfully estimate a bivariate GARCH model and use it to answer questions arising from the introductory discussion, namely do macroeconomic uncertainty and monetary uncertainty Granger-cause changes in real money and does monetary uncertainty impact economic activity and macroeconomic uncertainty.[74]

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[73] ECB (2005, p.65) also makes the point that the impact of another form of uncertainty - asset price uncertainty - on money demand is ambiguous on conceptual grounds and, therefore, can only be resolved empirically.

[74] Euro area M3 and related data were also examined. Features of the euro area data, however, did not allow us apply the GARCH method to that data. Nevertheless, we would hope that the paper's

With regard to the effect that uncertainty has on money growth, our findings, in summary form, are that macroeconomic uncertainty impacts positively on US real M2 growth but that monetary uncertainty does not cause changes in real M2. Instead, our results indicate that it is real money growth that causes monetary uncertainty. These results are interesting from a policy perspective. First of all, they back up the findings of other recent contributions (Choi and Oh, 2003, Atta-Mensah, 2004, Greiber and Lemke, 2005) that general macroeconomic uncertainty has a significant effect on money growth and provides support for the view, expressed in some of those papers, that an uncertainty variable, or variables, may need to be brought into money demand specifications. We also find that increased monetary uncertainty has a negative effect on economic growth.

Section 4 concludes by discussing some of the implications of the findings for monetary analysis, with specific reference to ECB monetary analysis.

2. Methodological Approach

2.1 The Serletis and Shahmoradi Critique

A number of papers over the years (e.g., Hall and Noble, 1987, and Thornton, 1995) have empirically tested the impact monetary uncertainty has on the demand for money by using moving sample standard deviations of money growth rates as their measure of monetary uncertainty. Serletis and Shahmoradi (2006) are critical of the use of such variability measures, which they point out are ad hoc estimates. Furthermore, moving standard deviation or variance series measure variability, not uncertainty.[75]

The Serletis and Shahmoradi critique also would appear to be appropriate to more recent papers that examine the effect uncertainty has on money holdings. Choi and Oh (2003), for instance, use a rolling regression VAR model to provide time-varying volatility series that are used as measures of uncertainty. Carstensen's

findings and observations can contribute to the discussion of these issues in the euro area and more generally.

[75] This critique of using moving standard deviations (or the cross-sectional dispersion of individual forecasts from surveys) as a measure of uncertainty was also put forward in an earlier paper by Grier and Perry (1998, p.674) in the context of measuring inflation uncertainty and gauging its impact on inflation rates.

(2006) stock market volatility variable is constructed as the two-year average of the conditional variance estimated from a leveraged GARCH model applied to daily data. In Atta-Mensah (2004), individual uncertainties are estimated using GARCH models and are then added together to provide a broadly-based measure of uncertainty. Greiber and Lemke (2005) construct a single measure of uncertainty from several observable indicators for the euro area. Through their use of constructed series or variability measures, these papers do not seem to meet the Serletis and Shahmoradi critique.

2.2 Our Empirical Approach

The question of whether uncertainty, specifically macroeconomic uncertainty and monetary uncertainty, impacts money holdings and economic activity can be investigated more rigorously by using a GARCH model that utilises features of the data, namely, the presence of ARCH effects in the series, to produce measures of macroeconomic uncertainty and monetary uncertainty.[76] The main benefit of this approach over moving-average standard-deviation type approaches is that whereas the estimated variances from the latter can produce inconsistent measures of the true level of uncertainty the GARCH model will not do so if the conditional variances are correctly parameterized.

The caveat is that the conditional variances from the GARCH model are themselves generated estimators and, thus, may be potentially inefficient. This means that individual t-statistics are not applicable. The Granger causality tests (in Table 4 below) that use the estimated conditional variances, however, do not involve inference on individual t-statistics but rather use joint tests of significance which, according to Beaudry et al. (2001), remain applicable.

Like Serletis and Shahmoradi (2006), we initially investigate the univariate properties of the money and output series. The features of the data allow us to pursue a multivariate – in effect, a bivariate - GARCH modelling of the macroeconomic and real money growth series. Whereas Serletis and Shahmoradi use an “in-mean” version of the multivariate GARCH model to examine Granger

[76] This is also the technique used by Grier and Perry (1998) to overcome the critique of variability measures already mentioned.

causality in the data, we use a two-step method, similar to that used by Fountas, Karanasos and Kim (2006). This method involves first estimating the conditional variances of both macroeconomic and real money growth within a bivariate BEKK GARCH model and then using those estimates to undertake Granger causality tests.

The benefits of the two-step approach over the "in-mean" approach are, first of all, that it allows us to examine causality on a bidirectional basis between various pairings of macroeconomic growth, money growth and the conditional volatility of both series, and at various lag lengths. Secondly, our reading of the 1980s literature discussing and testing, in the main, the hypothesis that money growth is a causal factor in changes in the velocity of money (e.g., Belongia 1984, Hall and Noble 1987, Brocato and Smith 1989, and Mehra 1989) is that uncertainty can be expected to have a delayed impact on real money holdings. We need to be able, therefore, to examine causal influences over various lag lengths, which the two-step method easily allows.[77] Thirdly, we note that this approach also minimizes the number of parameters to be estimated (Fountas and Karanasos, 2007, p. 236).

3. Empirical Modelling and Testing

3.1 Data

Two monthly US data series are used in our study. They are the real M2 stock (denoted $m2cpi$) (calculated as the natural log of nominal M2 less the natural log of the CPI), and the natural log of the Composite Index of Lagging Indicators (lai), a series published by the Conference Board.

We choose the Lagging Indicator index because it represents a broadly-based monthly indicator of macroeconomic activity, in comparison with more narrowly-defined indicators such as industrial production. It is a composite of several economic variables: the average duration of unemployment, the inventories-to-sales ratio, the change in the labour cost per unit of output, the average bank prime rate, the amount of commercial and industrial loans outstanding, the ratio of consumer instalment credit to personal income, and the CPI. A benefit of this

[77] We would acknowledge, however, that a VARMA BEEK GARCH-M model, such as used by Bredin and Fountas (2005) in a different context, could have a role in future research in this area, for example in modeling uncertainty within a money demand equation.

composite indicator is that it captures macroeconomic activity in a single variable whose volatility can then be examined.[78]

First-differences of these two data series, $\Delta m2cpi$ and Δlai (i.e., their month-to-month changes), are the variables used in the model. The sample period is 1959m1 to 2007m4.

3.2 Analysis of the Individual Series

It is necessary initially to examine the stationarity properties of both $\Delta m2cpi$ and Δlai. We used three variants of the Augmented Dickey-Fuller (ADF) test (with a constant and a trend term included; with just a constant term included; and with neither a constant nor a trend term included) where the optimal lag lengths are selected by the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC). These ADF tests point to both series being integrated of order zero. This result is confirmed by two supplementary unit root tests, the Dickey-Fuller Generalized Least Squares test and the non-parametric Phillips-Perron test.

Besides these unit root properties, descriptive statistics for both series are shown in Table 1. Excess kurtosis seems to be a feature of the series and the Jarque-Bera test does not support the hypothesis that the series each have a normal distribution.

3.3 Testing for the Presence of ARCH Effects

Given these univariate properties, we estimate VAR regressions using $\Delta m2cpi$ and Δlai. The general form of the bivariate VAR to be estimated is:

$$Z_t = A_0 + \sum_{i=1}^{12} A_i Z_{t-i} + \varepsilon_t \qquad (1)$$

Where Z_t is a vector containing both variables, $\Delta m2cpi$ and Δlai, A_0 is a vector containing two intercept terms, A_i is a matrix of coefficient estimates, and Z_{t-i} is

[78] The Conference Board publishes indices of Leading and Coincident Indicators, alongside that of the Lagging Indicators Index. We choose the latter for this study as it is intended to confirm how economic activity is behaving. By acting to verify what has happened, it appears to provide as close to an "ex-post" evaluation of economic circumstances as any of these three indicators allows and for that reason it is the index chosen here.

a matrix containing lagged values of both variables. Finally, ε_t is a vector containing the two residual terms from the VAR equations.

The chosen VAR order is four. For space considerations, we do not show the coefficient values from the regressions but can report that the equation coefficients seem well-behaved in general. The residual diagnostic tests associated with the two regressions are reported in Table 2. Non-normality and ARCH appear to be present in the regression residuals. This is prima facie evidence that ARCH is present in both series.

3.4 A Bivariate BEKK GARCH Model

Multivariate GARCH models account for the time-varying nature of variances and covariances. VECH, diagonal VECH and BEKK are the most common formulations for multivariate GARCH. Neither the VECH nor the diagonal VECH ensure a positive definite variance-covariance matrix. Equation (1) is, therefore, estimated using the BEKK approach (Engle & Kroner, 1995). The variance-covariance matrix is then described as,

$$H_t = CC' + A'H_{t-1}A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B \qquad (2)$$

Where H_t is the variance-covariance matrix, C is the intercept matrix and is decomposed into CC', where C is a lower triangle matrix. Without further assumption, CC' is positive semi-definite.

Table 1 Descriptive Statistics

	Δlai	$\Delta m2cpi$
Skewness	-0.74 [0.00]	0.17 [0.09]
Kurtosis (excess)	2.80 [0.00]	1.26 [0.00]
Jarque-Bera	242.03 [0.00]	41.21 [0.00]

Note: P-values in brackets.

Table 2 Residual Diagnostics from VAR Equations

	Δlai	$\Delta m2cpi$
ARCH test (χ^2, 1)	14.82 [0.00]	7.10 [0.00]
ARCH test (χ^2, 12)	37.35 [0.00]	18.68 [0.097]
Bera-Jarque normality test (χ^2, 2)	110.79 [0.00]	173.29 [0.00]

Note: P-values in brackets.

Table 3 Bivariate BEKK GARCH (1, 1) Model

$$C = \begin{pmatrix} \underset{(3.458)}{0.00078} & \\ \underset{(0.826)}{0.00065} & \underset{(2.473)}{0.00178} \end{pmatrix} \qquad A = \begin{pmatrix} \underset{(4.471)}{0.2847} & \underset{(-1.663)}{-0.131} \\ \underset{(0.4694)}{-0.0262} & \underset{(4.705)}{0.3483} \end{pmatrix}$$

$$B = \begin{pmatrix} \underset{(28.222)}{0.918} & \underset{(0.726)}{0.0428} \\ \underset{(1.165)}{-0.069} & \underset{(4.7312)}{0.7746} \end{pmatrix}$$

Note: Absolute t-statistics are given in brackets.

The estimated parameters of the conditional variance equations are shown in Table 3. These are well-behaved according to the usual conditions required of GARCH models. The diagonal elements of C are significant at the one percent confidence level. The diagonal elements of A and B, however, are also significant at that level, suggesting large deviations in short run variance from long run levels.

We plot the conditional volatility series in Figures 1a and 1b. The conditional volatility of the Δlai series (Figure 1a) picked up considerably at times during the 1970s and early-1980s and there were also some short-lived rises in recent years.

The conditional volatility of $\Delta m2cpi$ (Figure 1b) was high in the mid-1970s and early-1980s and was also relatively high at times in the 2000s.

3.5 Granger Causality Test Results

With a satisfactory bivariate GARCH model, we can proceed to testing, in the first instance, whether $h_{\Delta lai}$ and $h_{\Delta m2cpi}$ - measures of macroeconomic and monetary uncertainty, respectively – each Granger-cause changes in real M2, $\Delta m2cpi$, and whether their influence is positive or negative. We are also able to test whether causality runs in the opposite direction or in a bidirectional manner.

Four variables ($\Delta m2cpi$, Δlai, $h_{\Delta lai}$ and $h_{\Delta m2cpi}$), along with a constant term, are included in the equations on which the Granger-causality tests are undertaken. The equations are estimated with different lag structures, ranging from including only the first four lags (i.e., months) of each of the four variables up to including the first 24 lags of each. The choice of lag lengths is consistent with previous literature (Hall and Noble 1987; and Mehra 1989) and Friedman's indication that there are long and variable lags in the impact of money on other economic variables (see, for example, Friedman, 1961). The *F*-statistics arising from the variable deletion tests required to test for the presence of Granger causality are reported in Table 4. The statistical significance of the *F*-statistics is indicated and the sign of the sum of the lagged coefficients of the "causal" variable under consideration are shown in brackets.

The variable deletion tests in panel (a) of Table 4 indicate that the null hypothesis that the measure of macroeconomic uncertainty, $h_{\Delta lai}$, does not Granger-cause changes in real M2, $\Delta m2cpi$, can be rejected at lag 24 with this conditional volatility variable having a significant, positive cumulative effect on $\Delta m2cpi$. In contrast, the change in real M2, $\Delta m2cpi$, has no effect on the conditional volatility of the Lagged Indicator series, $h_{\Delta lai}$, across the various lag lengths examined.

Figure 1a Conditional Volatility of the Change in the Lagged Indicator

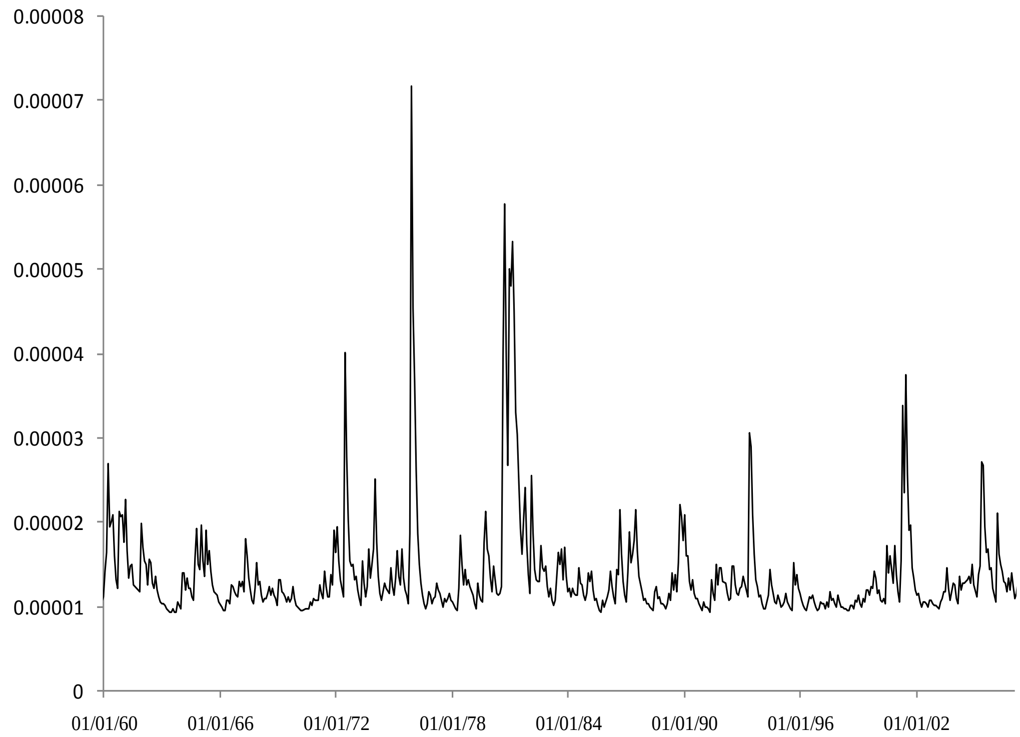

Figure 1b Conditional Volatility of the Change in Real M2

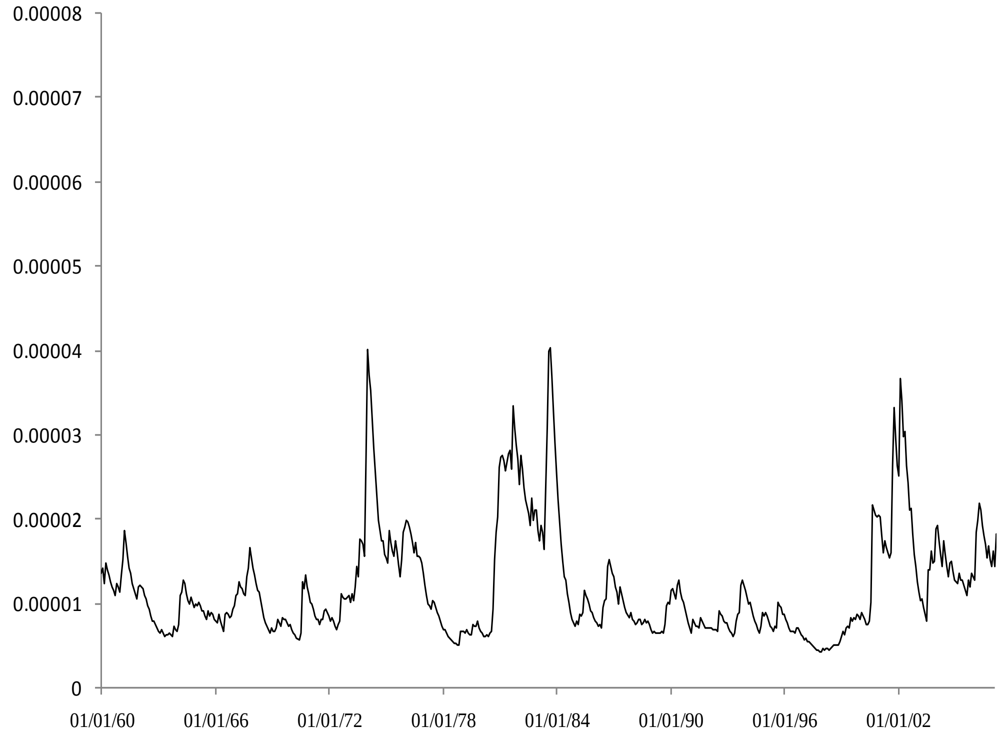

Table 4 Granger Causality Tests

(a)		
M	$H_0 : \sum_{j=1}^{M} h_{\Delta lai\, t-j} \to \Delta m2cpi_t$	$H_o : \sum_{j=1}^{M} \Delta m2cpi_{t-j} \to h_{\Delta lai\, t}$
4	1.08 (+)	1.85 (-)
8	1.24 (+)	1.40 (-)
12	1.42 (+)	0.77 (-)
16	1.45 (+)	0.76 (-)
20	1.01 (+)	0.80 (-)
24	1.60** (+)	0.67 (-)

(b)		
M	$H_0 : \sum_{j=1}^{M} h_{\Delta m2cpi_{t-j}} \to \Delta m2cpi_t$	$H_0 : \sum_{j=1}^{M} \Delta m2cpi_{t-j} \to h_{\Delta m2cpi_t}$
4	0.47 (+)	0.89 (+)
8	1.14 (+)	3.61*** (+)
12	1.19 (+)	3.21*** (+)
16	1.15 (+)	2.48*** (+)
20	1.30 (+)	2.14*** (+)
24	1.22 (+)	1.98*** (+)

Table 4 Granger Causality Tests (contd.)

(c)

M	$H_0 : \sum_{j=1}^{M} h_{\Delta m2cpi_{t-j}} \rightarrow h_{\Delta lai_t}$	$H_o : \sum_{j=1}^{M} h_{\Delta lai\, t-j} \rightarrow h_{\Delta m2cpi\, t}$
4	0.20 (-)	2.75** (+)
8	0.59 (-)	1.97** (+)
12	1.14 (-)	1.51 (+)
16	1.05 (-)	1.24 (+)
20	1.16 (-)	1.37 (+)
24	1.77** (-)	1.29 (+)

(d)

M	$H_0 : \sum_{j=1}^{M} h_{\Delta m2cpi_{t-j}} \rightarrow \Delta lai_t$	$H_0 : \sum_{j=1}^{M} \Delta lai_{t-j} \rightarrow h_{\Delta m2cpi\, t}$
4	1.28 (-)	1.48 (+)
8	1.44 (-)	1.04 (-)
12	1.54 (+)	0.77 (-)
16	1.40 (-)	0.97 (+)
20	1.64** (-)	1.35 (+)
24	1.45* (-)	1.48* (-)

Note: Numerical entries in panels (a)-(d) are F-statistics. A + (-) indicates that the sum of the causing variable is positive (negative). ***, ** and * denote significance at the 1%, 5% and 10% significance levels, respectively. The first column gives the number of lags used in the causality tests.

The finding that macroeconomic uncertainty has a positive influence on real US M2 growth contrasts with that of Choi and Oh (2003) who, in their empirics, find macroeconomic uncertainty to have a negative effect on the narrower US monetary aggregate, real M1. Using Canadian data, Atta-Mensah obtains a positive association between macroeconomic volatility and narrower monetary aggregates and a negative relationship between the volatility variable and the broadest monetary aggregate used by him.

These contrasting findings can be most readily explained by Choi and Oh's model showing the influence of uncertainty on money holdings to be theoretically ambiguous and needing to be determined empirically. Nevertheless, our results require economic interpretation and the most appropriate is that in times of greater economic uncertainty, economic agents are inclined to raise their money holdings for precautionary purposes so that the increased holdings of real money provide a buffer against an uncertain economic future.

The view that monetary uncertainty impacts money growth, through an increase in the precautionary demand for money, is most closely associated with Milton Friedman and other monetarist economists. In panel (b) of Table 4, we find no significant causality arising from the measure of monetary uncertainty, $h_{\Delta m2cpi}$, to $\Delta m2cpi$ at all lag lengths examined. Instead, causation seems to run in the opposite direction and in a positive manner. This seems a plausible result if one believes monetary uncertainty must have its origin in money growth. We note too that monetary uncertainty is assumed in Choi and Oh's model to evolve from a stochastic process in money supply growth.

Two further aspects of the monetarist hypothesis can be investigated using the growth rate series and uncertainty measures available. Friedman (1984, p. 399) argues that a rise in monetary uncertainty can generate or add to general uncertainty within the economy. He is not specific about whether the "adding to" is a contemporaneous or lagged effect. The Granger causality methodology employed here allows one to test for a lagged effect of monetary uncertainty on macroeconomic uncertainty. The results in panel (c) indicate monetary uncertainty having a significant, negative influence on subsequent macroeconomic uncertainty at the longest lag length of one to 24 months. There is also evidence of causality running in the opposite direction at shorter lag lengths.

Given the number of intermediate relationships through which Friedman and other authors (e.g., Belongia, 1984) indicate greater monetary uncertainty impacts, in a negative manner, on economic growth, it is to be expected that a long lag will occur in any causal effect from monetary uncertainty to economic growth. Panel (d) of Table 4 confirms that a significant causal effect, with the expected negative sign, indeed arises at lags one to 20 and one to 24. Changes in economic activity cause monetary uncertainty at lags one to 24, albeit at the 10 percent significance level only.

To conclude our empirical analysis we conducted a robustness test of the results in panels (a) to (d) of Table 4 by undertaking the Granger causality tests for the shorter sample period of 1959m6 to 2004m4. The qualitative results are in line with those for the full sample.

4. Conclusion

A multivariate GARCH model was utilized in this article to examine the interrelationship between real money growth and measures of macroeconomic and monetary uncertainty, as well as to assess the impact of monetary uncertainty on economic activity. We find macroeconomic uncertainty to have a positive and significant impact on US real M2 growth at a one to 24 month lag length so that a rise in macroeconomic uncertainty will cause an increase in real money growth over a two year horizon. In contrast, monetary uncertainty has no discernible causal effect on real money growth at all lag lengths examined. Our results also indicate that changes in real money have a significant, positive effect on monetary uncertainty and that greater monetary uncertainty impacts negatively on economic activity and on macroeconomic uncertainty.

These results and the methodology used are relevant for central banks such as the European Central Bank which attach a prominent role to monetary developments in their monetary policy strategy. The first point we would make is that using a GARCH methodology, such as that used in this paper, to measure and analyse uncertainty's impact on other variables, including money, is *a priori* a better approach than some of the more ad-hoc approaches that have been used in recent years in this area.

Our results also underline how the interaction between uncertainty and monetary developments may be particularly relevant at this time. The ECB (2005) has already shown how greater economic and financial uncertainty in recent years has impacted and interacted with euro area M3 growth. Our econometric results show similar interactions at play in US data over an extended time period. They also indicate a sustained rise in monetary uncertainty and episodes of heightened economic uncertainty in the United States of late. These recent developments have been occurring alongside strong monetary growth and, as has now transpired, have been followed by lower economic growth. The results also support the emphasis placed by the ECB on the medium-to-longer term value of monetary analysis, with macroeconomic uncertainty, for example, impacting money growth with a twenty-four month lag and monetary uncertainty having a negative impact on economic activity over a similar timeframe.

Borio (2006) points out that changes in the financial, monetary and real economic environment in recent years are altering economies' dynamics and pose new policy challenges. The implication, in his view, is that money, credit and financial developments should be given renewed consideration in monetary policy and in assessing financial stability. The key point that can be taken from our study in this respect is that central banks must give uncertainty, in its various forms, careful consideration in their monetary analysis.

The ECB has identified general economic and financial uncertainty as capable of effecting "portfolio shifts" in euro area monetary aggregates and has shown itself to be adept in developing a diverse range of tools with which to undertake monetary analysis in response to such developments (Fischer et al. 2008). In this regard, measures of monetary uncertainty and macroeconomic uncertainty should be given due consideration in the holistic assessment of monetary data (to use Fischer et al.'s phrase, p. 105) favoured by central banks such as the ECB.

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Tranche 2

Commodity Prices, Money and Inflation

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Abstract We argue that long run and dynamic relationships should exist between commodity prices, consumer prices and money. Using a cointegrating VAR framework and US data, our empirical analysis shows equilibrium relationships existing between money, commodity prices and consumer prices, with both commodity and consumer prices proportional to the money supply in the long run. Persistence profiles reveal commodity prices initially overshooting their new equilibrium values in response to a money supply shock. We conclude that money has to be brought into analyses of the relationship between commodity prices and consumer prices.

Keywords: Monetary Policy - Commodity Prices – Overshooting

JEL Classification: C320, E310, E510

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1. Introduction

Commodity prices have recently re-surfaced in discussions of the inflationary outlook for western economies. The popular view seems to be that changes in commodity prices are a consequence of developments occurring solely in the relevant commodity market. Prompted perhaps by the recognition that recent experiences of steep commodity price increases have occurred alongside, or in the wake of, a relatively "easy" stance of monetary policy in advanced industrial economies, there has, however, been a resurgent interest in the argument that monetary conditions account for changes in commodity prices.[79] The implication for empirical work is that commodity prices' influence on consumer prices may not be captured adequately by mechanical pass-through effects and a richer, monetary-based characterisation and modelling of their relationship is required.

From a theoretical perspective, our view is that the influence of commodity prices on consumer prices occurs through a money-driven overshooting of commodity prices being corrected over time. In this paper, we investigate empirically whether the behaviour of both consumer goods prices and commodity prices are consistent with this perspective by using a cointegrating VAR framework. On the basis of an initial discussion and a simple, illustrative model, we formulate the qualitative relationships that we would expect to emerge in the econometric analysis. Our empirical findings are congruent with the long run and dynamic relationships that we posit exist between commodity prices, consumer prices, money and output.

Frankel (1986) has already provided an overshooting theory of commodity prices, drawing on Dornbusch's (1976) theory of exchange rate overshooting. Commodities are exchanged on fast-moving auction markets and, accordingly, are able to respond instantaneously to any pressure impacting on these markets. Following a change in monetary policy, their price reacts more than proportionately

[79] The relevance of monetary conditions to commodity price changes has been highlighted in the financial press; for example, in three *Financial Times* articles: "More to oil shocks than Middle East" (C. Clover and A. Fifield, 29 July 2004), "Too much money to blame for rising price of oil, economists claim" (A. Fifield, 18 August 2004), and "How real interest rates cast a shadow over oil" (15 April 2005 and written by Jeffrey Frankel, a leading academic contributor in the area).

(i.e., they overshoot their new long-run equilibrium) because the prices of other goods are sticky.

Surrey (1989), Boughton and Branson (1991), and Fuhrer and Moore (1992) are three other papers that have acknowledged the potential importance of monetary conditions to the relationship between commodity prices and consumer goods prices. Other, US studies on the commodity price-consumer price relationship include Webb (1988), Garner (1989), Marquis and Cunningham (1990), Sephton (1991), Cody and Mills (1991), Pecchenino (1992), Blomberg and Harris (1995), and Furlong and Ingenito (1996).

Our paper differs from those contributions in the form of model and econometric methodology used. In our view, we add to the literature in three ways. First, many of the aforementioned papers focus on the signalling or predictive power of commodity prices for consumer price inflation. Our contribution examines the intertemporal relationship between commodity and consumer prices and the role money plays in it. This still allows us, as will be seen, to use deviations in commodity prices from equilibrium values to predict subsequent CPI inflation.

Second, where formal modelling of the relationship between commodity prices, consumer prices and monetary policy in Frankel (1986), Boughton and Branson (1991) and other papers uses a Keynesian overshooting model, we examine the relationship in a pure exchange economy framework. Our reading of those papers also suggests that their emphasis is mainly on how monetary policy affects commodity prices. We want to examine whether an exogenous change in money supply causes price disequilibrium in both commodity and consumer goods markets and how measures of both of these disequilibria can explain future changes in CPI inflation.

Third, in terms of econometric examination of the relationship, we use a modelling approach (the Johansen cointegration procedure) that was not used in earlier studies in this area and which is superior and more versatile in a multivariate setting to the Engle-Granger approach to cointegration employed in some of the aforementioned papers. The Johansen procedure allows us to identify and quantify long run and short run relationships between commodity prices, consumer prices and other relevant variables in a rigorous manner and to examine the persistence profiles of system-wide and variable-specific shocks on the cointegrating relations.

The paper is organised as follows. In section 2, we distinguish between commodities, whose prices are flexible, on the one hand, and consumer goods, whose prices are sticky, on the other. With this characterisation, a simple two-good, two-period model is used to show that a flexible commodity price overshoots its new long run equilibrium value in the first period following a change in the money supply, doing so to ensure equilibrium in the overall system of money and prices. The extent of this overshooting acts to predict the next-period change in the price of the other good, namely the consumer good, whose price is unchanged in the first period.

In section 3, using quarterly US data, we employ the Johansen procedure to examine empirically the relationship between commodity prices, consumer good prices and money. Our findings are as follows. First, commodity and consumer prices are each, in turn, cointegrated with the money stock and output. Money and prices move in proportion in the long run. Secondly, commodity prices overshoot their new equilibrium level in response to a money shock, while consumer prices do not overshoot. For both price indices, the speed of convergence to equilibrium following a money shock is quite slow. Output is affected only in the short run by the money stock. Thirdly, one-quarter lagged values of the deviations of both the CPI and commodity price indices from their equilibrium values have explanatory power for current-quarter CPI inflation. A number of commodity price indices are used in the exercise to check the robustness of the results. Section 4 concludes by highlighting policy implications of these findings.

2. A Model of the Relationship between Consumer Prices, Commodity Prices and Money

2.1 Basic Propositions and Hypotheses

We combine two well-known monetarist propositions and an acknowledgement of the varying speeds of adjustment of prices across goods markets to put forward a view of the interrelationship between commodity prices, consumer prices and money. The first standard monetarist proposition is that exogenous changes in the money stock lead to equivalent percentage changes in the overall price level under conditions of stable money demand. The second proposition is the related, and equally conventional, monetarist argument that exogenous changes in the money stock are neutral in the long-run steady state. This implies that all individual prices, whether they be consumer goods or commodities, adjust in the same proportion as the money stock, thus leaving all relative prices unchanged in the new steady state relative to their pre-money stock change configuration. Intuitively, the one-for-one long run relationship between money and prices must ultimately hold for commodities as much as for consumer goods. This point is perhaps best made as follows: if cash (money) forms one-half of all transactions in the economy then a doubling of the amount of cash in the economy must result eventually, ceteris paribus, in the prices of all goods traded within the economy – be they commodities or consumer goods – increasing twofold.

The third proposition stems from prices in commodity markets being able to respond much more rapidly than prices in consumer goods markets to changes in economic conditions, including monetary conditions, so that they can be characterised as flexible price goods. Being auction-based, there are fewer frictions in the price-adjustment process in commodity markets because participants are more equally empowered with more balanced information and resources than their consumer goods market counterparts. This clearly enables them to react quickly to changes in monetary conditions. The subset of sluggish-adjusting, or sticky, goods prices can be identified as consumer goods whose prices usually respond only with long and variable lags to changes in monetary conditions (to use Milton Friedman’s characterisation). Such goods’ prices respond slowly and gradually to monetary conditions but eventually adjust fully to changes in the nominal money stock. This price stickiness tends to be attributed to frictions in labour and goods markets that slow down price adjustment. The CPI, in large part, comprises such goods. The third proposition then is that, in response to a change in the (exogenous) money supply, commodity prices will compensate in the short run for CPI price stickiness by overshooting their new long run equilibrium values.[80]

These three building blocks concerning the behaviour of prices then suggest a number of testable hypotheses about inflation. First, commodity prices, as well as consumer prices, move in proportion to the money stock in the long run. Secondly, commodity prices initially overshoot their long-run equilibrium in response to a change in monetary conditions to compensate for the sluggishness in consumer good prices. Third, an important variable in explaining inflation in the composite price of sluggishly-adjusting consumer goods (the CPI) is the correction of the prior overshooting in commodity prices. In other words, the mean-correction of commodity prices to equilibrium levels explains the subsequent adjustment in the price of the sluggish-price goods.[81]

2.2 The Price Adjustment Process

We now elucidate how consumer good and commodity markets interact in response to a change in the money supply. We assume, in the spirit of the quantity theory, that all money holdings are exogenously supplied and that there is a fixed endowment of goods in the economy in each period. There are two types of goods in the economy which are distinguished by their degree of price flexibility: a sticky-price (*S*) good (to represent consumer goods), whose price cannot adjust to a change

[80] This is Le Chatelier's principle as applied to price theory: if not all goods prices in the economy are free to adjust fully to a change in economic conditions then other goods prices must initially overshoot their new equilibrium values to compensate, a dynamic feature that holds until all prices are able to adjust to their new equilibrium values.

[81] It is well-known (see, for example, Friedman (1968)) that real output can react to a change in the money supply in the short run while being unaffected by it in the long run. Variations in real output also can occur in response to relative price shifts in the short run, such as arises here between commodity and consumer prices. The focus in this section, however, is on the relationship between consumer prices and commodity prices and how it responds to a change in the money stock. For this reason, we do not consider the impact of such a change on output explicitly. This means that we assume total output in the economy, y, as well as the velocity of money, to be unchanging in section 2.3. Nevertheless, in the empirical part of the paper (section 3), we do allow real output, as well as the prices of consumer goods and commodities, to react to a money shock and find its response to be in line with that expected by Friedman and others.

in the money supply until the following period, and a flexible-price (*F*) good (to represent commodities), whose price is fully flexible in each period.

Let's consider an exogenous increase in the money stock at the start of a period. Initially, there is no increase in the demand for money required for purchasing the *S* good (given its fixed endowment and unchanged price in the current period). To maintain overall equilibrium among goods prices, all of the additional money created must flow into the *F* good's own market driving up its fully flexible and instantaneously responsive price. Given that it only accounts for a fraction of the goods in the economy, its price, p^F, must rise further than will be required in the long run, in order to clear the money market. The price of the *F* good then overshoots its new long run value to equilibrate the money market.

The sticky price, p^S, rises in the second period. With the level of the nominal money stock fixed from the previous period, some of the excess money that flowed into the *F* sector in the first period is drained away causing p^F to fall. Invoking the second building block of the model concerning relative price neutrality, p^S rises in the same proportion as the money stock by the end of the second period. The first-round overshooting of p^F is corrected and it, accordingly, falls until its net increase over the two periods is also in proportion to the increase in the money stock.

2.3 A Simple Model of Price Adjustment in a Two-Good, Two-Period Exchange Economy

We now illustrate the relationship between money, sticky price goods and flexible price goods more formally. There are only two non-storable goods exchanged in the economy, whose volumes are unchanging and which together add up to total output in the economy, y. The general price level, p, is a weighted combination of the price of both goods, p^F and p^S (as defined earlier), where the weights are given by their respective shares of trade, λ and $(1-\lambda)$:

$$p = \lambda p^F + (1-\lambda) p^S$$

where $0 < \lambda < 1$.

The relationship between money and the general price level is as follows:

$m\, v = p\, y$

It is assumed that this holds in each period. The velocity of money, v, is assumed to be constant over time and to have a value of one. Given that y does not change, this means that the overall price level always adjusts fully in the current period to changes in the nominal money stock.[82]

We can now consider the effects of a once-off increase (of μ percent) in the money supply in period t. The money-general price level identity then implies that the general price level in period t, p_t, equals $(1+\mu_t)\, p_{t-1}$. The price of the sticky-price good, p^S, does not adjust to the change in the money stock until the following period (in this case, period $t+1$, and, by implication, it remains at its $t-1$ price in period t) while the price of F, p^F, can change freely in each period. The price relationship in period t then will be as follows:

$$p_t \; \{= (1+\mu_t)\, p_{t-1}\} = \lambda\, p^F{}_t + (1-\lambda)\, p^S{}_{t-1} \qquad (1)$$

In the following period, $t+1$, the price of S adjusts to its new equilibrium value [$p^S{}_{t+1} = (1+\mu_t)\, p^S{}_{t-1}$]. The prices relationship in period $t+1$ is then:

$$p_{t+1} = \lambda\, p^F{}_{t+1} + (1-\lambda)\, p^S{}_{t+1} \qquad (2)$$

Now since p_{t+1} is equal to p_t (as we are assuming no further change in the nominal stock of money in period $t+1$), we can then set the right-hand-sides of (1) and (2) equal to one another:

$$\lambda\, p^F{}_t + (1-\lambda)\, p^S{}_{t-1} = \lambda\, p^F{}_{t+1} + (1-\lambda)\, p^S{}_{t+1} \qquad (3)$$

[82] By implication, the real money supply does not change. There is consequently no need for an adjustment in the interest rate to equilibrate money demand to money supply and hence the interest rate does not need to be included in the money market equilibrium equation.

Since p^S_{t-1} equals p^S_t and p^F_{t+1} equals $(1+\mu_t)\, p^F_{t-1}$, this can be restated as:

$$\lambda\, p^F_t + (1-\lambda)\, p^S_t = \lambda(1+\mu_t)\, p^F_{t-1} + (1-\lambda)\, p^S_{t+1}$$

$$=> (1-\lambda)\{p^S_{t+1} - p^S_t\} = \lambda\, \{p^F_t - (1+\mu_t)\, p^F_{t-1}\}$$

$$=> p^S_{t+1} - p^S_t = \{\lambda/(1-\lambda)\}\{p^F_t - (1+\mu_t)\, p^F_{t-1}\} \qquad (4)$$

The difference in the price-flexibility properties of both goods means that the size of the change in the price of the sticky price good (*S*) in period *t+1* can be predicted in period *t* with knowledge of the difference between the current period known value of *F* (p^F_t) and the known equilibrium value to which it must adjust in period *t+1* (i.e., $(1+\mu_t)\, p^F_{t-1}$), which, in turn, is dependent on the change in the money stock in the current period (μ_t). It should be obvious also that for positive values of μ, the left-hand-side of (4) is a positive value and so we can conclude from the other side of the equation that p^F_t must be greater than p^F_{t+1} (the new and final equilibrium value of *F*, which is $(1+\mu_t)\, p^F_{t-1}$). This means that following an increase in the money stock the price of *F* must initially overshoot its new equilibrium value in period *t* before declining to that equilibrium value in period *t+1*. The extent to which p^F must overshoot its new long run value is also affected by the relative weights in trade of the two goods, $\lambda/(1-\lambda)$. At the end of period *t+1*, both *S* and *F*'s respective prices have adjusted fully, in proportion to the rise in the nominal money stock.

3. Econometric Assessment

3.1 Econometric Approach

In this empirical part of the paper, we employ the Johansen maximum likelihood approach to test for the existence of cointegrating relationships among four variables and to estimate any cointegrating vectors in an efficient manner, where those variables are selected on the basis of the discussion in section 2. The four variables are: a commodity price index (representing the flexible goods price, p^F), a consumer price index (for the sticky price good, p^S), the money stock (for *m* above), and a measure of national output (for *y* above). In using this econometric methodology, we are using a reduced form model, which allows us summarise the dynamics of the system of variables and the timing of those dynamics in the form of persistence profiles but does not allow structural interpretation *per se*.

What the discussion in section 2 does is provide guidance as to how we use the information coming from the Johansen approach. Thus, we are interested, among other things, in whether there are two cointegrating relationships present among the four variables and whether long-run proportionality between the money stock and the commodity price index and between the money stock and the consumer price index (CPI) is supported. The econometric approach also allows us examine how long deviations (or gaps) from equilibrium relationships among these variables persist in response to "average" reduced form shocks and whether one quarter lagged values of those gaps are significant in an equation explaining current-quarter CPI inflation.

3.2 Data

We assess our model using quarterly US data. This covers the period 1959Q1 to 2008Q4 for all series with the exception of the Sensitive Materials Index, which is available up to 2004Q2.[83] The "sticky" good price index series that we use in our study is the Consumer Price Index (CPI). We use a number of commodity price indices with the basic rationale being to see if there are similar results across these various indices. The selected series overlap with previous studies examining the relationship between commodity and consumer prices (Webb 1988, Marquis and Cunningham 1990, Furlong and Ingenito 1996).

The first commodity price index is the Commodity Research Bureau Spot Index (CRBSI). It is an index comprising the prices of 22 basic commodities whose markets are considered by the Bureau to be particularly sensitive to changes in economic conditions. Along with this most broadly defined CRB spot index, one of the two major divisions of the index, the Raw Industrials (CRBRI) index, is also

[83] The data series and sources are documented in the appendix.

used.[84] The Conference Board's Sensitive Materials Index (SENSI) is a third commodity price index examined. It comprises raw materials and metals but excludes food and energy. A benefit of using indices of commodity groups rather than individual commodity prices is that idiosyncratic factors impacting on individual commodity markets should have far less influence at the level of a multi-commodity, broadly-based index.

Given the number of price relationships being examined, we use only one nominal money stock variable, the M2 money stock (M2), and one scale variable, real Gross Domestic Product (GDP), to keep the analysis focussed on the relationship between the price indices.

3.3 Econometric Results

Natural logs of the aforementioned variables are treated as I(1), consistent with the outcome of standard unit root tests. Johansen's maximum likelihood procedure provides a unified framework for the estimation and testing of cointegrating relations among such variables in the context of vector autoregressions (VARs). In estimating each cointegrating VAR, we are using four variables. The consumer price index, CPI, the nominal money variable, M2, and the scale variable, GDP, are common to all sets of estimations while a different commodity price index is used in each VAR. In Table 1 then, the sticky price variable in each row is CPI while the commodity price indices used in each row are, respectively, CRBSI, CRBRI, and SENSI. In undertaking the cointegrating VAR estimation, the final eight

[84] The CRBSI comprises commodities that are either raw materials or products close to the initial stage of production. Criteria for the selection of individual commodities include that they are freely traded in an open market and are sufficiently homogenous or standardised so that uniform and representative price quotations can be obtained over a period of time. The commodities' spot prices, i.e. the price at which they are available for immediate delivery on selected major US commodity exchanges, are used in the construction of the CRBSI and its two major sub-divisions, the Raw Materials Index and the Foodstuffs Index. These spot prices are obtained from trade publications and government agencies.

The indices are calculated as an unweighted geometric mean of the individual commodity prices relative to their base period values. The Raw Materials component, and that individual index, comprises hides, tallow, copper scrap, lead scrap, steel scrap, zinc, tin, burlap, cotton, print cloth, wool tops, rosin, and rubber. The Foodstuffs component, and individual index, comprises hogs, steers, lard, butter, soybean oil, cocoa, corn, wheat, and sugar.

observations for each commodity price index are held over for predictive failure tests when examining short run dynamic equations.

The results for the three commodity indices are shown in turn in rows (a) to (c) of Table 1. The chosen VAR lag length is six. We estimate with no intercepts and no trends in the cointegrating vectors.[85] With these choices made, the first step is to test for cointegration among the four variables (CPI, M2, GDP, and each alternative commodity price index) using Johansen's (1988) trace statistic. The results are reported in column (i) of Table 1. The trace statistic supports the number of cointegrating vectors being two among the variables at the 90 percent significance level in the case of rows (a) and (c) and at the 95 percent level for row (b). Given these results and our priors, we proceed on the basis that there are exactly two cointegrating vectors for each of these three sets of variables.

With these trace statistic findings, exactly-identifying restrictions are initially imposed in each row. For each set of variables, CPI is set equal to one and the commodity price index equal to zero in the first vector while the numerical ordering is reversed for the second vector, i.e. CPI is set equal to zero and the commodity price index to one. The maximum-likelihood estimates of these exactly-identified cointegrating relations are shown in column (ii) of Table 1.

We next test the over-identifying restrictions of setting the M2 coefficient equal to –1 for both cointegrating relations in each of the three sets of regressions. The log-likelihood ratio (LR) tests of these restrictions are reported in column (iii) of Table 1. The restrictions receive general support across all rows with the LR statistic being less than the 95 percent critical value in all cases.

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[85] While the Akaike-Information selection criterion suggested a lag length of 4 across all three commodity price alternatives, some of the underlying VAR equations at this lag length had issues concerning the distribution and independence of the error terms. A lag length of six, however, led to VAR estimations with well-behaved error terms. The qualitative outturn of the econometric results in terms of the restrictions imposed, the signs on the error correction coefficients in the short-run equations and the various persistence profiles and impulse responses do not differ at lag lengths of 4, 5 and 6.

The choice of no intercepts in the cointegrating vectors reflects intercept terms in the underlying VAR equations being in all cases statistically insignificant. A restricted intercept and no trends option, however, would produce, with appropriate restrictions, similar results to that shown in Table 1 and Figures 1 to 4.

Table 1: Johansen Cointegration Analysis and Short Run Dynamic Equation Results

	(i)			(ii)	(iii)	(iv)	(v)
P^F	**Trace Statistic** r = 1	2	3	**Exactly Identified Restrictions**	**LR statistic**	**Over Identifying Restrictions**	**Short Run Dynamic Equations**
(a) CRBSI	51.59	22.83	10.80	CPI - 0.82 M2 + 0.21 GDP (0.09) (0.10) CRBSI - 0.51 M2 - 0.03 GDP (0.18) (0.20)	1.55	CPI - M2 + 0.42 GDP (0.03) CRBSI - M2 + 0.53 GDP (0.08)	ΔCPI = -0.0178 EC1[-1] + 0.0054 EC2[-1] … (0.0072) (0.0025) R-SQUARE = 0.71; SC: CHSQ (4) = 7.18; PF: CHSQ (8) = 31.37
(b) CRBRI	52.14	25.18	11.45	CPI - 0.83 M2 + 0.23 GDP (0.09) (0.10) CRBRI - 0.58 M2 + 0.03 GDP (0.19) (0.23)	1.07	CPI - M2 + 0.42 GDP (0.03) CRBRI - M2 + 0.50 GDP (0.07)	ΔCPI = -0.0186 EC1[-1] + 0.0060 EC2[-1] … (0.0076) (0.0027) R-SQUARE = 0.70; SC: CHSQ (4) = 6.56; PF: CHSQ (8) = 26.81
(c) SENSI	49.01	22.57	8.64	CPI - 0.83 M2 + 0.22 GDP (0.07) (0.07) SENSI - 0.71 M2 + 0.21 GDP (0.13) (0.14)	1.50	CPI - M2 + 0.41 GDP (0.03) SENSI - M2 + 0.53 GDP (0.06)	ΔCPI = -0.0232 EC1[-1] +0.011 EC2[-1] … (0.0083) (0.0042) R-SQUARE= 0.73; SC: CHSQ (4) = 1.75; PF: CHSQ (8) = 3.01

The 95 per cent critical values for the trace statistic in column (i) are, for each respective r, 39.81, 24.05 and 12.36. The 90 per cent critical values are, respectively, 36.69, 21.46 and 10.25.

In column (iii), the LR statistic has a chi-square distribution with two degrees of freedom. The 95 percent critical value is 5.99 and the 99 percent critical value is 9.21.

Standard error in round brackets ( ), Lags in square brackets [ ].

Figures 1 to 4 plot the persistence profiles of system-wide shocks and a money-specific shock on the cointegrating relations. They also show the dynamic effects (including their speeds of convergence toward equilibrium) of the latter variable-specific shock on individual variables in the cointegrating VAR model. In Figure 1, the time profiles of the effects of system-wide shocks on the cointegrating vectors are shown.[86] These indicate stability in the cointegrating vectors with each relation converging, albeit slowly, towards their respective equilibria. With support for systemic stability across each set of cointegrating vectors, we next focus on the response of the price variables to a M2-specific shock. We plot first in Figure 2 the impact of the money shock on the cointegrating vectors and then on the individual variables in Figure 3. In the Figure 2 panels, it can be seen that convergence toward their respective equilibria is evident over time for the CPI and relevant commodity price index cointegrating vectors following the money shock. Convergence to equilibrium is quite slow, a process that would seem consistent with a long transmission of money to prices.

The patterns of convergence for the cointegrating vectors in the three panels of Figure 2 can be understood better by looking at the impact over time of the M2 shock on the consumer and commodity price variables in Figure 3. The CPI and commodity price series plotted in each panel seem to converge toward the same, higher level over time. The adjustment pattern for the two price indices is also similar across the three panels with the commodity price index rising quickly over the first 12 quarters or so to a peak while the CPI adjusts only slowly and steadily upwards over time. In panels (a) and (b), there is an overshooting of its equilibrium value by the commodity price index followed by a subsequent decline. For panel (c), where SENSI is the commodity price index, there is a sharp initial rise in the commodity price index but it does not overshoot its new long-run equilibrium. It does, however, overshoot its medium-term values. In all three panels, the CPI can be seen to adjust little in the initial quarters after the money shock and then to rise steadily toward its new equilibrium.

[86] The units on the horizontal axis of all panels of Figures 1 to 4 are quarter-years.

The response of the GDP variable is also shown in the Figure 3 panels. It receives a slight, short-lived boost from the money supply shock before reverting to its initial value. This is in line with standard quantity theory, which indicates that a positive change in the money stock will raise real output in the short run only with no long run consequence for the course real output takes. The short-run rise in total output may reflect output adjustments in commodity and consumer good markets in response to relative price changes.

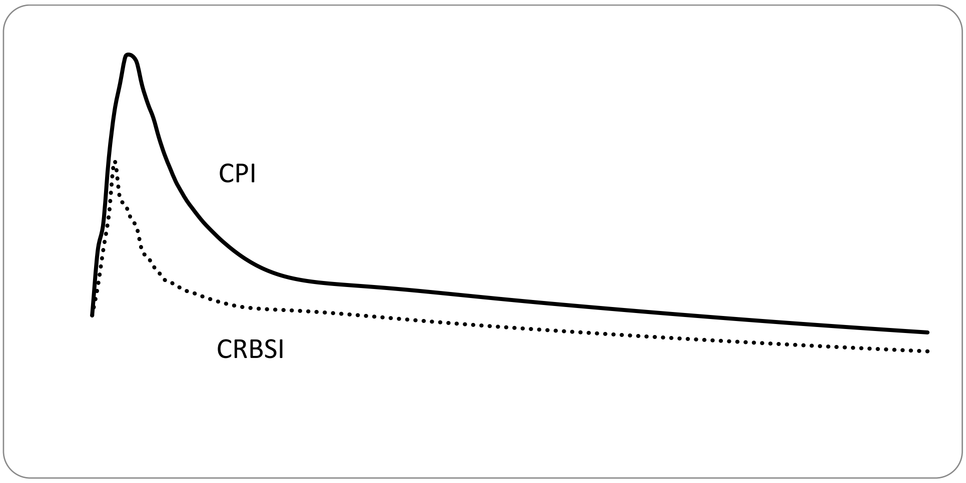
We plot the rates of change of these responses of CPI, GDP and the respective commodity price indices to the money shock in Figure 4. The rate of change (or inflation rate) of each of the commodity price indices peaks after five quarters and then starts to decline. The rate of change moves into negative territory after 12-14 quarters, a development consistent with the correction of the overshooting. CPI inflation only picks up after about five quarters, i.e. after commodity price inflation has peaked. It then rises steadily to a peak at quarter 12, broadly coinciding with commodity price inflation turning negative in value. This shows that with the CPI rising towards its new equilibrium value, the commodity price index is correcting the initial overshooting of its own new stable level that followed the money shock.

CPI inflation only declines slowly and steadily after its peak and the entire CPI inflation rate response to the money shock can be described as one of a slow rise-and-decline. The peak rate of CPI inflation is quite low relative to that of the various commodity price indices. The boost to GDP growth is quite small and only lasts about six or seven quarters.

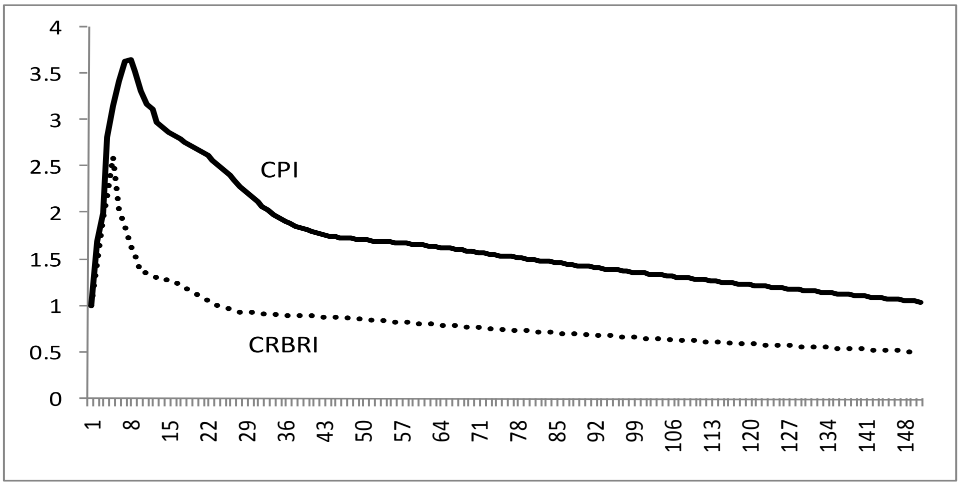
As the final part of our econometric analysis, we note that the Johansen procedure provides us with a model of the short run behaviour of the CPI, where its first difference (ΔCPI) is regressed on the first-quarter lags of the two error-correction (EC) terms and, in this case, the first five lags of the changes in the four variables included in the cointegrating VAR system. The EC terms are the deviation of the respective price variables from their equilibrium values. It is common to examine their significance in explaining changes in any of the variables under consideration.

Figure 1: Persistence Profiles of Cointegrating Vectors to System-wide Shocks

(a) CRBSI



(b) CRBRI



(c) SENSI

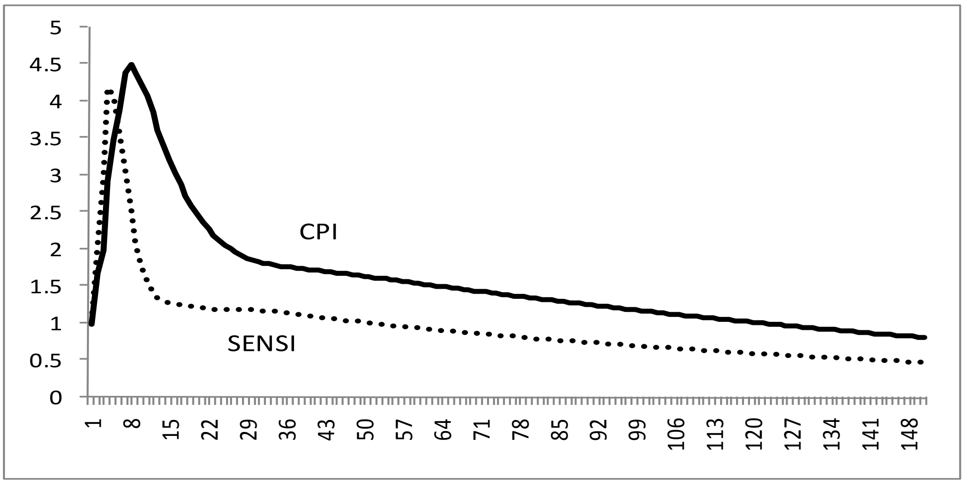
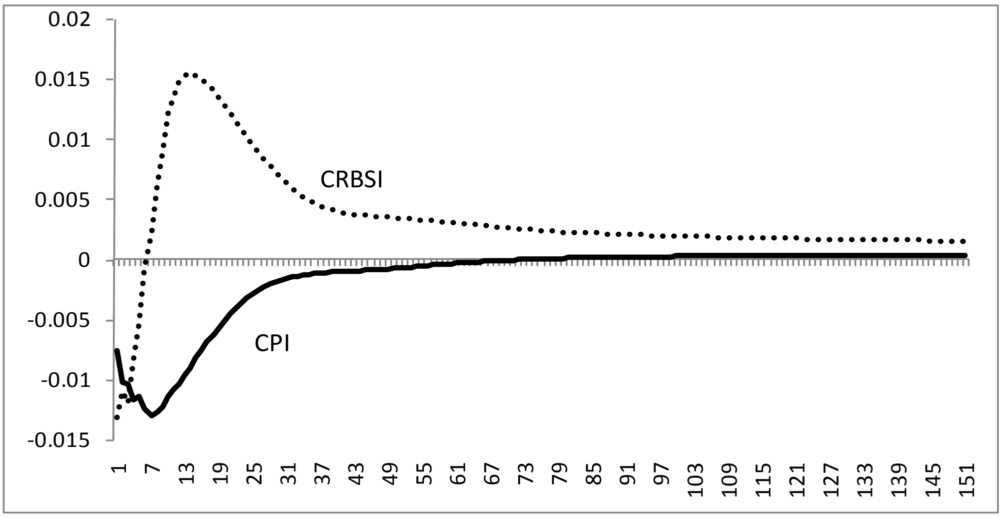
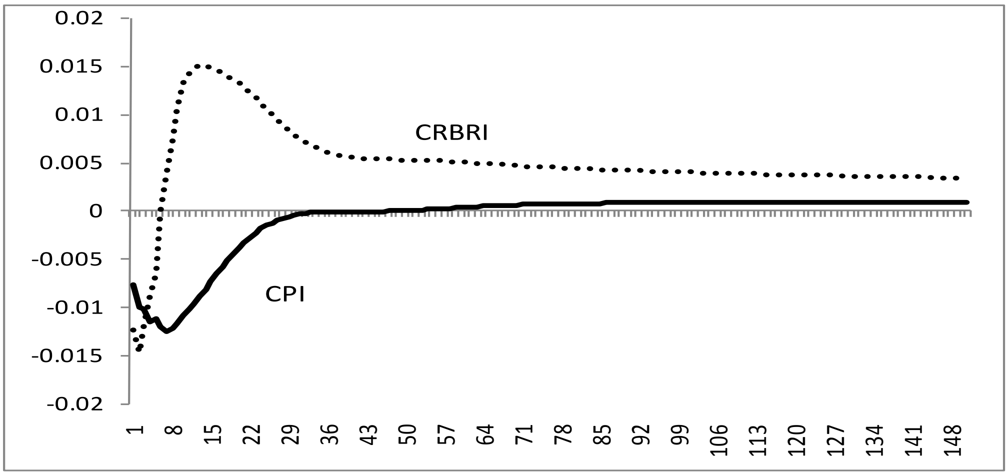

CPI
SENSI

Figure 2: Persistence Profile of Cointegrating Vectors to a M2 Shock

(a) CRBSI



(b) CRBRI



(c) SENSI

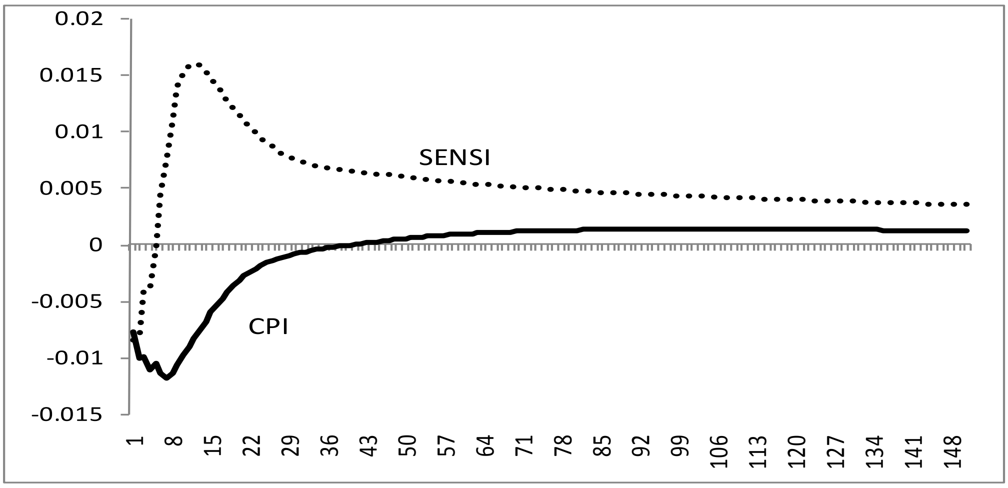
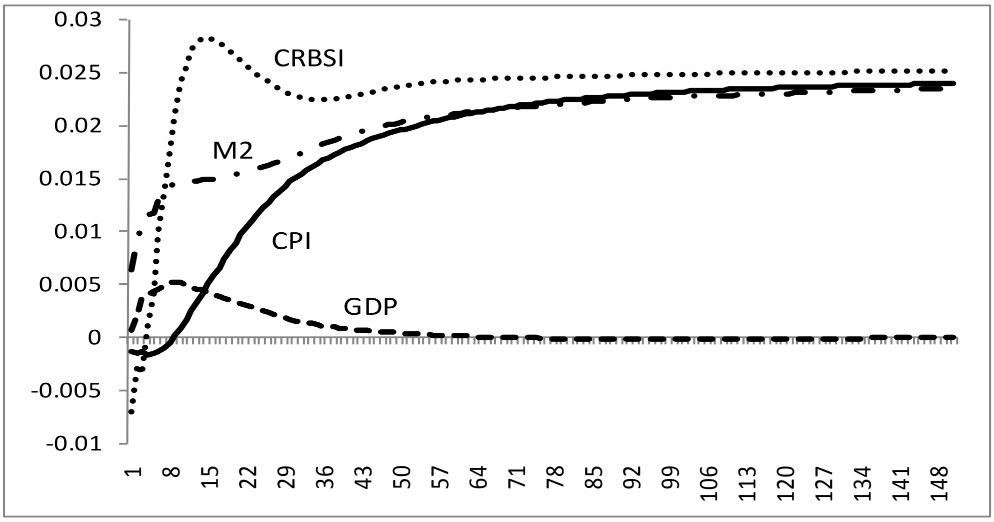
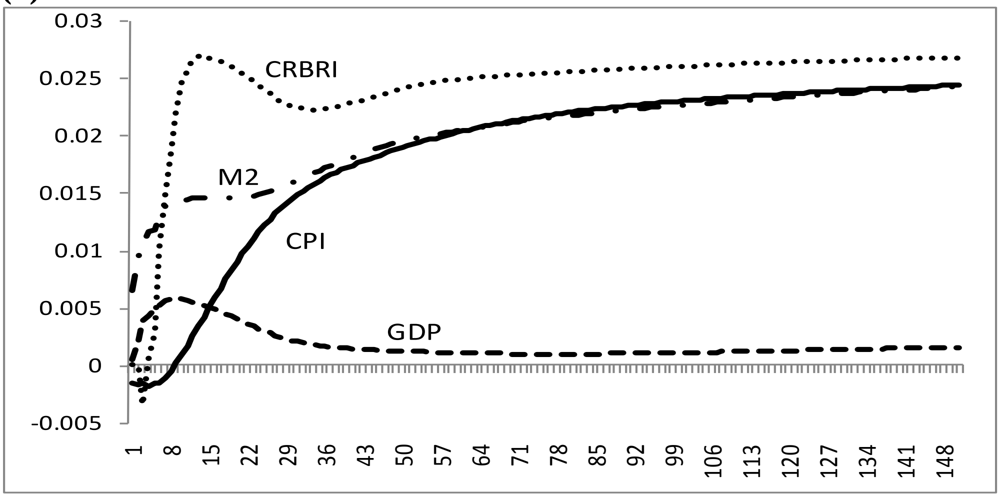


Figure 3: Response of Variables to a Shock in the M2 Equation

(a) CRBSI



(b) CRBRI



(c) SENSI

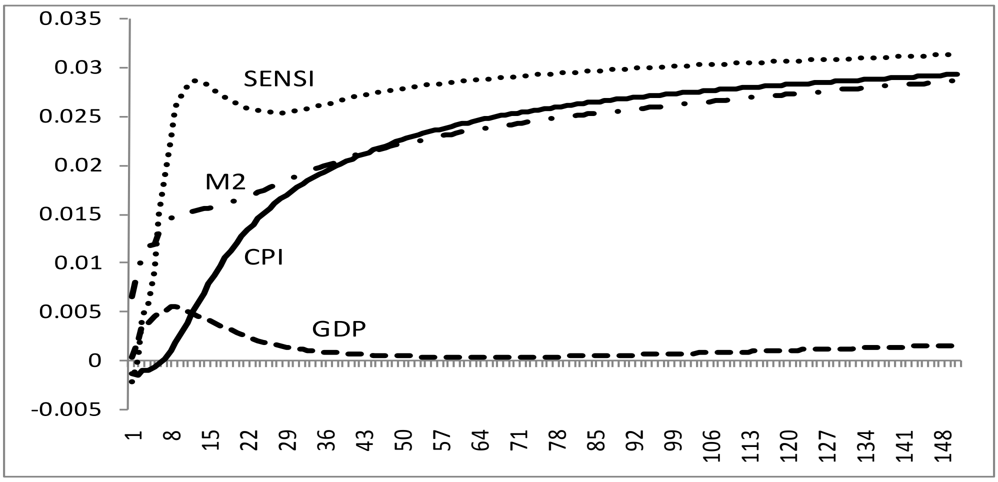
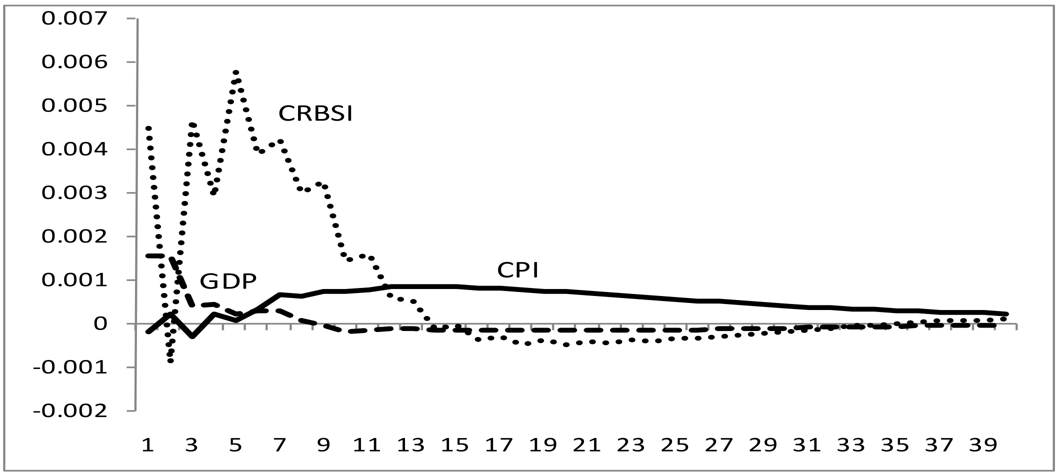
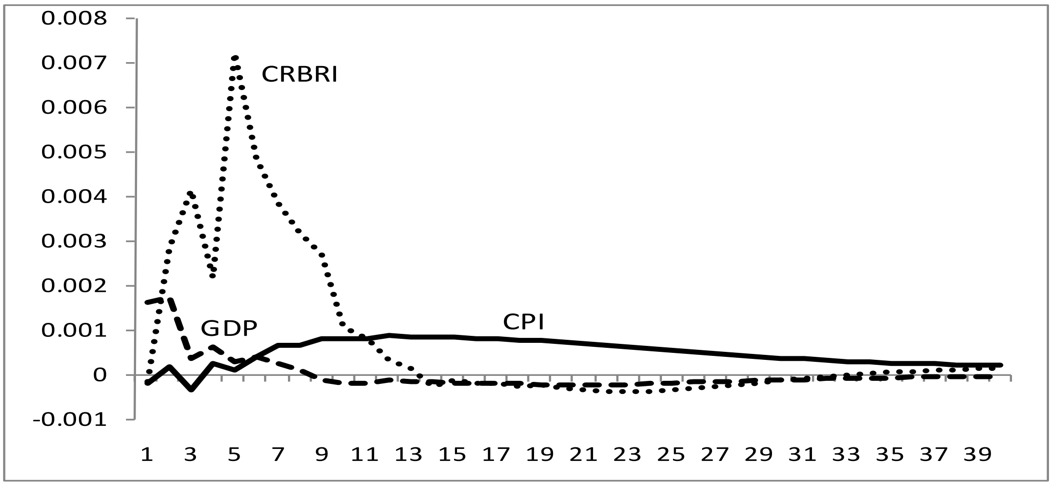


Figure 4: Response of Variables to a Shock in the M2 Equation – Rates of Change

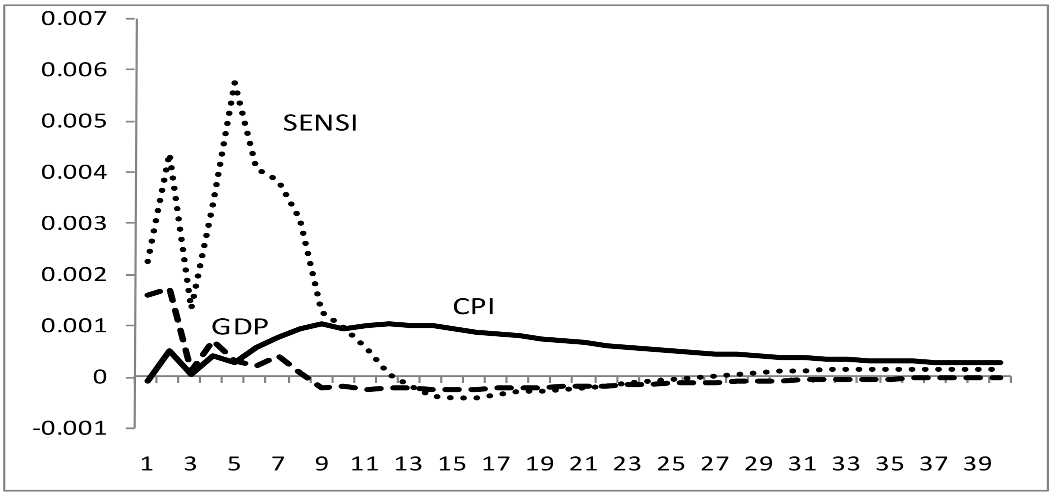
(a) CRBSI



(b) CRBRI



(c) SENSI



In the equation explaining CPI inflation, the error correction term, EC1 (-1), is the one-quarter lagged residual from the cointegrating vector involving the dependent variable in the short-run model (for example, the residual from the "CPI – M2 + 0.41 GDP" vector in column (iv), row (a) of Table 1 is the subsequent EC1 term used in the final column for that row). This error term measures how much the CPI deviates from its own long-run value. In line with section 2, we expect the first lag of this EC term, EC1 (-1), to have a negative coefficient in a model where the current period change in the CPI is the dependent variable.

The second lagged EC term, EC2 (-1), is the deviation of the particular commodity price index under consideration from its equilibrium value (so, to continue the previous example, in column (iv), row (a) of Table 1 it is the residual from the "CRBSI – M2 + 0.49 GDP" vector). By reference to our theoretical model and earlier discussion, we expect EC2 (-1) to have a positive coefficient in explaining the current period change in the CPI. The pair of cointegrating vectors in each row then provide the two error correction terms reported in the final column, (v), of Table 1 for each of these respective rows.

For space considerations, we report only the coefficients on the two lagged error correction terms from among all the coefficients in the CPI inflation equation in column (v) of Table 1.[87] Both EC terms have the expected signs and are statistically significant in all rows. The residual diagnostics point to well-specified models, although there is predictive failure in the case where CRBSI and CRBRI are the commodity price indices under consideration. CUSUM and CUSUMQ tests of structural stability, not shown, do not detect any systematic changes in the regression coefficients at the 5 percent level.

4. Conclusion

This paper is motivated largely by recent experience of rapid commodity price increases, following closely on a fairly prolonged accommodating stance of US Federal Reserve monetary policy that was accompanied by strong money growth.

[87] We also report R-square values, predictive failure (PF) and serial correlation (SC) statistics.

When combined with similar policy stances and rapid money growth in the euro area and Japan, it suggests a causal role for monetary developments in driving commodity prices and the likelihood of this spilling over to consumer good prices in time.

Our key empirical findings are that there is support for: commodity and consumer prices each, in turn, being cointegrated with the money stock and output; long run proportionality between money and consumer prices and between money and commodity prices; a slow speed of convergence to equilibrium among the variables following shocks; and commodity prices reacting relatively quickly following a money shock and having a tendency to overshoot their new equilibrium values. While acknowledging the reduced-form nature of the econometric model used, we believe the empirical findings are supportive of the discussion in section 2.

From a policy perspective, we would conclude that it is important that monetary aggregates are brought into analyses of the commodity price-consumer price relationship and that it is unsurprising that commodity price rises can lead consumer price inflation. Generalised commodity price increases lead consumer price inflation as a manifestation of the differing speeds of adjustment of the prices of both types of goods to monetary developments and not necessarily the result of exogenous, commodity market-specific events.

Our results also suggest that the trend towards downplaying monetary aggregates in the broad formulation of monetary policy could usefully be re-examined. This point is being restated of late, with papers such as Reynard (2007), Hafer, Haslag and Jones (2007), and Hafer and Jones (2008) showing that monetary shocks – measured as changes in money supply – statistically affect or predict economic activity. We believe our paper complements and adds to that literature by showing that a money shock affects output in the short run and causes different, but related, responses in the prices of commodities and consumer goods over the short-to-medium term.

The findings in the paper may also help to explain the role monetary shocks played in the recent financial crisis. It was preceded by strong money growth, relatively low CPI inflation and a rapid rise in commodity prices, the kind of short-to-medium-term price behaviour associated with positive money shocks in our empirical results. Given that the prices of most asset classes rose substantially from around mid-2003 to late-2007, it can also be asked whether the overshooting-followed-by-a-correction relationship between money and commodity prices documented in this paper may also exist between money and asset classes more generally. Future research in this area could look at using and adapting the methodological approach employed here to examine and understand better the relationship between money, consumer prices, and the price behaviour of various asset classes. Modelling the supply of money explicitly could also play a part in the development of the approach.

Finally, it should be pointed out that a substantial correction in asset prices and associated uncertainty may in itself be seen as a significant negative shock by policymakers and the public alike. This may put the central bank under pressure to ease monetary policy and increase the money supply. If it is not able to sterilise such a rise in the money stock when the uncertainty eventually dissipates, there is then likely to be a large residue of a monetary overhang. In turn, this may instigate a fresh round of asset price increases and overshooting of equilibrium asset values. The way in which the central bank reacts (or is forced to react) to a sharp decline in asset prices then could have the effect of propagating a new asset price cycle.

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Appendix: Description and Sources of Data

Consumer Price Index for All Urban Consumers: All Items	Index: 1982-84 = 100	SA	US Department of Labor: Bureau of Labor Statistics
CRB Spot Index	Index: 1967 = 100	NSA	Commodity Research Bureau
CRB Raw Industrials Sub-Index	Index: 1967 = 100	NSA	Commodity Research Bureau
Index of Sensitive Materials Prices	Index: 1992=100	SA	The Conference Board
M2	$ billion	SA	Board of Governors of the Federal Reserve System
Gross Domestic Product	Billions of Chained 2005 Dollars	SAAR	US Department of Commerce: Bureau of Economic Analysis

SA: Seasonally-Adjusted; NSA: Not Seasonally-Adjusted; SAAR: Seasonally Adjusted Annual Rate.

A Monetary Perspective on the Relationship between Commodity and Consumer Prices

Frank Browne and David Cronin

Abstract

In this article, we argue that long run monetary determination of both commodity and consumer prices and their differing, but related, short-to-medium term responses to monetary pressures may help explain US CPI and commodity price index (comprising agricultural items and raw materials) data since the early 2000s. We draw on a recent paper of ours (Browne and Cronin, 2006), and an overshooting model therein, for our analysis. It is argued, firstly, that a long run proportional relationship should exist between commodity prices and the money supply on the one hand and between consumer prices and the money supply on the other. Secondly, following a change in the money supply commodity prices will overshoot their new long run value before readjusting back toward it while consumer prices will move slowly toward their new equilibrium. These arguments are supported by the US data used.

We also make a new application of the model to the constituent components of the US CPI and find that it can also explain recent price behaviour in this case. Our analysis suggests that the food component of the CPI should not, at least in the US case, be seen as a "nuisance" variable in monetary policy analysis.

The authors are Head and Senior Economist, respectively, in the Bank's Financial Stability and Payments department. The views expressed in this article are the sole responsibility of the authors and are not necessarily those held by the CBFSAI or the European System of Central Banks.

1. *Introduction*

Money growth and real interest rates have been respectively high and low by historical cyclical precedent since the start of the current decade. Their failure to show up in subsequent headline (e.g. CPI) inflation in developed countries has been a source of puzzlement. At the same time, commodity prices have risen considerably. Why has headline inflation behaved as it has when two supposedly key influences on it – commodity prices and monetary pressures – are behaving in a way that might be associated with higher inflation rates?

In this article, we argue that long run monetary determination of both commodity and consumer prices and their differing, but related, short-to-medium term responses to monetary pressures may help explain their price behaviour since the early 2000s. Our theoretical argument is that in a world comprising goods whose prices are highly flexible, like commodities which are traded on exchanges, and other goods whose prices are sluggish, such as consumer goods which are subject to longer-term contracts and menu costs, the prices of the former initially over-adjust (overshoot) in the face of monetary pressures to compensate for the prices of the latter not being able to respond immediately. This overshooting, however, is not long-lived as consumer good prices begin to respond to changes in the money stock. As consumer good prices start to adjust, the overshooting of commodity prices is corrected. Ultimately, both types of goods prices change by the same percentage amount as the money stock.

We draw on a recent paper of ours (Browne and Cronin, 2006) as the basis for the arguments in this article. There, as well as discussing and formalising our perspective on the relationship between commodity prices, consumer prices and money, we used econometric techniques and US data to investigate our model's empirical relevance. We found that both consumer prices and commodity prices move in proportion to the money stock in the long run. In the short-to-medium term though, commodity prices are much more responsive than consumer prices to changes in the money stock. It takes time for money growth to manifest itself in consumer prices while the more flexible commodity prices overshoot their long run values. Over time, consumer prices duly respond to money growth and the commodity price overshooting is corrected. Eventually both adjust in proportion to the money stock. The empirics, therefore, provide broad support for our prior views in this area, with the temporal behaviour of both consumer prices and commodity indices comprising agricultural and raw material prices being explained by money.

In section 2, we provide a review of the literature that has previously examined the relationship between money, commodity prices and the CPI. In section 3, we expand on the outline of our own theory of their interrelationship given above and summarise the econometric evidence that supports our view. We also look at developments in commodity prices and the US CPI since 2001 and identify some patterns therein that we believe can be explained by our perspective.

We make a new application of our model in section 4 by examining the constituent components of the US CPI and seeing whether the model can explain their behaviour. We find that both the CPI less food and energy (sometimes referred to as “core CPI”) and the food component of the CPI move in proportion to the money stock in the long run. While the CPI food component does not overshoot its long run value in response to a change in the money stock, it does move more quickly towards it than the core CPI does. As a result, the food component of the CPI should not, at least in the US case, be seen as a “nuisance” variable in monetary policy analysis. We conclude in section 5 with a number of suggestions that we believe arise for monetary policy analysis from our research.

2. Commodity Prices, Inflation and Monetary Policy: A Literature Review

The interaction between consumer prices, commodity prices and monetary policy has been the subject of numerous papers over the past twenty-five years or so. Many US studies of the commodity price-consumer price relationship, written between the mid-1980s and mid-1990s, often give little attention to the role of monetary variables in the relationship between commodity and consumer prices.[88] Instead, they tend to examine the signalling or predictive power of commodity prices for consumer price inflation as a basis for assessing how commodity prices could serve as an input into monetary policy formulation. The papers were written,

[88] See Webb (1988), Garner (1989), Marquis and Cunningham (1990), Cody and Mills (1991), Pecchenino (1992), Blomberg and Harris (1995), and Furlong and Ingenito (1996).

in many cases, in response to actual prices behaviour in the 1970s and early 1980s when rising commodity prices seemed to lead a pickup in CPI inflation. In the main, they examine whether commodity prices actually lead and have predictive power for CPI inflation. Their evidence is quite mixed. A notable feature of these papers is that the existence of a long-run relationship between consumer and commodity prices is often examined in a bivariate context, where commodity prices are identified beforehand as the variable driving consumer good prices. Most studies do not find a cointegrating relationship existing between the two price variables.

Monetary variables as drivers of related movements in both commodity and consumer prices is considered in Jeffrey Frankel's overshooting theory of commodity price behaviour (Frankel 1984, 1986). His thesis is that real interest rates exert an important influence on real commodity prices because of the stickiness of what he terms "manufactured goods", or finished goods (these would encompass consumer goods). Accordingly, monetary policy has an impact on commodity prices through its effect on real interest rates.

A monetary policy-induced rise in the real short-term interest rate, for example, causes commodity prices to fall according to Frankel's model. This occurs because a rise in nominal interest rates effected by monetary policy, for instance, will be associated with a higher real interest rate as the price of finished goods are sticky in the short run. Since the real interest rate represents the opportunity cost of tying up resources in commodities then, all other things being equal, an increase in the real interest rate reduces the demand for commodities leading to a drop in their real prices. This price change occurs quickly as commodities are traded in auction markets, which are particularly responsive to policy measures.

The extent of the decline in commodity prices is dictated by an arbitrage condition. This requires that they fall sufficiently far to ensure that their subsequent appreciation to their equilibrium value compensates their holder fully for the increased cost of carrying them. They "overshoot" their long run value in order to ensure equilibrium is maintained in financial markets. Eventually, as all prices adjust fully to the monetary policy action, the real interest rate and the real commodity price return to their equilibrium values.

Frankel's focus is primarily on the impact real interest rates have on real commodity prices, with the stickiness of finished goods prices relative to commodity prices playing a key role in the dynamic response of commodity prices to monetary policy. Boughton and Branson (1991) derive a number of empirically testable propositions from an extension of Frankel's model where the CPI is used as the measure of manufactured or finished goods. Their propositions find mixed empirical support. There is no evidence of a long run relationship between the level of consumer prices and commodity prices while the inclusion of commodity prices does not improve post-sample forecasts of the CPI. They do find that turning points in commodity-price inflation frequently precede turning points in CPI inflation.

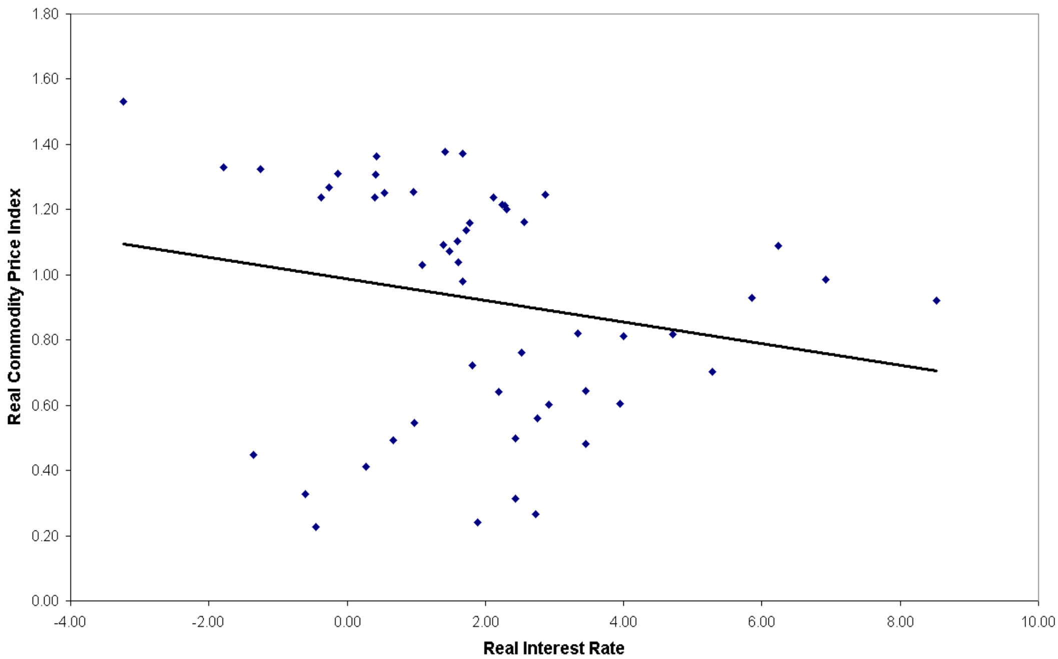
Following a hiatus in the late1990s, recent years have seen renewed interest in the links between commodity prices and consumer prices, as well as the role monetary policy may be playing in their movements over time.[89] Barsky and Kilian (2002) revisited the Great Stagflation of the 1970s and show that monetary contractions and expansions can explain stagflation. This runs counter to the traditional view that oil price rises owing to supply shocks were the main force driving high inflation in goods and services and lower output in the 1970s. Barsky and Kilian's econometric evidence indicates that monetary conditions can account for the rise in the price of oil and other commodities at that time. They conclude that stagflation is first and foremost a monetary phenomenon.

Frankel (2007) reasserts the relevance of his overshooting theory to developments in commodity prices. The key point made in his earlier contributions, he stresses, is that real commodity prices will respond in the opposite direction to changes in real interest rates. For this reason, he argues that declining real interest rates may help explain rising commodity prices during 2002-4. Frankel illustrates this relationship by graphing annual observations of the US real interest rate against an annual series of US real commodity price indices over the period 1950 to 2005, which shows a negative relationship existing between the real interest rate and those price series. We replicate this relationship in Figure 1, fitting a trend-line to the

[89] Frankel (2007) suggests that interest in commodity prices' impact on the economy tends to rise and fall in line with actual commodity prices.

scatter-plot.[90] His own theory, Frankel emphasises, attributes this empirical phenomenon to monetary policy increasing or decreasing real interest rates in the short run with predictable knock-on effects for commodity prices. Among the implications for monetary policy, Frankel suggests that central banks must monitor real commodity prices as their values may reflect whether real interest rates are at

Figure 1. US Real Commodity Prices and Real Interest Rates, 1954-2006



an appropriate level for meeting policy objectives. He specifically points out that high real commodity prices can be a signal that monetary policy is too loose.

3. A New Model of the Relationship between Money, Commodity Prices and Consumer Prices

- The Overshooting Model

In our 2006 paper, we offer a fresh, monetary-based perspective on the relationship between commodity prices and consumer prices. We argue, on the basis of a number of propositions and a formal model, that, firstly, a long run proportional relationship exists between commodity prices and the money supply on the one

[90] For the real commodity price index, we use an annualised average of the CRB Spot Index, a broadly-based US commodity index, deflated by the CPI. The real interest rate is calculated as an annualized average of the (nominal) rate on a one-year constant-maturity US T-bill less the annualized average of the CPI inflation rate in the same year. Our sample period is shorter than Frankel's, covering the years 1954-2006.

hand and between consumer prices and the money supply on the other. Secondly, we contend that, following a change in the money supply commodity prices will overshoot their new long run value before readjusting back toward it while consumer prices will move slowly toward their new equilibrium.

The three propositions on which we base our model and subsequent empirics are:

(i) exogenous changes in the nominal money stock lead to equivalent percentage changes in the overall price level, which comprises commodity and consumer prices, under conditions of stable money demand;

(ii) exogenous changes in the money stock are neutral in the long-run steady state, implying that all individual prices, whether they be consumer goods or commodities, adjust over time in the same proportion as the money stock, thus leaving all relative prices unchanged in the new steady state; and

(iii) in response to a change in the (exogenous) money supply, commodity prices will compensate in the short run for CPI price stickiness by overshooting their new long run equilibrium values.

The first two propositions are essentially monetarist in nature. The one-for-one relationship between money and the overall price level must hold at all times to maintain monetary equilibrium and it must also hold for commodities and consumer goods in the long run. A doubling of the money stock, for instance, must, all other things being equal, have as its final outcome the prices of all goods traded within the economy increasing twofold. The third proposition stems from commodity goods being traded in auction markets, allowing them to respond quickly to monetary stimuli. In contrast, consumer prices are "sticky" in nature, responding slowly to changes in monetary conditions. A rise in consumer prices proportional to an increase in the money stock occurs gradually and is only completed with a considerable lag. Our third proposition then reflects the view that flexible commodity prices will overshoot their new long run value following a change in the money stock to maintain proportionality between money and the overall price level.[91] This overshooting will be corrected over time as consumer good prices

[91] This is the well-known Le Chatelier's principle as applied to price theory: if not all goods prices in the economy are free to adjust fully to a change in economic conditions then other goods prices must

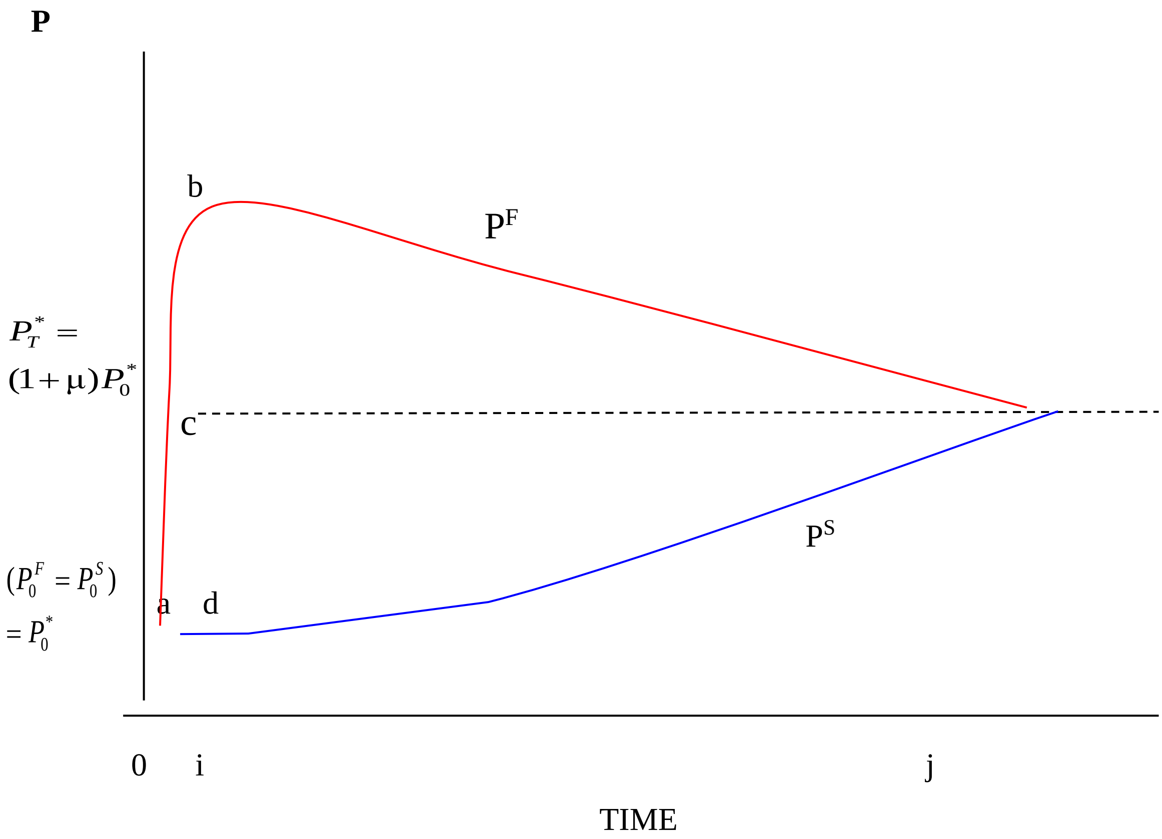
adjust. The correction is complete when both sets of prices have adjusted proportionally to the change in the money stock.

Chart 1 illustrates how, according to this model, commodity and consumer prices react over time in response to a once-off change in the money supply. It is assumed that there are only two types of goods in the economy, commodities (or commodity goods) and consumer goods. Three price indices are shown on the prices axis (the y-axis). The first is the index of commodity goods prices, P^F, denoted with the superscript "F" to reflect its flexible price nature, while the second is the index of consumer prices, P^S, with the "S" superscript reflecting consumer prices being sticky in nature. The third index represents the overall index of goods prices in the economy, P, comprising commodity and consumer good prices. It is assumed, for the sake of simplicity, that both P^F and P^S have the same nominal value in the initial period (0). This means that their weighted average, the overall index P, will also have the same value at that time. This allows us plot all three indices in the initial period (0) at the same point on the price axis (as P_0^F, P_0^S, and P_0). The overall index, P_0, is further designated with an asterisk to indicate that it is an equilibrium value, that is a price level determined by the size of the money stock at that time. Both P_0^F and P_0^S can also be considered to be at their long run money-determined values at that particular time.

Suppose now that in the next period, there is a one-off increase in the money stock of μ percent. The first proposition above indicates that the overall price level will also increase in that period by μ percent to P_T*. This price level is designated with a "T" subscript to indicate that, in the absence of any further changes in the money stock, which we assume to be the case, this is the overall price level that will hold indefinitely into the future. In Chart 1, a dotted line denoting this new long run level of P is drawn off P_T* on the y-axis and it runs parallel to the time axis (x-axis) in all subsequent periods.

Chart 1: The Overshooting Model

initially overshoot their new equilibrium values to compensate, a dynamic feature that holds until all prices are able to adjust to their new equilibrium values.



The second proposition above points to both P^F and P^S rising in proportion to the money stock in the longer run, i.e. by μ percent. This means, given their initial values at time 0, the price of both categories of goods will eventually converge on the dotted horizontal line in Chart 1. The third proposition, however, is that in the short-to-medium term the commodity price, P^F, will respond to the change in the money stock by initially overshooting its new long run value owing to the price of the consumer good being unable to adjust immediately to its new equilibrium value, which is also on the dotted line. In other words, the commodity price will lie above the dotted line for some time after the monetary stimulus while the consumer good price lies below it. As the consumer price starts to rise, the commodity price begins to decline downwards towards the dotted line, thus correcting the overshooting of its price. Eventually, at time j in Chart 1, both prices converge on the dotted line and the adjustment of both to the change in the money stock is complete.

Another feature of this perspective on commodity and consumer price adjustments over time in response to changes in the money stock is that the deviations of both consumer prices and commodity prices from their equilibrium values should contain information on subsequent changes in consumer prices. These two gaps are shown in Chart 1. At time i (it would be possible to choose any point along the y-axis up to j), the gap between the current commodity price and its equilibrium value is given by bc. This is deemed a positive gap because the current commodity price (at b on the solid red line) exceeds its long run value (at c on the dotted line). In contrast, there is a negative consumer price gap (of cd) as the long run price of this good (of c on the dotted line) exceeds its current price (of d on the solid blue line).

It can be seen in Chart 1 that P^S is rising in the quarters subsequent to time i so that its rate of change must be positive. This connection between a negative gap in consumer prices, such as exists at time i, and subsequent positive consumer price inflation has previously been made in monetary economics in the so-called P-star theory (see Hallman, Porter and Small (1991)). Our theory, summarised in Chart 1, makes this connection as well and also suggests that a positive commodity price gap, such as bc in that chart, will be followed by a rise in consumer good prices. Commodity price gaps then should be an indicator of consumer price pressures and, if quantifiable, could provide a useful tool in monetary analysis.

- An Empirical Investigation of the Overshooting Model

In our 2006 paper, we undertake an econometric analysis to test whether our perspective on the relationship between commodity prices, consumer prices and money finds support empirically. The details of that analysis and the specific methodology used are included in that paper. Here, we report the principal findings.

Initially, we found that, for US data, long run proportional relationships exist between a number of commodity price indices and money and, in turn, between the CPI and money.[92] This means that a ten percent rise in the money stock, for example, manifests itself in the long run in a matching ten percent increase in both the CPI and the respective commodity price index under consideration.

[92] We also examined euro area data but found its features did not lend itself to the econometric methodology we use.

We also examined how both types of price index adjust over time to a change in the money stock, en route to their long run, proportional relationships with the money stock being re-established. Figures 2a and 2b illustrate the patterns of adjustment for the CPI and one of the three commodity price indices considered in the 2006 paper, the Commodity Research Bureau Spot Index (CRBSI).[93] Figure 2a shows the indices' response over time while Figure 2b plots the rate of change per quarter in those responses, i.e. the rates of inflation/deflation in the respective indices.

Figure 2a shows patterns of adjustment over time in the actual data that are qualitatively close to those in Chart 1 above. Following an exogenous increase in the money stock, the CRBSI initially rises very quickly, reaching a maximum value after 13 quarters. At first, the CPI changes little, then starts to rise, and does so at an accelerating pace after about 5 quarters. Figure 2b shows CPI inflation peaking after about 12-14 quarters just as the rate of change in the CRBSI moves into negative territory. Obviously, a negative rate of change means that the level of the CRBSI is falling: an overshooting of the CRBSI in response to the money disturbance is being corrected. Eventually, as Figure 2a shows, both the CPI and CRBSI are converging to the same level.

Some further observations can be made on Figure 2b. The CRBSI reaches much higher rates of inflation than the CPI. It also has a prolonged episode of negative inflation rates, or deflation, between 14 and 33 quarters after the initial money disturbance. Its range of inflation rates is much larger than that of the CPI. The CPI inflation rate is initially unresponsive to the money shock but starts to rise steadily after 5 quarters or so before reaching a peak between quarters 12 and 14. Its decline thereafter is also slow. The overall system of prices starts to settle down after about 40 quarters or so.[94] The impact of a money shock on prices then is quite long, a familiar finding from studies of the interaction between money and prices.[95] A final feature of the empirical analysis in our 2006 paper is that lagged values of the gap between the observed CPI and its long run, equilibrium value and the gap between the observed commodity price index and its long run value each have

[93] The CRB Spot Index is a broadly-based index comprising 22 food and raw material commodities.
[94] It is for this reason that the number of quarters on the horizontal axis differs between Figures 2a and 2b.
[95] See, for example, Batini and Nelson (2001).

explanatory power, with the expected sign, in an equation explaining current period CPI inflation.

These empirical results are based on US data from 1959q1 to 2004q1. An obvious question is whether the patterns initially hypothesised and then broadly supported over that sample period can help explain CPI and commodity price behaviour in the current decade. In Figure 3, we plot year-on-year rates of growth in the CRBSI, the US CPI and US M2 on a quarterly basis from January 2001 to October 2007. The starting date is chosen because that was the month when the Federal Reserve began to lower its Federal Funds rate target from a 9-year high of 6½ percent in the wake of the dotcom collapse. This interest rate continued to decline in an intermittent fashion to a rate of 1 percent in mid-2003, where it remained for close to a year before a subsequent, progressive raising of that interest rate commenced in mid-2004. That concluded in mid-2006 and the target rate remained at a level of 5¼ percent up to September 2007. The target rate was then lowered in two steps to 4½ percent by end-October 2007.

Figure 3 shows that as interest rates were lowered in 2001, money growth rates started to rise and remained relatively high, on a year-on-year basis, up until mid-2003 as the policy target interest rate declined. The graph indicates that the CPI inflation rate was initially unresponsive to the monetary stimulus then occurring. A sustained rise in CPI inflation seems only to commence in early 2004, some 3 years, or 12 quarters, after the initial loosening of monetary policy. While M2 growth in the period covered in Figure 3 peaked in 2001q4, the subsequent peak in CPI inflation occurs in 2005q4, implying a peak-to-peak delay of 16 quarters. This is a broadly similar lag to the peak response of CPI inflation following a rise in the money stock in Figure 2b.

The CRBSI seems more responsive to money growth. Its rate of inflation peaks in the second quarter of 2004. After this, it starts to decline through late-2004 and early-2005 before its rate of inflation turns negative, albeit briefly, in mid-2005, just as CPI inflation is rising toward a four-year high. This pattern is comparable to that in Figure 2b. We also see that the CRBSI inflation rate fluctuated across a greater range than the CPI rate during the 2001-7 period covered in Figure 3 – also in keeping with the pattern shown in Figure 2b. Finally, we note that since mid-2006, a gap between the year-on-year rate of change in M2 and the CPI has re-emerged and has been accompanied by CRBSI inflation rising substantially.

4. The Core CPI and Other CPI Components: Another Application of the Model

Our model was initially applied, in our 2006 paper, to studying the relationship between commodity prices and the CPI. Commodities and consumer goods are considered to have starkly contrasting price properties, with commodity prices being determined in auction markets and consumer goods, as the final output of production, being impacted much more slowly by economic events. This dichotomy places commodities and consumer goods at opposite ends of the price adjustment spectrum. There are many goods and goods indices, however, that lie somewhere in between commodities and consumer goods in terms of how quickly they are likely to respond to economic developments. These include wholesale price indices, producer price indices, as well as deflators used in measuring nominal changes in economic activity, such as trade deflators.

Even within the CPI, there are goods whose prices are more flexible than others. Using micro data, Alvarez et al (2006) find that energy and unprocessed food have the most flexible prices among consumer goods within the euro area while services have the lowest. For the United States, Bils and Klenow (2004) find energy-related and fresh food products in the CPI to display frequent price changes. They also find durable goods show more frequent price changes than the overall consumer bundle while goods sold in more competitive markets change more often than other goods.

Figure 2a. Responses of Price Indices to a Change in the Money Stock

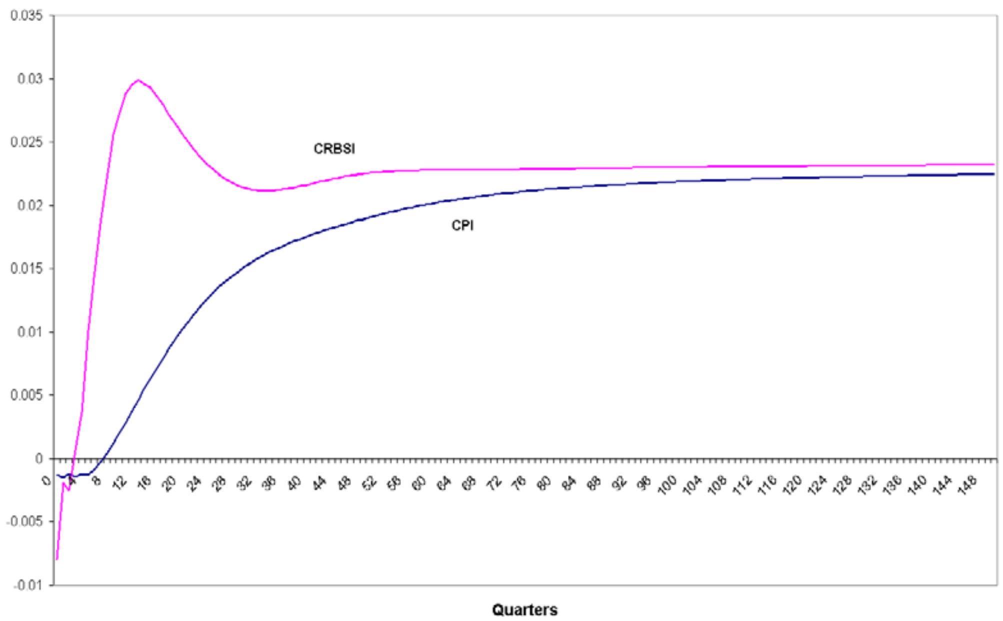


Figure 2b. Rates of Change in Price Indices

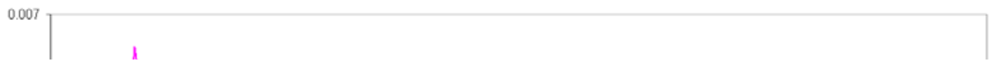
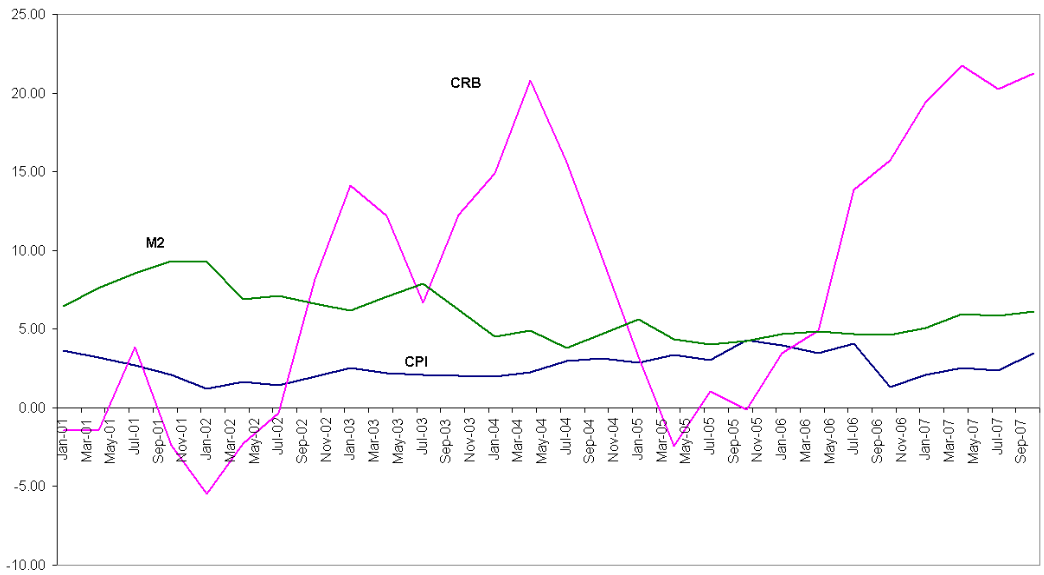


Figure 3. Year-on-Year Rates of Change (%) in US M2 and Price Indices, 2001q1 (Jan.) - 2007q4 (Oct.)



In relation to monetary policy, a conceptual demarcation is often made between "core" and "non-core" CPI inflation, with core inflation reflecting monetary developments and non-core inflation owing to market-specific and other non-monetary events. In other words, there is a monetary and non-monetary component to the overall, or "headline", CPI. It follows from this perspective that the monetary-driven, core CPI inflation should be extracted from overall CPI inflation and be given particular attention in monetary analysis. One means of undertaking this is to remove transitory elements from the aggregate index or the prices of the various goods and services that make it up. The factor driving the remaining component(s) is taken to be monetary policy and, therefore, the adjusted CPI provides a measure of monetary or core inflation.

Such measures of core inflation, however, by often requiring statistical analysis of individual good price series, are computationally involved and have their own drawbacks. A more pragmatic suggestion for measuring core inflation is based on the notion that while monetary policy will transmit an impulse to the prices of all the goods that make up the overall CPI, the prices of some of its components are excessively volatile owing to the impact of other transient, non-monetary influences. The food and energy components of the CPI are considered particularly volatile relative to the other components of the CPI. For this reason, a CPI less food-and-energy index is often published and is usually referred to as "core CPI".

This convenience, however, can lead to the perception that the food and energy components of the CPI are not determined in the long run by money and, accordingly, have little relevance for monetary policy analysis. Our discussion in sections 2 and 3, would lead us to surmise that volatile movements in the food and energy components of the CPI may reflect a swifter response of those components of the CPI to changes in the money stock. Figure 2b shows that, in reality, commodity inflation can indeed be much more volatile than headline CPI inflation while still being driven by money. If this holds true also for the food or energy components of the CPI then it is not appropriate to discard either or both from monetary analysis, rather it is imperative to see what valuable information may be extracted from them for policymaking purposes.

We reapplied our empirical methodology, substituting CPI less food and energy and a second CPI component for the overall CPI and commodity price index used in our 2006 paper. US data are again used, covering the period 1959q1 to 2007q2.

Ideally, the second CPI component would comprise both the food and energy components excluded from the core measure would be used but such a measure is not published by the relevant source, the US Bureau of Labor Statistics. It only publishes separate "Food" and "Energy" components. We examined each, in turn, as the respective second index alongside core CPI.

While the results for the Energy component were disappointing, those for the Food component, however, were both satisfactory from a statistical perspective and illuminating, as will be discussed. The poor performance of the Energy component may be attributable to it being exceptionally volatile, relative to both CPI Food and core CPI.

The results where CPI-less-Food-and-Energy and CPI Food are used are statistically well-behaved and show long-run proportional relationships arising between CPI-less-Food-and-Energy and the M2 money stock and between CPI Food and the same money stock.[96] Figure 4a shows how both price indices adjust to a positive change in the money stock. While both converge over time towards their new long run values and do so without any obvious overshooting, CPI Food responds more quickly to the change in the money stock. It leads CPI-less-Food-and-Energy in adjusting to a monetary stimulus. Figure 4b shows CPI Food inflation peaking earlier and at a higher rate than CPI-less-Food-and-Energy inflation. Also, the adjustments of both indices to the change in the money stock involve sharper changes in CPI Food inflation. This may go some way to explaining the observed higher volatility of CPI food inflation relative to core CPI inflation while underlining that this feature of the data is money-driven.

Bryan and Cecchetti (1994, p. 197) identify the term core CPI in many economists' minds with "the long-run, or persistent, component of the measured price index, which is in some way tied to money growth". Using this yardstick, CPI-less-Food-and-Energy and the CPI Food component should, according to our results, both be classified as core CPI components. The obvious follow-on suggestion is that it would be worthwhile examining, at least in the US case, whether only the energy

[96] Those particular results are not shown here but are available on request from the authors.

component of the CPI should be excluded from the overall CPI in arriving at a measure of core CPI and in studying underlying inflationary trends.[97]

It is again interesting to look at developments in CPI-less-food-and-energy and CPI Food inflation in the current decade and compare them with the longer-sample based plots in Figure 4b. Year-on-year changes in both indices are shown in Figure 5 from 2001q1 onwards, the same starting point as that in Figure 3. The rate of CPI Food inflation can be seen to have fluctuated more than that of CPI-less-Food-and-Energy. There is also some indication that the pattern in CPI Food inflation has led that in core CPI inflation in recent years. This seems evident between late-2001 and early-2004 when a fall in the CPI Food inflation rate up to mid-2002 led a decline in core CPI inflation up to early-2004. In the period from mid-2003 to mid-2005, CPI Food inflation rose sharply and then declined, a pattern that also appears to be occurring in a milder form for CPI-less-Food-and-Energy inflation between early-2004 and end-2007. These developments are close to those in Figure 4b where the rise-and-fall in CPI Food inflation occurred before that in CPI-less-Food-and-Energy.

Finally, we note that year-on-year CPI Food inflation has, like CRBSI inflation, picked up sharply in 2007.

5. Conclusion

In this article, we have discussed a model that we believe can account for the long run and dynamic behaviour of commodity prices and consumer prices and that may go some way toward explaining how both sets of prices have behaved in recent years. The building blocks of the model invoke long-run monetary neutrality conditions pertaining to relative prices along with the observation that commodities, being traded on auction markets, have prices that adjust quickly to economic events while consumer prices are subject to rigidities in the short-to-medium term arising from menu costs and contracts. This leads, among other things, commodity prices to overshoot long run values in response to exogenous money growth. In sections 3 and 4, we related empirical findings from an earlier paper of ours, along with new

[97] Using a different form of analysis, such a proposal has already been made by Gavin and Mandal (2002).

results, that, we believe, back up our perspective on the relationship between money and different price indices.

There are a number of key points that emerge from the model and the empirical results. First, monetary developments would seem to have a strong bearing on how price indices behave. Our results suggest money determines the price of both commodity and consumer price indices in the long run. Likewise, it can explain their behaviour in the short to medium term. The indices' individual responses to monetary pressures seem, in our view, related and can be explained by their varying degrees of price stickiness. It is noteworthy that monetary developments can help explain the behaviour of agricultural and raw material commodity prices over time.

Figure 4a. Responses of CPI Indices to a Change in the Money Stock

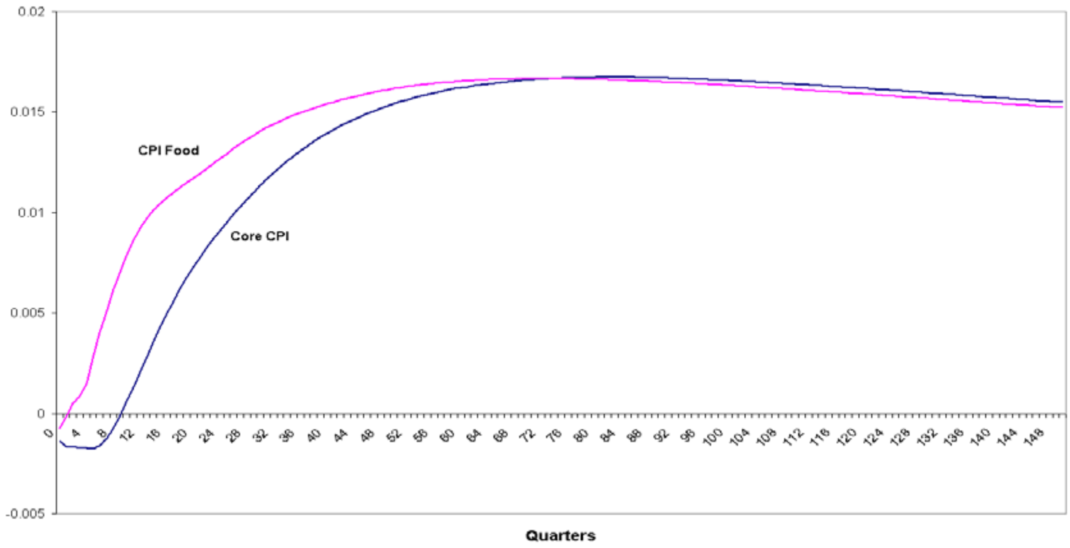
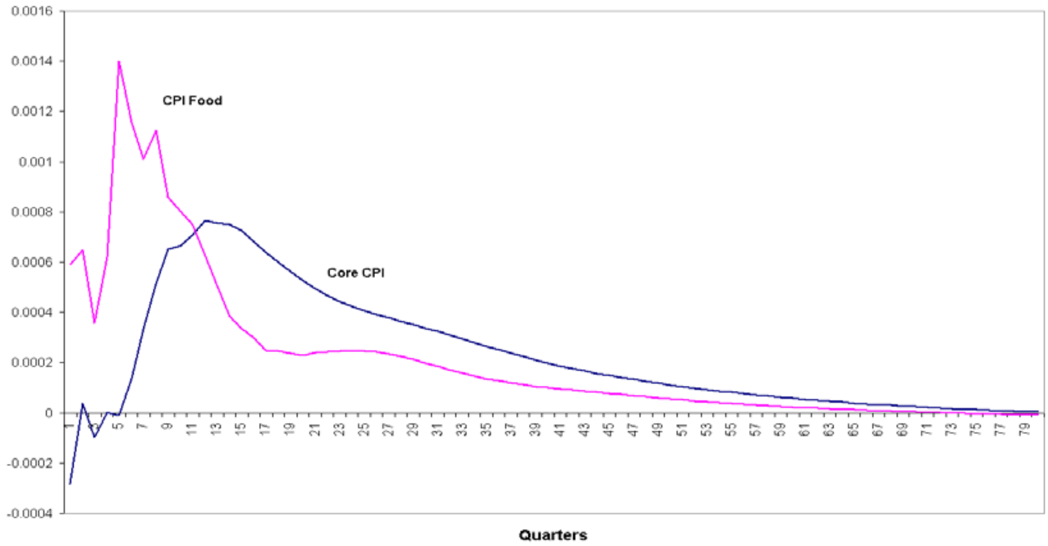


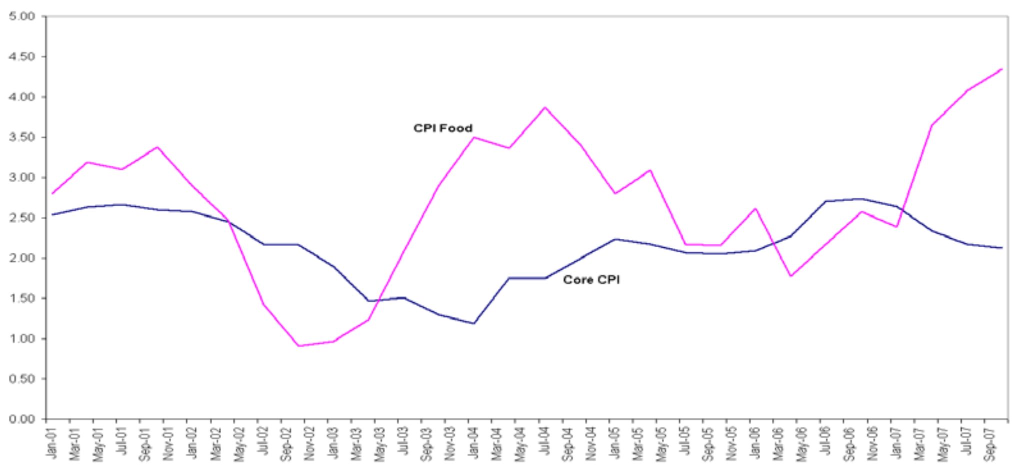
Figure 4b. Rates of Change in CPI Indices



Another point we would make is that commodity prices can provide some indication as to how the CPI or a similar final goods price index will behave in the near future. A sharp pickup in commodity prices (particularly if it is occurring across a broad range of commodity classes) may reflect a monetary policy that is too loose. A sudden fall-off in commodity prices (including negative rates of change) may actually precede a rise in CPI inflation. Commodity and CPI gap variables can explain next-quarter CPI inflation.

Finally, the behaviour of what many commentators consider one of the two non-core components of the US CPI, CPI Food, can be explained by money. This means that it cannot be classified as a nuisance or be easily discarded in monetary analysis. Indeed, if core CPI is a useful means of assessing longer-term price

Figure 5. Year-on-Year Rates of Change (%) in Core CPI and CPI Food, 2001q1 (Jan.) - 2007q4 (Oct.)



adjustment then our results suggest that, at least in the US case, there may be grounds for examining whether CPI's food component should be included in it.

We would conclude by observing that the pickup in commodity inflation rates in recent years should, according to our perspective, start to translate into higher CPI inflation rates. We would also note that the rise in commodity prices in recent years has been broadly based across commodity classes. This suggests some common factor behind these movements, which we would expect to be strong rates of global money growth.

At the same time, another account of money and price developments in recent years seems to be losing its force. It explains low headline inflation occurring against a backdrop of strong money growth and low real interest rates by emerging markets, especially China, “exporting” deflation to the developed world in the form of lower-priced finished goods with this acting to offset inflationary pressures worldwide (reference). Deflation in Japan would also be considered to have had a similar impact (reference). These factors, however, seem to have fallen away and been reversed in the last year or so. Between October 2006 and October 2007, the annualised rate of change in US import prices from China went from -1.3 per cent to 2.2 percent. China’s domestic inflation rate has accelerated from moderately negative levels to 6½ percent in August 2007. Much of this increase has been attributed to raw material and basic commodity price increases but more especially to food price increases. Japan also now seems to be facing big hikes in food prices after a long period of extreme monetary accommodation. Some of the benign influences on inflation in developed countries, it seems, are being removed, with possible adverse implications for developed countries’ inflation prospects.

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Monetary Policy, Inflation and Commodity Prices

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Introduction

The interaction between commodity prices, general inflation and monetary policy has re-emerged in recent years as a topic of interest among academic economists, central bankers, and financial market participants alike. A sustained, broadly based increase in commodity prices started in the mid-2000s, and rising prices have been evident also in other major asset classes (stocks, bonds, property). These price increases occurred against a monetary policy stance, in the major advanced industrial countries, that was viewed as broadly accommodating in many quarters at that time, and as being appropriate given that general inflation rates, e.g. consumer price index (CPI) inflation rates, were relatively low, and within or close to targets set for, or by, central banks. Moreover, rising commodity prices were not seen as having any substantial impact on consumer prices.

Most asset prices started to decline in late 2007. Commodity prices fell rapidly and steeply in the second half of 2008. Ironically, this occurred against a background of policy interest rates being reduced close to zero, and an unconventional monetary policy tool, quantitative easing, being introduced by the main central banks. Since then, and against a background of a continuing accommodative monetary policy stance, commodity prices have regained upward momentum.

While the pickup in commodity prices in recent years has had an effect on the headline consumer inflation rate, its "core inflation" component, as measured by headline CPI inflation less its food and energy components, remains close to acceptable values in the major developed countries. Commodity price developments, then, do not seem to be translating into a broadly based effect on consumer prices, in contrast to the 1970s, and early 1980s. This feature of recent data, and indeed the ability of core inflation to remain anchored at low values through the 1990s and the 2000s regardless of the shocks hitting the economy, has been attributed to the adoption of a monetary policy framework, inflation targeting, that has as one of its main goals stopping one-off price pressures becoming embedded in inflation expectations. Of course, another factor behind the diminishing pass-through from commodity prices to consumer prices is the smaller role raw materials, most notably oil, play in economic activity in modern developed economies.

It is, nevertheless, clear now that the inflation targeting framework was found wanting in the financial crisis. It did not provide any advance warning of the effect of collapsing bubbles, and the massive deflationary forces unleashed as a consequence. This stemmed, in our view, from its neglect of the role of asset prices, as well as the vast changes that have occurred in the financial system over the last few decades, which have enhanced the substitutability between money and financial assets.

This short overview points to the need to examine a number of specific issues in coming to understand better the nexus between commodity prices, CPI inflation, and monetary policy. Setting an explicit numerical target for inflation, or at least a target of low and stable inflation, plays a critical role in monetary policy today. This practice of "inflation targeting" anchors price expectations, by requiring central banks to set out their inflation target, how they intend to achieve it, and holding them accountable for meeting that target. As well as explaining the rationale for and practice of inflation targeting, we also provide an overview of criticism of this monetary policy strategy, in particular versions of it that ignore developments in financial markets, and in money and credit variables. This strategy meant that central banks, by remaining steadfast to inflation targeting in the face of imbalances and distortions evident in asset markets, contributed to the financial instability of recent years.

The challenges in addressing and rectifying the current difficulties in financial markets, and the wider economy, are acute for leading central banks, such as the Federal Reserve and the European Central Bank. Policy interest rates are close to zero, thus limiting their scope as instruments of monetary policy. As discussed later, one policy innovation brought in, in response to the loss of leverage from conventional monetary policy instruments, has been quantitative easing. In increasing the amount of liquidity in the economy, and in reducing the yield on a competing asset class, government bonds, quantitative easing may have stoked the surge in commodity prices since 2009.

It may also be that a "super-cycle" is present in commodity markets in recent years, with rising prices therein not a temporary phenomenon, but part of a long period of sustained high commodity prices. This is owing to countries such as China and India emerging as industrial superpowers, leading to an increased demand for commodities as industrial inputs, and in building up capacity in those economies.[98] At the same time, there appears to be a stronger co-movement in the prices of different commodities. This suggests that there may be common factors at play in commodity markets. One such possibility is that the growing treatment of commodities as a separate asset class in recent years, and their being added to asset portfolios as a means of reducing the risk of those portfolios, may have increased co-movement in their prices.

Another viewpoint, discussed in detail later in this chapter, stresses the capacity of commodity prices in general to respond quickly to changes in monetary policy and, indeed, to overshoot equilibrium values, so as to maintain overall prices in the economy in line with the level of the money stock (Frankel 2008, Browne and Cronin 2010). High commodity prices then can occur in response to loose monetary policy conditions, such as have existed over much of the last ten years or so, and are consistent with a low CPI inflation rate in the short-to-medium term, with that inflation rate rising subsequently.

Inflation-targeting and modern monetary policy-making

The 1970s and early 1980s proved to be difficult times for central banks. High inflation rates and low, and even on occasion negative, growth rates – a phenomenon known as "stagflation" – were a feature of the economic environment in many western countries. Cost-push-related policy measures (direct control of wage and price increases) were pursued in the 1970s to address this malaise, but were unsuccessful in bringing inflation down from high rates. Later, however, a form of the quantity theory of money,[99] labelled monetarism and most closely associated with economist Milton Friedman, came to form the basis for reducing inflation. The so-called Volcker disinflation (named after the former Federal Reserve chairman) in the United States saw the Federal Reserve aggressively raise interest rates in the early 1980s, with inflation subsequently declining.

The intervening quarter of a century, up to the late 2000s, saw a decline in inflation rates to low single-digit figures, occurring alongside generally buoyant economic growth. Furthermore, the variability of inflation, and output growth rates, fell progressively.

[98] Using an econometric technique called band-pass filtering, Cuddington and Jerrett (2008) provide evidence consistent with there being three super cycles in metal prices in the past 150 years or so and with world metal markets currently being in the early stages of a fourth super cycle. They note that the latter is being attributed to Chinese urbanisation and industrialisation.

[99] The quantity of money theory links money supply with overall price levels.

While there is an acknowledgement that “good luck” in the form of fewer large shocks, such as oil price shocks, played its part, it is commonly accepted that improvements in macroeconomic policy, in particular monetary policy, were central to the economic stability and prosperity achieved during this period.

As might be expected, the negative experiences of the 1970s stimulated a lot of research in how monetary policy could be improved in practice. Among the earliest advances in that research was the identification of structural credibility problems in the conduct of monetary policy. Specifically, it was found that rules were better than discretion in guiding policy. Adherence to rules leaves the public more assured as to how the central bank conducts itself and, accordingly, guides its own expectations and behaviour that are, in turn, key to the success of monetary policy. In practice, rules-based monetary policy was supported by the granting of independent statutes to central banks. This often included specific inflation targets to be achieved. In essence, three “Cs” came to underlie central banking: credibility, consistency and continuity (Stark, 2007).

A clear focus on the need to maintain price stability became the centre-point of central banks’ activities. Through the late 1980s and into the 1990s, central banks were increasingly successful at achieving price stability. With inflation reduced to moderate levels, and their standing high, central banks faced a new set of challenges in the 1990s. First, having reduced inflation, over the previous ten years or so, to low levels, central banks now needed to maintain inflation rates close to the price stability benchmarks explicit or implied in their statutes. Secondly, the high standing of central banks meant that their statements and comments were carefully scrutinised by the public. Communication was vital to the success of monetary policy, and openness and transparency were recognised as key elements of the communication policy. At the same time, central banks had to be careful and precise in explaining their monetary policy actions and intentions, so that the public would not misinterpret, or be confused about, what was being said.

A number of concurrent developments in academic research and policy analysis seemed to provide a mean of conducting and communicating monetary policy. Explicit numerical inflation benchmarks were often set for, or by, central banks, and those inflation targets became the focal point of decision-making. The Taylor Rule, named after its proposer Professor John Taylor (1993), was initially used as a descriptive tool, but was promoted in some circles as a means of setting monetary policy. Under this rule, the central bank would mechanically set the short-term interest rate as a function of the deviation of the actual inflation rate from its target rate, and the deviation of output (GNP/GDP) growth from its long-run potential growth rate. The Taylor Rule became one of the three key elements of the so-called "New Keynesian" model of the economy, which offered, according to its advocates, a parsimonious, but integrated and realistic, description of aggregate demand and inflation determination. Even where central banks do not explicitly follow the Taylor Rule, it is accepted as playing a prominent role in how many go about devising their monetary policy stance.

There is no need for a money demand function or, indeed, for any money variable within the inflation-targeting paradigm. Instead, inflation is seen as originating in the labour, rather than money, market. A version of the Phillips' curve,[100] where the size of the output gap indicates inflationary pressures within the economy, plays an important analytical role in the inflation-targeting approach. These developments in macroeconomic modelling happened to coincide with increased difficulties in assessing and forecasting the public's demand for holding money balances. In the United States especially, where the New Keynesian perspective is particularly popular among academics, financial innovation and liberalisation made it difficult to model the demand for money successfully. The development of near-money substitutes, such as mutual funds, made it hard to ascertain the public's demand for money if it shifted its liquid wealth between money and near-money assets. Consequently, the information coming from the monetary sphere was not as helpful to monetary policy formulation as previously. Accordingly, what could be termed "economic analysis", i.e., analysis focussing on the real economy, became increasingly stressed as the basis for monetary policy decision-making. Aggregate demand (and its components), potential output/aggregate supply, unemployment and inflation expectations are the key variables to be assessed in this sphere.

Inflation targeting appears to have been a success, at least in terms of inflation performance. In a review of emerging market economies, the IMF (2005) found that

[100] Uncovered by the seminal work of A.W. Phillips, the original Phillips' curve refers to the inverse relationship between unemployment and money wage rates. Other versions of the model were later introduced, linking inflation with various measures of broad economic activity and, later, inflation expectations.

those countries that followed an inflation-targeting approach had a better inflation performance than non-targeting countries, both in terms of average inflation rates and volatility of those rates. Habermeier et al (2009) find that inflation-targeting countries appear to have done better than others in minimising the inflationary impact of the 2007 surge in commodity prices.

This approach has benefited the investment community. The forward-looking approach taken by central banks to assessing inflationary pressures, their willingness to disclose publicly the basis for their monetary policy decisions, and their determination to ensure any price developments do not become embedded in inflation expectations, have provided investors with confidence that swings in inflation rates are not likely to impact on financial outturns. Furthermore, to the extent that price stability leads to a better allocation of resources in the economy (one of the main rationales for its pursuit), the waste that is thereby obviated should accrue to investors in the form of an enhanced risk-adjusted rate of return.

The culmination of events in the new millennium, however, has seen the inflation-targeting approach to monetary policy come under the spotlight. Most importantly, the question arises as to whether inflation targeting itself played a role in the shocks and events that have impacted severely on developed economies. Advocates of inflation targeting do not see monetary policy having to react to changes in asset prices, other than to use any information they may provide as to how final goods inflation rates will develop over time. Likewise, as long as central banks remain focussed on the long term path of the inflation rate, and maintain it close to target values, periodic variations in headline inflation rates owing to commodity prices are not of great concern. The credibility afforded to monetary policy by inflation targeting can also diminish economies' vulnerability to the inflationary impact of commodity price shocks, by ensuring those shocks do not become embedded in expected inflation.

The narrow focus on the real economy and performance associated with inflation targeting nevertheless means that important information concerning developments in money and financial market variables may have been ignored in setting monetary policy. Moreover, inflation targeting operates through one policy variable – the central bank policy interest rate. Whether that interest rate is a sufficiently robust instrument in avoiding or addressing major disturbances to economic and financial performance is open to question. Taylor (2009) apportions part of the blame for the financial crisis that emerged in 2007 to monetary policy having pursued persistently low interest rates for an extended period. He shows (2009, p. 2), that "monetary excesses" were the main cause of the boom and subsequent bust that occurred in the mid-2000s.

While inflation targets were being met in most developed countries during the mid-2000s, monetary policy, mainly through the provision of cheap credit, was contributing to excessive risk-taking in financial markets, and an over-pricing of financial and real assets such as property. Eventually, this led to substantial falls in asset prices, as well as the threat of deflation hanging over western economies. The inflation targeting framework could not have foreseen this, because of its belief in the second-order importance of asset markets for monetary policy.

Besides raising potential issues for the maintenance of price stability, an accommodative monetary policy stance, if maintained over a long period, can pose a threat to financial stability. This view that financial imbalances, especially excess money and credit growth, brought about by monetary policy pose a threat to the well-being of economies was most prominently expressed by Bank for International Settlements economists (e.g., Borio and Lowe, 2002, and Borio and White, 2004) in the years leading up to the current economic crisis. They argue that the simultaneous development of imbalances in monetary variables, such as credit, and in asset prices should be of concern to central banks. Financial liberalisation and innovation can generate such imbalances, and encourage greater procyclicality in financial markets. This can occur against a background of low and stable inflation. Excess demand can show up first in asset prices rather than consumer prices, which may explain why financial imbalances and rising asset prices occur in a low inflation environment. The concerns expressed by BIS and other economists underline the need for central banks to monitor monetary and financial developments, as well as those in the real economy, closely.

Monetary policy in the financial crisis

Inflation targeting, which seemed to do a good job in the not too distant past, has been found wanting in recent years. As others have noted - for example, Canuto (2009) - well behaved inflation and output performance, which were features of advanced industrial economies leading up to the crash, are no guarantee against a dangerous upward asset price spiral developing and then collapsing, with enormous implications for the central bank and its ability to maintain a stable monetary and financial system.

In the wake of the financial crisis, central banks, faced with either a liquidity trap or the zero lower bound on nominal interest rates, had to turn to using an alternative policy instrument, quantitative easing. This has been utilised because nominal interest rates were already close to zero, and thus the scope for reducing them further was limited. Quantitative easing involves proactively buying up a large fraction of the stock of government bonds, at whatever price is needed for holders to be willing to engage in exchange. Its purpose is to accommodate the need for liquidity in financial markets, and the economy more generally.

It goes beyond, however, a normal accommodating monetary policy, which tends to occur at a positive value for the nominal rate of interest, when the central bank makes funding available in infinitely elastic amounts at that rate (subject to good collateral). The difficulty with conventional monetary policy is that the amount of liquidity injected into the financial system may be deemed to be inadequate, even with full accommodation and at a zero rate of interest, in the type of distressed state in which financial markets found themselves in in the wake of the financial crisis. This is where the need for quantitative easing comes in. It involves purchasing what has turned out to be an extremely large amount of government securities outright, as a way of injecting liquidity into the banking system, with the ultimate objective of kick-starting the economy, and obviating deflation.

Quantitative easing was employed by the Bank of Japan during the early-to-mid 2000s in its attempts to tackle deflation in the Japanese economy. Assessments of the impact of this policy are that it had limited effect in raising aggregate demand and prices, but provided some support to the country's banking sector (Spiegel (2006), Ugai (2007)).

The Federal Reserve and other central banks have introduced extremely large amounts of funds into the financial system through quantitative easing. The sizes of their balance sheets have increased considerably since 2007. This expansion of liquidity has so far been largely contained to the banking sector. It has not yet, for the most part, resulted in a corresponding improvement in the supply of credit and liquidity to the retail non-banking sector.

Quantitative easing might also affect behaviour in financial markets in another way. Large purchases of government securities by the central bank will likely drive their prices to levels that reduce, if not eliminate altogether, their attractiveness as an investment option. Koo (2011) argues that, with the private sector deleveraging due to balance-sheet difficulties, fund managers, devoid of both private sector and public sector borrowers, will turn to commodities as an alternative investment option. This effect may have been at play in commodity price behaviour in recent years.

It is important to remember that this is a portfolio rebalancing effect and may not have a lasting effect on commodity prices, given that other asset markets should be expected to return to normality at some time in the future. The portfolio rebalancing effect, however, is distortionary in the short run, as investors are effectively constrained into purchasing commodities. This cannot be beneficial to commodity markets, and to the efficient allocation of investment resources more generally within the economy.

The acceleration in the growth of the money stock in the latter half of 2008 while the US economy was still in recession is likely to have helped maintain momentum to commodity prices. In the next section, we discuss how a monetary shock has a proportionate impact on commodity prices and consumer prices in the long run, while causing an overshooting of equilibrium commodity values in the nearer term.

The Influence of Commodity Prices on Final Goods Inflation

Developments in commodity markets routinely and directly impact on final good prices, as commodities constitute an input into the production of those goods. The impact of commodity prices, however, is less strongly felt nowadays than, say, in the 1970s, as commodities account for a smaller share of final expenditure. This reflects the changing structure of the economy over time, away from manufacturing and towards services. It also reflects improved production techniques, requiring less raw material and energy inputs. As already mentioned, central banks are also now more skilled in ensuring that large commodity price increases do not become embedded in the inflationary process.

Econometric assessments made around 2010 supported the diminished influence of commodity prices on overall final good prices. Blanchard and Gali (2010), for example, find that the pass-through from oil price changes to overall inflation rates has declined over time in a set of industrialised economies.

The origin of commodity price changes is debated in the economics literature. One perspective sees developments in commodity prices arising from market-specific, supply-demand shocks. There may, for instance, be some new or enhanced source of demand for a commodity, a sudden disruption to supply due to weather affecting crop harvests, or political events threatening the availability of a raw material. The commodity price changes that result are ultimately relative price changes, and may often be transitory. They can have direct price effects on the CPI, if the commodities are a part of the consumer basket, and indirect pass-through effects when the commodities affected are part of the production process of consumer goods.

Market shocks can have a rapid and sizeable effect on the prices of the particular commodities affected. This follows from the fact that they are traded on open markets, which helps make commodity prices relatively flexible. Since final goods prices are less flexible, and adjust slowly to economic developments, commodity prices may contain useful information as to how consumer prices will behave in the future.[101] Many older US studies of the commodity price-consumer price relationship focussed on the predictive power of commodity prices for CPI inflation.[102] The evidence presented in these studies with regard to the predictive power of commodity prices is mixed.

The price-flexibility attribute of commodity markets may also contribute to the view that, since market-specific shocks are short-lived, the resulting pronounced directional changes in commodity prices will be a temporary, and self-correcting, phenomenon. This view, and the recognition that relative price shifts are a necessary and valid part of economic activity, may contribute to the aforementioned monetary policy perspective that commodity price shocks can be ignored.

[101] Within the CPI, there are goods whose prices are more flexible than others. Bils and Klenow (2004) find the fresh food, energy-related products, and durable goods components of the CPI to change relatively frequently. In the euro area, energy and unprocessed food have the most flexible prices among consumer goods, while services have the lowest (Alvarez et al, 2006).

[102] See Webb (1988), Garner (1989), Marquis and Cunningham (1990), Cody and Mills (1991), Pecchenino (1992), Blomberg and Harris (1995), and Furlong and Ingenito (1996).

An alternative viewpoint starts from the premise that the level of prices in the economy is determined in the long run by the money supply, and that the central bank, through its ability to control the money supply by monetary policy, has an influence on how commodity prices and final good prices develop over time. Commodity price increases then may be seen as not originating exclusively in market-specific shocks but as arising, in part at least, from the monetary policy stance. Insofar as commodity price developments feed through into CPI inflation rates from this source, it has a monetary basis.

This perspective, focussing on the role of money supply, and monetary policy more generally, in effecting commodity price changes, has re-emerged in the 2000s. Barsky and Kilian (2002), for instance, examine the Great Stagflation of the 1970s, and produce econometric evidence that monetary conditions explain the rise in the price of oil and other commodities at that time. This runs counter to the more orthodox perspective that supply shocks impacted oil prices and caused both high inflation in goods and services, and lower output.

Frankel (2008) revisits an overshooting theory of commodity prices that he first put forward some twenty years previously (Frankel 1984, 1986). This theory follows from the view that monetary policy-induced changes in interest rates affect real/inflation-adjusted interest rates because the CPI is "sticky", i.e. inclined to change only slowly. Suppose that monetary policy causes a rise in the nominal interest rate. This will also lead the real interest rate to increase, since the CPI inflation rate is fixed in the short run. The relevance of the real interest rate for commodities is that it represents the opportunity cost of holding them. A rise in the real interest rate then reduces the demand for commodities, causing their real prices to fall. In this way, monetary policy has an impact on commodity prices through its effect on real interest rates.

In the Frankel model, the amount by which commodity prices decline is determined by a no-arbitrage condition. Commodity prices must fall to the extent that their subsequent appreciation to long-run values compensates their holders fully for the increased cost of carrying them. Prices, then, "overshoot" equilibrium values to meet this market requirement. Subsequently, the CPI inflation rate will itself adjust (slowly) upwards, and the real interest rate will decline, acting to restore equilibrium to the commodity market.

In his 2008 article, Frankel emphasises the relevance of his overshooting theory to developments in commodity prices around that time. He attributes the rise in commodity prices in 2002-4 to declining real interest rates. A number of other recent studies find a similar relationship between commodity prices and real interest rates. Using quarterly data covering the years 1990-2007, Akram (2009) finds commodity prices increase significantly in response to reductions in real interest rates. The econometric results of Anzuini et al. (2010) indicate that expansionary US monetary policy shocks increase commodity prices, albeit to a limited extent.

In Browne and Cronin (2010), we also provide an overshooting theory of commodity prices. Whereas Frankel's perspective draws on the Dornbusch (1976) theory of exchange rate overshooting in framing his model, we use two (essentially Friedman-style) monetarist propositions to develop ours. Those are that exogenous changes in the nominal money stock lead to equivalent percentage changes in the overall price level (comprising commodity and consumer good prices); and that exogenous changes in the money stock are neutral in the long run, implying that all individual prices, whether they be of consumer goods or commodities, adjust over time in the same proportion as the money stock, thus leaving all relative prices unchanged.

When these two propositions are combined with an acknowledgement that commodity prices are more flexible than consumer prices, commodity prices are shown to overshoot their new long run equilibrium values in response to a change in the exogenous money supply, to compensate for the inability of consumer prices to adjust in the short run. In this way, the overall price level moves at the same rate as the money stock, but, initially, commodity prices move more than they do in the long run to offset the stickiness of consumer prices.

A Theory of Overshooting

A simple two-period model might help develop some insight, and guide a more formal statistical approach (see also Browne and Cronin 2010). We assume there are two exchangeable goods, that is commodities and the CPI basket, which together add up to the real output Y of the economy. At any time, the overall price level P will be the weighted average (with weight w, $0<w<1$) of the commodities price index F, which is flexible, and the consumer price index S, whose price is sticky. For example at time t:

$$P_t = \; wF_t + (1-w)S_t$$

The relationship between the money stock, M, and the overall price level is given, at each time t, by the Fisher identity, that is:

$$M_t V_t = P_t Y_t$$

We assume that the velocity of money V_t is constant and equal to 1, and that the volumes of the two goods in our economy, and thus the real output Y_t, do not change (this restriction is relaxed in our econometric analysis, where real GDP is one of the statistical variables). When the assumptions about the exogeneity of Y and the constancy of V (equal to 1) are added to the exogeneity of M (controlled by monetary policy) then the Fisher identity becomes the so-called quantity of money theory, and the overall price level P_t moves in line with the nominal money stock M_t.

Assume all prices are in equilibrium at time t-1, and P_{t-1} is the overall price level, as determined by the size of the money stock at that time, i.e. M_{t-1}:

$$P_{t-1} = \; M_{t-1} V_{t-1} / \, Y_{t-1}$$

Next, suppose there is a one-off increase in the money stock of $\mu > 0$ percentage points (of course a similar analysis can be done for a negative shock):

$$M_t \; = \; (1 + \mu) \, M_{t-1}$$

$$P_t = \; M_t V_t \, / Y_t$$

The overall price level also rises by the same percentage amount, given the proposition that it moves contemporaneously with the size of the money stock ($V_{t-1} = V_t = 1$; $Y_{t-1} = Y_t = Y$). Without other shocks, the new equilibrium overall price level $P_{NEW\,EQ}$ will hold indefinitely into the future:

$$P_t = (1 + \mu) \, P_{t-1} = P_{NEW\,EQ} = w \, F_{NEW\,EQ} + (1-w) \, S_{NEW\,EQ}$$

Over time, both commodity and consumer price indices converge to their equilibrium levels $F_{NEW\,EQ}$ and $S_{NEW\,EQ}$, but it is what happens in the meantime that is of most interest. In particular, we assume that the consumer price index is sticky for one period after the money shock, that is:

$$S_t = (1 + \sigma) S_{t-1} \qquad \text{with } \sigma < \mu$$

while commodities prices, which are traded on spot auction markets, are fully flexible, and move φ percentage points in order to maintain overall price equilibrium, i.e.:

$$P_t = (1 + \mu) P_{t-1} = w F_t + (1-w) S_t = w (1 + \varphi) F_{t-1} + (1-w)(1 + \sigma) S_{t-1}$$

or rearranging the terms above:

$$\frac{1+\varphi}{1+\mu} = 1 + \frac{1-w}{w}\frac{S_{t-1}}{F_{t-1}}\left[1 - \frac{1+\sigma}{1+\mu}\right]$$

Thus, it is clear that if $\mu > 0$, and $\sigma < \mu$, then:

$$\varphi > \mu$$

which means that commodity prices initially overshoot equilibrium, to compensate for the interim stickiness of consumer prices. Next, if we assume that in period t+1, commodity prices and consumer prices both adjust to their new respective equilibrium levels, i.e.:

$$F_{t+1} = (1 + \mu) F_{t-1} = F_{NEW\ EQ}$$

$$S_{t+1} = (1 + \mu) S_{t-1} = S_{NEW\ EQ}$$

Then, from the overall price equation that holds at all times:

$$w F_t + (1-w) S_t = w F_{t+1} + (1-w) S_{t+1} = w F_{NEW\ EQ} + (1-w) S_{t+1}$$

so that:

$$S_{t+1} - S_t = \frac{w}{1-w}\left[F_t - F_{NEW\ EQ}\right] = -\left[S_t - S_{NEW\ EQ}\right]$$

which tells us that the overshooting of commodity prices (or the undershooting in consumer prices) at time t, coupled with our knowledge of reversion towards equilibrium, should help to forecast the change in the CPI price index in period t+1.

Econometric Findings

In Browne and Cronin (2010), we tested this intuitive formal theory empirically as a basis for shedding light on the nature of both short-term dynamics and long-term relationships among four US variables: (1) the M2 money stock; (2) the Consumer Price Index (CPI); (3) the Commodity Research Bureau spot Index (CRBSI), which comprises 22 basic commodities; and (4) Real Gross Domestic Product (GDP) to measure output in the US economy. (The data used in the empirical estimations and the figures are outlined in Table 1.) These correspond to M, S, F, and Y above, respectively. The sample period covered was 1959q1-2008q4.

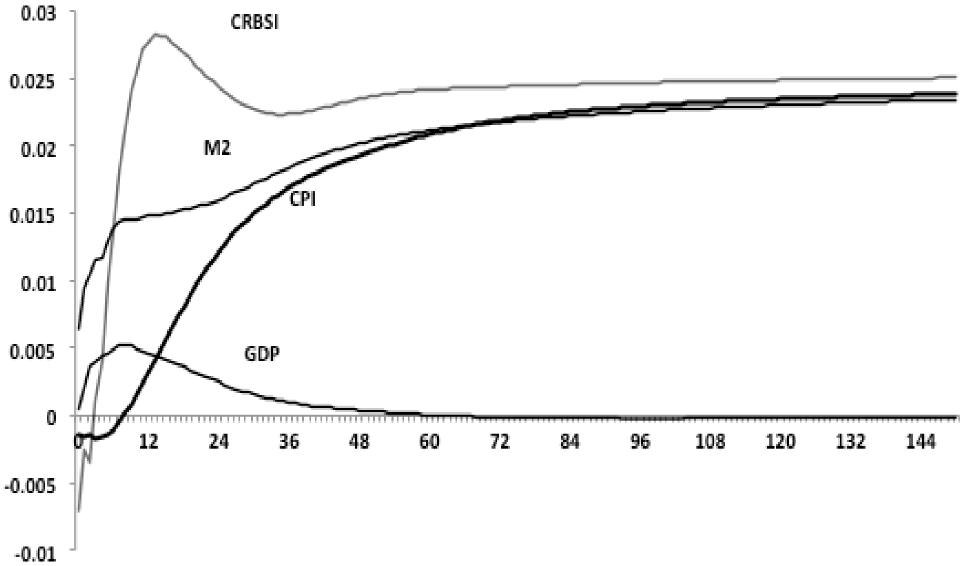
We initially undertook standard unit root tests on natural logs of the four variables, which indicated that they could be treated as integrated of order one. This property of the series allowed us to use the Johansen cointegration technique to assess the existence of a long-run proportional relationship between M2 and each of the two price variables and to assess the short-run dynamics relationship between the variables.

Table 1: Description and Sources of Data

Consumer Price Index for All Urban Consumers: All Items	Index: 1982-84 = 100	SA	US Department of Labor: Bureau of Labor Statistics
CRB Spot Index	Index: 1967 = 100	NSA	Commodity Research Bureau
M2	$ billion	SA	Board of Governors of the Federal Reserve System
Real Gross Domestic Product	Billions of Chained 2005 Dollars	SAAR	US Department of Commerce: Bureau of Economic Analysis

SA: Seasonally Adjusted; NSA: Not Seasonally Adjusted; SAAR: Seasonally Adjusted Annualized Rate.

Figure1: Response of Variables to a M2 shock



Source: Browne and Cronin (2010)

Our empirical results provide support for the theory (and are summarised in Figure 1). In summary, we find the following:

(i) commodity and consumer prices each move in proportion to the money stock in the long run, although convergence is rather slow (measured in quarters on the x-axis in Figure 1);

(ii) commodity prices initially overshoot their new equilibrium value in response to a money supply shock; the CPI is initially slow to adjust, but eventually picks up after commodities prices have peaked;

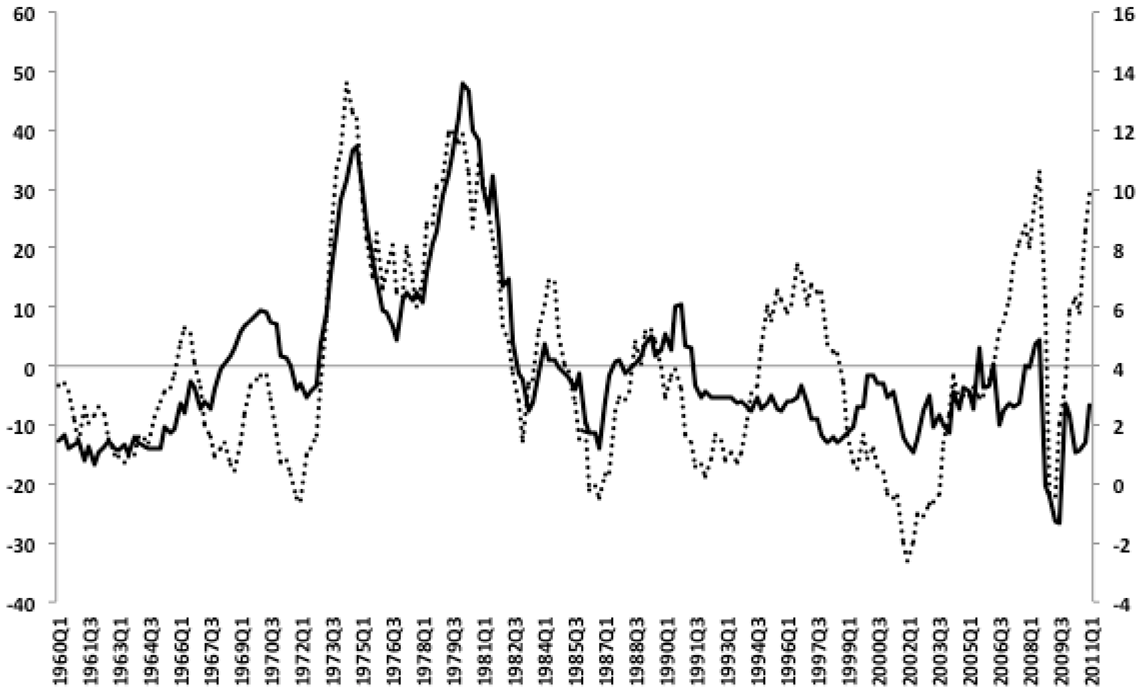
(iii) one–quarter lagged values of the deviation of the commodity price index from its equilibrium/money-determined value have explanatory power for current-quarter CPI inflation;

(iv) the sign of the coefficient for the lagged commodity price gap is positive, as to be expected from the theory;

(v) GDP receives a temporary boost from an increase in money stock, lasting about two or three quarters, but it then reverts to its initial value.

For this chapter, we revisited the relationship between the variables, extending the dataset up to 2011q1, and present the results in a new way. Figure 2 contains two series. The first is the year-on-year rate of CPI inflation on a quarterly basis from 1960q1 to 2011q1, with the 1960q1 value reflecting the rate of inflation over the previous four quarters, i.e. the percentage change in the CPI between 1959q1 and 1960q1, and so forth. The second series is a measure of the commodity price gap, where the commodity index is the CRBSI, and the gap is defined as the percentage difference between the actual index value and our estimate of the corresponding equilibrium value, as determined by the money equation at that time. A positive gap indicates actual commodity prices being above equilibrium. Given the discussion above, the expectation is that when the gap is positive, the rate of CPI inflation will subsequently increase.

Figure 2: Year-on-year CPI inflation rates (solid line, right-hand-side scale) and Commodity Price Gap, 1960q1-2011q1 (left-hand-side scale) in percentage points



As a general observation, the co-movement between CPI inflation rates and the commodity price gap is noticeable. Looking at how the two variables behaved over time, the period up until the early 1970s was one when the commodity price gap was usually negative and CPI inflation relatively low. A large positive commodity price gap emerged in 1973-4 and the CPI inflation rate responded accordingly, moving into double-digit values. This situation prevailed through the rest of the 1970s. The CPI inflation rate declined steadily between 1980 and 1983, as the positive commodity price gap was also eroded. Thereafter, through the 1980s and 1990s, the CPI inflation rate remained at low values and the commodity price gap moved around the origin.

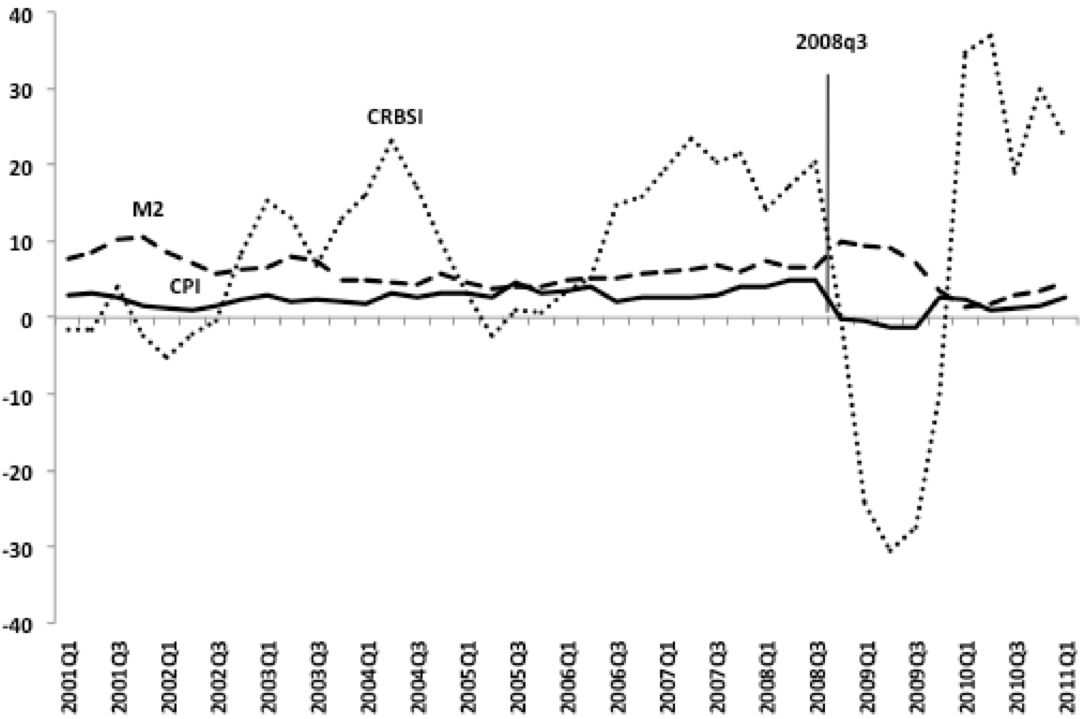
The 2000s proved a more interesting decade. A large negative commodity price gap had developed up to the end of 2001/early 2002. Over the next six years, however, the gap first closed and then moved into positive values, reaching a local high value in 2008q3. CPI inflation increased slowly from a rate just above 1% in 2002q2 to a value close to 5% in 2008q3.

Figure 3 helps to illustrate how our overshooting theory can explain these developments in the early- to mid-2000s, as well as those that have occurred since 2008. It shows year-on-year rates of change in US M2, US CPI and the CRSBI commodity index, from 2001q1 to 2011q1 (so, for example, the 2001q1 observations are the year-on-year changes in the respective variables between end-2000q1 and end-2001q1). A vertical line is added at 2008q3. Prior to that quarter, the rate of M2 growth can be seen to have been in excess of that of the CPI from the early 2000s. The money stock grew by 68% between 2000q1 and 2008q2, while CPI increased by just 28%. The difference could not be explained by the greater need for real money balances for transactions purposes associated with real GDP growth, which totalled 20% over that period. In these circumstances, it is unsurprising to us that the CRBSI rose strongly in value. It more than doubled during this timeframe, increasing by 115% between 2000q1 and 2008q2. With the rate of change in the CPI not keeping pace with that in M2, the monetary impulse affected commodity prices.

The differential between the M2 growth rate and the CPI inflation rate is particularly noticeable between 2001 and 2003, as can be seen in Figure 3. The rate of change in the CRBSI did not pick up until 2003 and was maintained into 2005. The overshooting theory would explain this by noting that the response of commodity prices to a monetary stimulus is not instantaneous, but rather occurs with a lag; however, that lag is relatively short and the response is faster than that of consumer prices.

There was some pickup in the CPI inflation rate in 2004-5, as the rate of commodity price inflation declined. This would be consistent with the eventual catch-up in CPI inflation rates that would be expected in the wake of strong money growth, and in the initial momentum to commodity prices from that monetary source falling away. The period from early-2006 to mid-2008 saw a fresh surge in commodity prices taking place. Money growth was also above the CPI inflation rate at that time. As in 2005, the decline in the rate of increase in commodity prices that was occurring just prior to 2008q3 coincided with a steady rise in the CPI inflation rate to a value of 5% in 2008q2.

Figure 3: Year-on-year rates of change in M2 and price indices, 2000q1-2011q1, in percentage points



The vertical line at 2008q3 in Figure 4 marks the start of a sudden collapse in commodity prices in the second half of that year. Year-on-year rates of growth in the CRBSI remained negative until 2010q1. Given that the rate of money growth was much greater than the rate of the CPI inflation rate in late-2008 and 2009 when commodity prices were, in general, falling, this commodity price behaviour may appear unusual.[103] We would suggest that a flight from risky assets, such as commodities, to "safe haven" assets, like money (accommodated by monetary policy), by consumers and investors was the

[103] Another factor at play here is that the massive amount of hoarding of liquid balances induced by the crisis has undermined the assumption of constant velocity, as often happens in recessions.

predominant force at work in financial markets in late-2008/early-2009 and goes a long way towards explaining the money and commodity price growth rates in Figure 3 during that time. Since the level of uncertainty and investor nervousness in the economy has receded somewhat since then, it is unsurprising that strong money growth manifests itself in rising commodity prices. A positive commodity price gap is now evident (see Figure 2). This raises the prospect of CPI inflation rates rising from current levels in the years ahead.

Conclusion

In this chapter, we described how inflation targeting became a central plank of modern monetary policy. It contributed to a reduction in inflation rates from the high values that prevailed in the 1970s and 1980s, and did so mainly through succeeding in anchoring inflation expectations close to low levels. Inflation targeting's biggest shortcoming, in our view, is that it has not taken account of the vast changes that have occurred in the financial system since the 1990s. These have enhanced substitutability between money and financial assets. These patterns of substitution vary with the boom/bust cycle in asset prices. Indeed, they are an important ingredient of the boom/bust cycles of the 1980s and 1990s. This has had the effect of enhancing the role of money in the economy, but arguably in a disruptive way, something which has been at the heart of the 2007-9 financial crisis, but which most advocates of inflation targeting regard as something of a sideshow.

Our overshooting model provides some input into understanding the potential for money to affect prices, including relative prices between different classes of goods, such as commodities and consumer goods. It shows that monetary shocks can cause commodity prices to react quickly to maintain equilibrium in the overall price level. This can arguably prove unsettling for investors, as rising commodity prices may be interpreted as signalling a higher sustained level of real demand for a commodity or commodity class when, in fact, their prices are only reacting to a generalised, i.e. monetary, stimulus to prices in the economy. Monetary policymakers, mistakenly reading rising commodity prices as caused by market-specific demand or supply shocks, might thus adopt inappropriate monetary policy responses, including no response at all. For both investors and central banks, money is a variable that needs to be analysed and understood, and not neglected.

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US Inflation and Output since the 1970s: A P-Star Approach

David Cronin

Abstract

US inflation and output developments since the 1970s are considered using the P-star model and the VAR-based Diebold-Yilmaz spillover index approach. Shocks to monetary variables explain a substantial share of US GDP deflator inflation shocks over time, particularly in the late 1980s and early 1990s but also in recent years, a time when quantitative easing was employed by the Federal Reserve. Monetary factors, and not oil shocks, underlie price developments in the 1970s and early 1980s. Monetary shocks' influence on oil prices has become noticeably stronger over the past ten years or so, supporting the greater attention being paid of late to the impact of the monetary environment on commodity markets. Shocks to the velocity-of-money variable affect output developments, with the exception of the 1970s and early 1980s when inflation shocks and, to a lesser extent, oil inflation shocks dominate the cross-variance share of output gap shocks. After the Volcker disinflation, the influence of both inflation and oil price shocks on the output gap wane and those of velocity gap shocks increase.

Keywords: P-star model; inflation; output; oil prices; forecast error variance decompositions

JEL classification: C30, E31, E32, E51

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1 Introduction

Given that inflation has been widely acknowledged as a monetary phenomenon, the absence of models of inflation involving monetary variables, specifically money aggregates, in the recent economics literature is noteworthy. This is particularly the case for studies of US inflation. An emphasis in the profession on New Keynesian models of inflation, within which money usually plays no role, is one factor explaining this absence. Another is the breakdown of the relationship between money aggregates and inflation in econometric studies, particularly during the 1990s, and the related issue of instability in money demand functions.

In this article, the P-star model of inflation, introduced by Hallman, Porter and Small (1991) and based on a link between money, economic activity and prices, is revisited using an empirical framework that utilises forecast-error variance decompositions from vector-autoregressive regressions (VAR) to provide measures of the spillover of shocks between variables over time (Diebold and Yilmaz 2009; 2012).

The P-star model posits a lagged adjustment of the actual price level to an equilibrium value (the P-star, or P*) consistent with the current money stock. The difference between the actual and equilibrium price level (the price gap) at any time captures the extent of inflationary, or deflationary, pressure in the economy. The (lagged) gap variable will then have explanatory power for inflation in a dynamic least-squares regression. The price gap is equivalent to the sum of a velocity (of money) gap and an output gap so that lags of both could be substituted for it in econometric applications. Inertia in inflation is captured through the inclusion of lagged inflation rates in the regression specification.

The VAR econometric approach used here is different to the dynamic least-squares regression specification usually employed in empirical applications of the P-star model. The VAR output allows the error variance in forecasting a variable at a chosen horizon to be explained by its own shocks (own-variance share) and shocks in other variables (cross-variance shares). It can then be ascertained whether the velocity gap and output gap account for a sizeable share of inflation's forecast error variance. Quarterly US data, covering the period from 1959 onwards, are used. Two different money aggregates, M2 and MZM, provide alternative velocity gap measures.

The forecast-error-variance decompositions are estimated on a rolling-window basis, with the first window ending in 1975Q3 and the final one in 2016Q2. One can then observe the extent to which the gap variables' influence on inflation, both collectively and relative to one another, varies over time. Both gaps accounting for a substantial share of the forecast error variance decomposition of inflation provides support to the P-star model. The velocity gap and output gap's relative share of the decomposition would indicate whether monetary policy was operating more strongly through the money market or good market channels. The own-variance share of the inflation decomposition reveals the influence of past inflation shocks.

Oil price inflation is also included in the VAR estimations so as to consider how cost-push factors compare to monetary variables in influencing inflation. The cost-push (or supply-shock) view attributes inflation to an increase in the price of inputs feeding through to the price of goods. Such exogenous shocks can also have an impact on output growth. The relative influence of cost-push factors (in particular, oil market developments) and monetary variables on inflation and output in the 1970s and early 1980s have received considerable attention in the economics literature (see, for example, Bohi 1989; Bernanke et al. 1997; Barsky and Kilian 2002).

The main finding here is that shocks to the monetary variables (the velocity gap and output gap) explain a large share of US GDP implicit deflator (GDPD) inflation shocks over time and particularly so in the late 1980s-early 1990s and in recent years, a time when quantitative easing, raising the money supply, was undertaken by the Federal Reserve. Oil price shocks have a low share of the inflation decomposition. The econometric evidence also points to the gap variables' combined share of the forecast error variance of GDPD inflation being much higher than that of oil price inflation in the 1970s, indicating monetary factors and not oil shocks underlying the inflation rates of the period. Oil price shocks maintain a low share of the decomposition of inflation after the 1970s. The results then are supportive of a P-star/monetary explanation of inflation.

The definition of the money stock is found to be important to the strength of the link between money and inflation at different points in time. This is illustrated by MZM velocity gap shocks accounting for a particularly large share (at times well over half) of the forecast error variance decomposition of inflation in the late-1980s and early-1990s. The influence of the M2 velocity gap is below that of the MZM velocity gap at that time and its decomposition share experiences a trend decline from the early 1990s through to the early 2000s. This is consistent with Carlson et al. (2000), which finds a breakdown in the M2 money demand function around 1990 while at the same time a stable MZM money demand function is evident throughout the 1990s.

The VAR output also provides an assessment of the relative importance of shocks from the two gap variables to oil price developments. It points to their combined influence on oil prices diminishing from the mid-1970s through to the mid-1990s before increasing thereafter. It has become noticeably stronger over the past ten years or so, which supports the increased emphasis that is being given to the impact of the monetary environment on commodity markets.[104]

Finally, a decomposition of the forecast error variance for the output gap is also considered. It is included here as the P-star model indicates changes in the money stock having effect on output, at least over the short term. While the velocity gap is generally found to have an impact on output developments, the 1970s and early 1980s prove to be an exception. At that time, it is inflation shocks and, to a lesser extent, oil inflation shocks that dominate the cross-variance share of output gap shocks. After the Volcker disinflation of the early 1980s, the influence of both inflation and oil price shocks on the output gap decomposition wane and those of velocity gap shocks increase.

2 The P-star model of inflation

The P-star model of inflation was formulated in Hallman et al. (1991).[105] They propose a dynamic model of inflation derived from the quantity theory of money equation. They note that the equilibrium price level, P^*, consistent with the current money stock, M, can be defined as:

$$P^* = \frac{MV^*}{Q^*} \qquad (1)$$

[104] The relevance of monetary conditions to commodity price changes was highlighted in the financial press during the mid-2000s; see, for example, Clover and Fifield (2004) and Fifield (2004). Academic contributions that have considered the influence of monetary conditions on commodity markets include Frankel (2008) and Browne and Cronin (2010).

[105] Humphrey (1989) identifies precursors to the P-star approach in the older economics literature, stretching as far back as David Hume.

Where V^* is the long-run equilibrium value of the velocity of money and Q^* is potential real output. The long-run equilibrium of velocity is not directly observed, can differ from current velocity, and could be expected to have a varying value over time, reflecting, among other factors, changing transactions technology. Potential real output will also vary over time and usually differs from observed real output.

The money stock, M, also satisfies the determination of the current price level, P:

$$P = \frac{MV}{Q} \qquad (2)$$

Where V is the velocity of money and Q is real output.

For the money stock, M, and using a natural log representation (denoted in lower-case variables), combining the two identities above leads to:

$$p - p^* = (v - v^*) + (q^* - q) \qquad (3)$$

If the money stock implies an equilibrium price value that is above the actual price level then it will either cause the velocity of money (v) to be below its equilibrium value (v^*) or output (q) to be above potential (q^*), or both. These deviations, or gaps, from equilibrium values for velocity and output will exercise upward pressure on the price level (i.e., it will cause inflation) such that the gap between it and the equilibrium price level closes over time. Deflationary pressure will arise when $v > v^*$ and/or $q < q^*$, with p declining towards p^* over time. When the price level is at its long-run value then equilibrium will also be prevailing in goods and money markets, i.e. the two gap variables, $(v - v^*)$ and $(q^* - q)$, will have zero values.

From this relationship, Hallman et al. (1991) and others (for example, Tatom 1990) estimate single-equation models where inflation (or the change in inflation from the previous period) in period t is a function of the price gap, $p - p^*$, in period $t - 1$. A richer approach involves the velocity (v) gap and the output (q) gap both being used in place of the price gap. Among the additional explanatory variables that have been used in the econometric estimation of the P-star model are lags of the inflation rate itself and a measure of cost-push/non-monetary pressures, such as oil price inflation.

The P-star model of inflation then has been translated to the following form for econometric estimation:

$$\pi_t = f((v_{t-1}^* - v_{t-1}), (q_{t-1} - q_{t-1}^*), \sum_{i=1}^{K} z_{t-i}, \sum_{i=1}^{K} \pi_{t-i}) \quad (4)$$

The two gap variables are lagged one period to inflation, π.[106] Lags of a cost-push variable, z, can also be included in the specification as it may account for a fraction of the short-term variability in inflation. Its inclusion allows the explanatory power of a cost-push view of inflation to be compared to that of the P-star model. Lags of the inflation rate are also included.

The specified regression equation is typically estimated using an ordinary-least-squares procedure over a single sample period or a number of sub-samples. The estimated coefficients indicate whether the lagged gap variables have the posited sign and are statistically significant, and whether, accordingly, support for the P-star model arises or not.

The output gap is emphasised in Phillips-curve models of inflation, with a positive output gap generating inflationary pressure within the economy. In the P-star model, the output gap represents one of the two forms of disequilibrium that arise (in the goods market; the other being in the money market and represented by the velocity gap) when the price level differs from the equilibrium value implied by the existing money stock. Thus, the two gap variables are complementary within the P-star model and in what follows a deviation in output from equilibrium and its influence on inflation is viewed as stemming from changes in the money stock, and not from a Phillips-curve based model of inflation.[107]

3 Diebold-Yilmaz measure of spillover between variables

In this article, a different econometric approach to assessing the P-star model is taken to the one based on a least-squares regression of equation (4). A VAR estimation is applied

[106] Note that the two gap variables are mostly usually stated as $(v^* - v)$ and $(q - q^*)$ in regression specifications with the estimated sign on both expected to have a positive value in explaining inflation, or changes in it.

[107] Variants of the P-star model have been presented over the years. For example, Gerlach and Svensson (2003) put forward a real money gap, i.e. the gap between the current real money stock and the long-run equilibrium money stock, alongside the output gap in a model of inflation and find it to have significant predictive power for inflation in the euro area. Trecroci and Vega (2002) present a model of inflation where both a money gap and an output gap are explanatory variables.

to time series of the four variables in (4), i.e. inflation, a velocity gap, an output gap, and a cost-push variable, with each of the variables having a common number of lags within the VAR. A forecast error variance decomposition is then provided for each variable at a given horizon as part of the "innovation accounting" that is at the centre of the VAR econometric approach. The decomposition shows the proportion of a variable's shocks that are accounted for by past innovations, or shocks, to the other variables (cross-variance shares) in the VAR and by past shocks to the variable itself (the own-variance share).

Diebold and Yilmaz (2009; 2012) propose using the sum of the cross-variance shares for each variable in the VAR, aggregated across all variables in the VAR, to produce a total spillover index (TSI) for the system of variables as a whole. The higher the value of the TSI, the greater the spillover, or interaction, that is occurring among the variables. This is particularly useful when a rolling-regression approach is used: it allows periods of higher, and lower, spillover to be identified.

The components of the TSI can also prove informative and it is those that are the focus of attention here. For each rolling window, the proportions of the error variance in forecasting N-quarter-ahead GDPD inflation that are attributable to past innovations in the two gap variables and in the cost-push variable are provided. A substantial combined share for the two gap variables, including relative to the share of the cost-push variable, would provide support for a monetary influence on, or determination of, inflation. The share of one gap variable relative to the other will shed light on whether that influence is emanating more strongly from the velocity gap (money market) or output gap (goods market).

The Diebold-Yilmaz approach then does not focus on the significance and sign of regression coefficients that arise with a standard least-squares estimation of equation (4) but rather it allows one to judge the influence of the gap variables on inflation, and whether it is rising or falling over time, through the size of their share of its forecast error variance decomposition. In Diebold and Yilmaz (2009), the TSI and its components are constructed on the basis of orthogonalised shocks, so that the ordering of the variables in the VAR matters to the decomposition. In their later, 2012 article, the error variance decompositions are invariant to the ordering, i.e. generalised, as opposed to orthogonalised, forecast error variance decompositions are provided. In this article, the orthogonalised approach is used for economic reasons outlined in section 5, although the generalised version of the spillover index is used as part of a suite of robustness tests.

4 Data and related issues

Following on the discussion above, empirical analysis of the P-star model requires time series for a number of variables: the velocity of money, real GDP, real potential GDP, a cost-push variable (oil price), and a measure of inflation. Series relating to the velocity of money on the Federal Reserve Bank of St. Louis FRED database are calculated as quarterly nominal GDP divided by the average money stock within the quarter. This informs the choice of real GDP as the measure of economic activity in the econometric work undertaken here and, likewise, the GDP implicit deflator as the appropriate price level, and percentage changes in it as the measure of inflation. Series for these variables and for real potential GDP and oil prices (West Texas Crude spot price) are also available on a quarterly basis from 1959Q1 onwards on FRED.

Two measures of money velocity are used. The first is that of M2. The M2 money stock has been used in many studies of money's relationship to nominal economic developments (for example, Friedman and Schwartz 1963; Feldstein and Stock 1994). It is also a money aggregate where a previously stable relationship between it and nominal output appeared to break down during the 1980s and 1990s (Friedman and Kuttner 1992; Estrella and Mishkin 1997). The role of M2 in monetary policy was downgraded by the Federal Open Market Committee in 1993. In using M2 velocity in the econometric analysis here, the innovation accounting provided by the Diebold-Yilmaz approach may indicate whether shocks to this money variable, captured through its velocity gap, had a declining share in explaining inflation shocks during the 1980s or early 1990s, as might be expected if there was a breakdown in the M2 money demand relationship at that time.

The other velocity measure used is that of the MZM (Money Zero Maturity) money stock. It is also a broad money aggregate and is defined as M2 less small-denomination time deposits plus institutional money funds. Using alternative measures of the velocity of money provides a check on the sensitivity of the results to the choice of money aggregate. Moreover, Carlson et al. (2000) provides evidence that the stability of the standard M2 demand function was undermined around 1990 by households reallocating a portion of their money holdings from time deposits to mutual funds, whereas that of MZM was not. Using the velocity of MZM as an alternative to that of M2 in the VAR analysis could provide further insight on this episode. In particular, it is of interest whether the Carlson et al. finding that MZM had a more easily established link to nominal economic activity than M2 in the 1990s is mirrored by its velocity gap accounting for a larger share of inflation's forecast error variance decomposition than M2's share at that time.[108]

A preliminary consideration for the empirical work is that the equilibrium velocity value is not directly observed and, unlike potential GDP, an estimated series is not provided by the St. Louis FRED database. In Hallman et al. (1991), velocity is noted as being trendless over the sample period and, consequently, its sample mean provides a single measure of equilibrium velocity. The rise-and-fall in both M2 and MZM velocity over time, as shown in natural log form in panels (i) and (ii) of Figure 1, render such an approach inappropriate here. Orphanides and Porter (2001) acknowledge the challenge to measuring equilibrium velocity when such variation in observed velocity arises. To account for the upward movement in M2 velocity during the 1990s, they incorporate a smooth underlying trend in their specification for estimating equilibrium velocity. Subsequent to the timeframe they studied, M2 velocity declined, further complicating the extraction of an equilibrium series from actual velocity. The approach taken here is to apply a Hodrick-Prescott filter, with a lambda value of 1600 (the value for quarterly data suggested by Hodrick and Prescott (1997)), to the natural log of the M2 and MZM velocity series.[109] Projections for both velocity series are made beyond 2016Q2, up to 2017Q4 using an autoregressive forecasting process. When the Hodrick-Prescott filter is then applied to the extended velocity series, the initial six values (1959Q1-1960Q2) and final six (2016Q3-2017Q4) are discarded to address the end-point problem associated with the Hodrick-Prescott filter. The fitted values – the measures of equilibrium velocity - are shown by the dotted lines in panels (i) and (ii) of Figure 1.

The various series in Figure 1 are plotted over the period 1960Q3-2016Q2. The two velocity gaps, measured as percentage deviations of actual from equilibrium values, are shown in panels (iii) and (iv) of Figure 1. Both gap variables are, in effect, error-

[108] Carlson et al. also use M2M as a third money aggregate in their study. It is not available over a sufficiently long period (data are available from 1967 to 2013 only) for the rolling-window estimations used here.
[109] This atheoretical approach to estimating an equilibrium value from a series is often applied to real output data, with the difference between the two series providing measures of the output gap.

correction terms within the P-star model. Standard unit root tests indicate the series for both to be stationary processes. The other variables used in the VAR estimations are also plotted in that figure: the real GDP gap (the difference between actual and potential output, stated as a percentage of potential real GDP) and the percentage rates of change in oil prices and in the GDPD from one quarter to the next.[110] The shaded areas in Figure 1 and subsequent charts are those quarters where the NBER has identified the US economy to have been in recession.

5 Econometric results

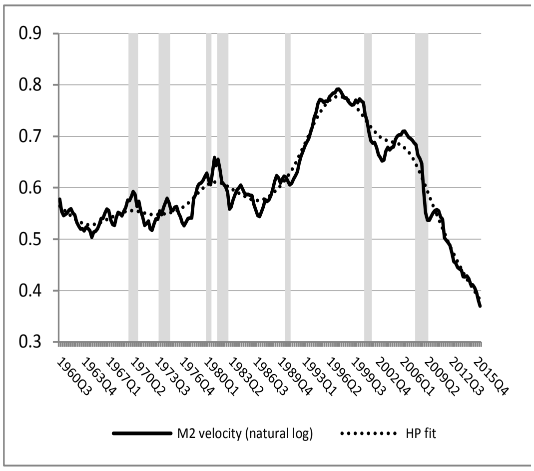
5.1 Full sample results

VAR estimations are undertaken according to two groupings of variables. The first comprises GDPD inflation, the M2 velocity gap, the output gap and oil inflation, while in the second, the MZM velocity gap substitutes for its M2 counterpart. Information criteria for selecting the order of the VARs (which include constant terms) point to a lag length of 4 (i.e., lags of each variable from 1 to 4 are included in the regressions) for both sets of variables. The variables are also arranged in the VAR in the order given above (i.e., inflation, velocity gap, output gap, oil inflation) to allow orthogonalised forecast error variance decompositions to be used in constructing the spillover index. The placing of GDPD inflation as the first variable ensures that shocks to the other three variables do not affect its decomposition until the quarter after the shocks occur. This is consistent with the P-star model where the gap variables only have an effect on inflation with a lag. The ordering of the VAR allows the two gap variables to have contemporaneous effect on oil price inflation. The velocity gap is placed before the output gap in the VAR in line with Milton Friedman's argument that a change in the money stock first affects the velocity of money and then output before those variables, and the price level, return to equilibrium values (see Humphrey 1989).

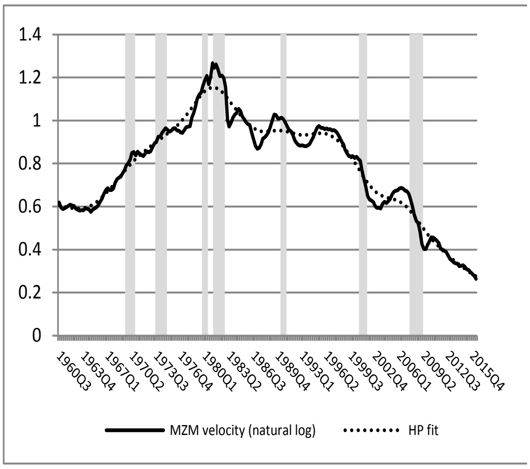
[110] The GDP implicit deflator, velocity and real GDP series are all seasonally-adjusted, while those of potential real GDP and oil prices are not.

Fig. 1 Variable series

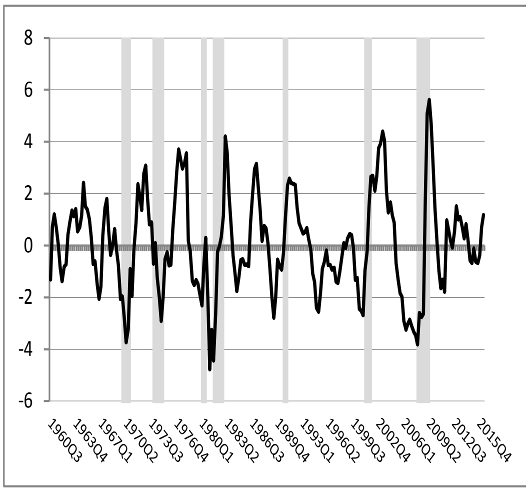
ii. M2 Velocity and filtered series



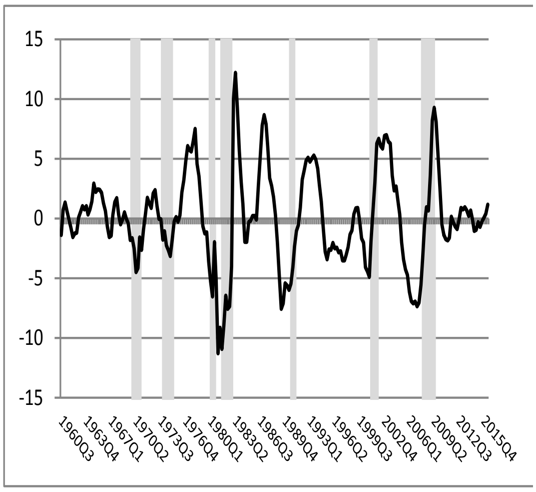
ii. MZM Velocity and filtered series



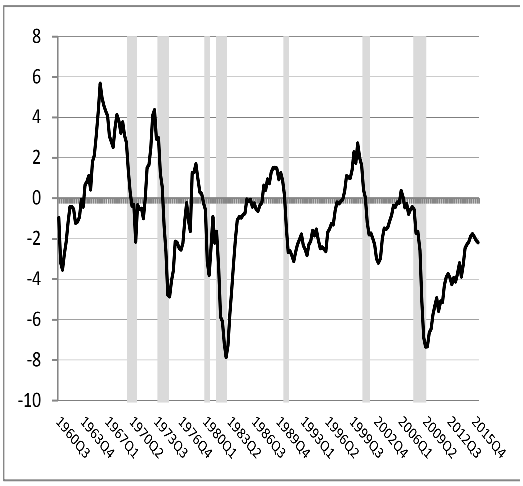
iv. M2 Velocity Gap (%)



iv. MZM Velocity Gap (%)



vi. Output Gap (%)



vi. Oil price inflation (%)

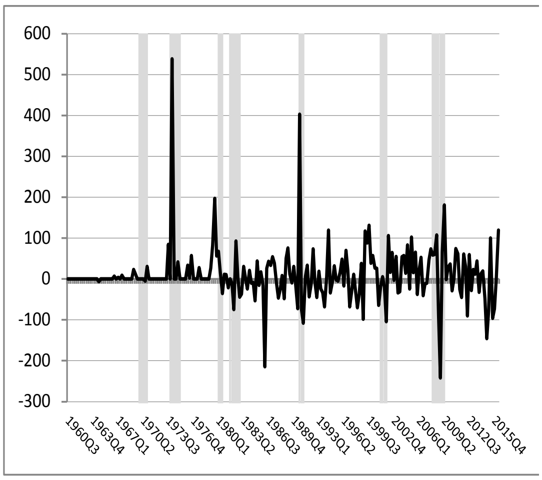
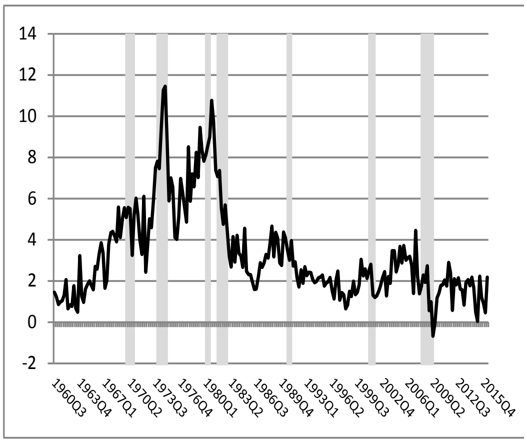
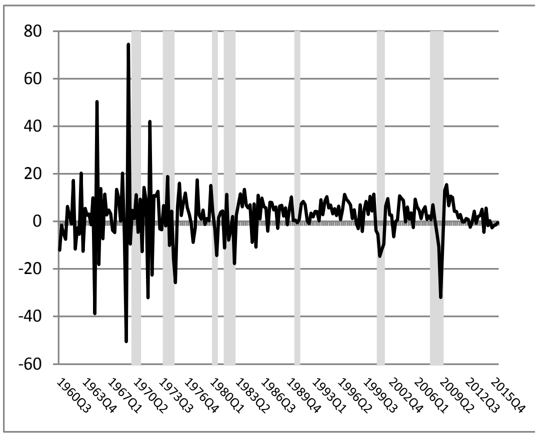


Fig. 1 (contd.) Variable series

vii. GDPD inflation (%)



viii. Change in Openness



The forecast horizon for the decompositions is 10 quarters ahead. This reflects both econometric (a longer forecast horizon could be expected to see the decomposition shares between variables stabilise) and economic (monetary policy will have effect on inflation with a lag – a 10-quarter ahead horizon would be broadly in line with some of the empirical findings as to when policy has its peak effect on inflation in the US case) considerations.[111]

Table 1 provides the full sample (1960Q3-2016Q2) estimate of the TSI and its components. The results are of less interest than the rolling-window estimations that follow but provide the reader with an insight, through a practical example, into the information provided by the Diebold-Yilmaz framework.

The TSI and its components have broadly similar values in both panels of Table 1, so only the results where the M2 velocity gap is used (i.e., panel (i)) are discussed. The index has a value of 22.9%, pointing to relatively low spillover (or, alternatively, own variance shocks being dominant).[112] The first row of the table indicates that 18.3% of the forecast error variance decomposition of GDPD inflation is explained by shocks to the M2 velocity gap, while the share of the output gap is 15.5%. Oil price inflation has a cross-variance share of 9%. The own-share variance for GDPD inflation comes in at

[111] See Friedman (1961; 1972); Batini and Nelson (2001).

[112] The 22.9% value is arrived at by dividing the sum of the “directional from others” entries for each of the four variables (located above it in that column and totalling 91.4%) by four (the number of variables in the VAR).

57.2% (the own-variance shares for each variable can be found on the diagonal of the table). The decomposition for the other price variable, oil inflation, is shown in the fourth row of the table. It can be seen that oil inflation has the highest own-variance share (highest diagonal entry) of all the variables, at 90.3%. The two monetary variables (i.e., the gap variables) have a combined value of 6.2% in that row, much lower than their combined value in the decomposition of GDPD inflation (33.8%).

Table 1 Spillover index and components: full sample estimation (%)

(i) 10-quarter horizon

	GDPD inflation	***M2 Velocity Gap***	***Output gap***	***Oil inflation***	***Directional from others***
GDPD inflation	57.2	18.3	15.5	9	42.8
M2 Velocity Gap	11.9	85.6	0.4	2.1	14.4
Output Gap	5.2	10.3	75.5	9	24.5
Oil inflation	3.5	3.1	3.1	90.3	9.7
Directional to others	20.6	31.7	19	20.1	91.4
					Total Spillover Index:
Directional including own	77.8	117.3	94.5	110.4	22.9

(ii) 10-quarter horizon

	GDPD inflation	***MZM Velocity Gap***	***Output gap***	***Oil inflation***	***Directional from others***
GDPD inflation	61.7	18.2	11.5	8.5	38.3
MZM Velocity Gap	8.3	85.2	3.1	3.4	14.8
Output Gap	2.1	5.6	81.9	10.4	18.1
Oil inflation	4.1	1.8	2	92	8
Directional to others	14.5	25.6	16.6	22.3	79.2
					Total Spillover Index:

Directional including own	76.2	110.8	98.5	114.3	19.8

5.2 Rolling window TSI

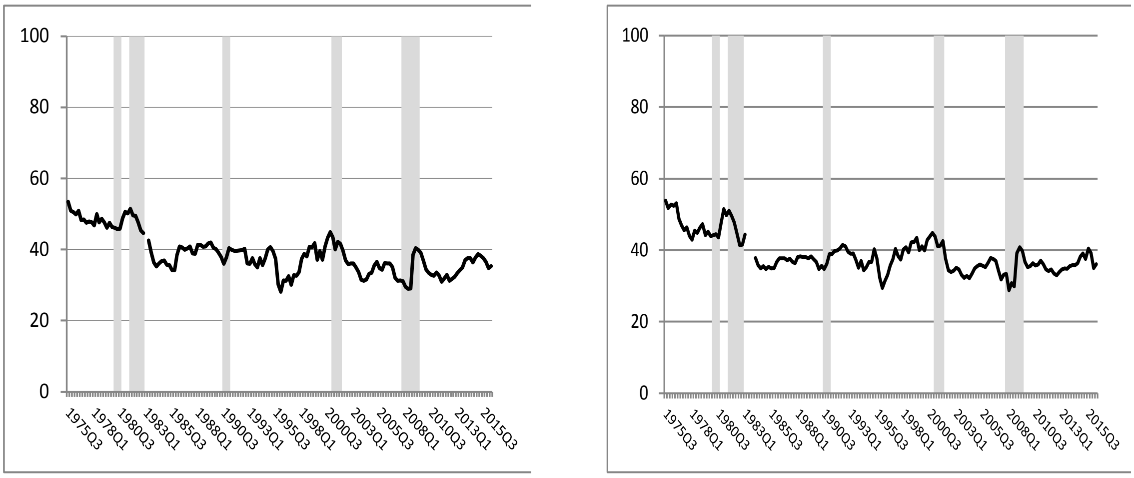
When estimated on a rolling window basis, the TSI provides a measure of how interaction among a set of variables varies over time. Figure 2 provides the rolling measure for this index. As with all subsequent figures, the charts in the left-hand-side column of each page refer to those VARs where the M2 velocity gap measure is utilised alongside the GDPD inflation, output gap and oil inflation variables (i.e., they are the variables used in panel (i) of Table 1). In the right-hand-side charts, the MZM velocity gap measure is that used with the inflation, output gap and oil inflation variables (i.e., mirroring panel (ii) of Table 1). The rolling window size chosen is 60 quarters. This means that the first data-point in each chart covers the initial window (ending in 1975Q3), with the window end-date being indicated on the horizontal axis of the chart, while the final window ends in 2016Q2. Index values are recorded for all windows except for that ending in 1983q1 in the case where the M2 velocity gap is used in the VAR and for three windows, those ending in 1983Q2-Q4, where the MZM velocity gap is employed.

In Figure 2, both TSIs have similar values throughout the rolling-window sequence. They decline after the initial window, ending in 1975Q3, through to the mid-1980s and move in a narrow range thereafter. These values indicate total spillover among the variables remaining relatively stable over time. The most noticeable change in both panels occurs from about the start of the 1981-82 recession through until late-1983 or early-1984. This was a period when there was a sharp fall in inflation rates (see Figure 1, panel (vii)), which coincided with a tight-money policy being adopted by the Federal Reserve (the so-called "Volcker disinflation").[113]

[113] In the appendix, robustness tests of the impact on the TSI values of different choices of lag length, forecast horizon, window size, form of shocks, and number of variables used are considered.

Fig. 2   Total spillover index (%)

i.   M2 velocity as money variable   ***ii.   MZM velocity as money variable***



5.3 Spillover to GDPD inflation

The forecast error variance decomposition of GDPD inflation allows the impact of velocity gap shocks and output gap shocks over a ten-quarter-ahead horizon to be assessed.   The entries in panels (i) and (ii) of Figure 3 are labelled “monetary impulse”. They are the sum of the shares of the decomposition attributable to the velocity gap and to the output gap.   In other words, in panel (i), it is the sum of the entries, for each particular estimation window, in panels (iii) and (v), and in the case of panel (ii), the sum of the entries in panels (iv) and (vi).   This seems to be an appropriate summation to provide as the P-star theory indicates the gap variables together capturing the influence of monetary developments on inflation.

In panel (i) of Figure 3, where the velocity gap component is that of M2, the combined forecast error variance share of the two gap variables is close to 40% in the initial windows and then increases, reaching a peak of 60% in 1990Q4.   It experiences a trend decline thereafter up to 2008Q3.   It rises sharply after 2008Q3 and reports values of close to 40% up to 2014Q4 before declining.   This period, 2008Q3-2014Q4, bookends the three programmes of quantitative easing undertaken by the Federal Reserve after the 2008 financial crisis.   The goal of quantitative easing was to stimulate the economy through an increased money supply. The evidence here is that shocks to M2 velocity have a strong influence on inflation during the period when quantitative easing was occurring. The rise-and-fall in the monetary impulse between 2008 and 2014 also holds when MZM is used (panel (ii) of Figure 3).

The respective shares of each of the gap variables are shown in panels (iii)-(vi) of Figure 3. In both the left-hand-side and right-hand-side columns, the output gap can be seen to be exercising a stronger influence on inflation shocks than the velocity gap prior to the 1980 recession. Subsequently, the velocity gap has the higher share of the decomposition for most of the rolling windows up until the mid-to-late-1990s. The influence of the M2 velocity gap (panel (iii)) is strong during the 1970s and 1980s but declines during the 1990s and has very low values in the early 2000s. The percentage share of GDPD inflation's forecast error variance accounted for by MZM velocity (in panel (iv)) rises during the 1980s and is at its strongest during the early 1990s, peaking at over 60% at that time. In comparison, the share of the M2 velocity gap (in panel (iii)) is lower than MZM's during the same period and up until the early 2000s. These results appear consistent with the findings of Carlson et al. (2000) that M2's link to nominal economic activity became unstable at that time, while MZM's was stable.

In general, output gap shocks' influence on inflation shocks (shown in panels (v) and (vi) of Figure 3) is low or declining prior to the late-1990s and is usually below that of the velocity gap, thus indicating the money market to be more important than the goods market to the transmission of monetary policy to inflation. The output gap's error variance share increases thereafter and is particularly high in the early 2000s. In more recent years, the output gap's percentage share of the decomposition for inflation is low in panel (v) but much higher in panel (vi). The M2 velocity gap's share (panel (iii)) is high since the 2007-9 recession and above its historical average, while that of the MZM velocity gap is low by comparison (panel (iv)). The M2 velocity gap then appears to be dominating the output gap in describing inflation shocks in recent years, while the MZM velocity gap's explanatory power is relatively low.

In panels (vii) and (viii) of Figure 3, the influence of oil inflation shocks on GDPD inflation is low for most of the windows in those two panels. Higher values are recorded for windows ending in quarters in the 1970s and after the mid-2000s compared to other periods but are, nevertheless, mostly below those of the velocity gap and output gap and always well below those gap variables' combined share (with the exception of the two windows ending in 2008Q2 and 2008Q3 in the left-hand-side column of Figure 3).

The 1970s is a period of particular interest in relation to the influence of oil market developments on goods markets, with a popular view being that exogenous oil supply shocks caused high and variable inflation at that time. In contrast, Barsky and Kilian (2000; 2002) attribute high and variable inflation and low or negative output growth during this period to monetary expansions and contractions. They argue that oil prices cannot explain the sustained inflation in the GDP deflator in the 1970s.[114] While the decomposition shares in panels (vii) and (viii) of Figure 3 are high (close to 20%) at that time relative to later years, they are lower than their respective monetary counterpart in panels (i) and (ii). Monetary variables then are more important than oil price developments in accounting for inflation shocks during the 1970s and, indeed, over almost all of the 164 rolling windows shown in the charts. Finally, panels (ix) and (x) capture the own-shocks share of the forecast error variance for GDPD inflation. It indicates that share accounting for, on average, about 50% of the total decomposition.

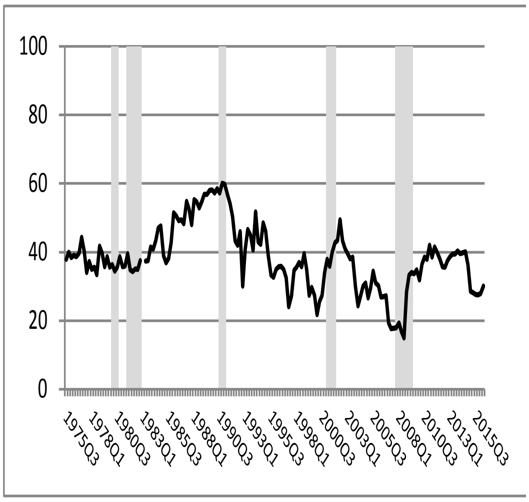
To sum up, Figure 3 indicates the P-star gap variables together accounting for, on average, just over one-third of the decomposition of inflation shocks over the 152 rolling windows; the velocity gap accounts for a larger share of the decomposition than the output gap on average;[115] the MZM velocity gap has higher explanatory power than M2's in the late 1980s-early 1990s; the M2 velocity gap has had increased influence on inflation since the 2007-9 recession; the monetary impulse in the current decade is close to, or slightly above, its historical average.

[114] They point out that only two of the five major oil price shocks between 1970 and the time of their study were followed by significant changes in GDPD inflation rates.

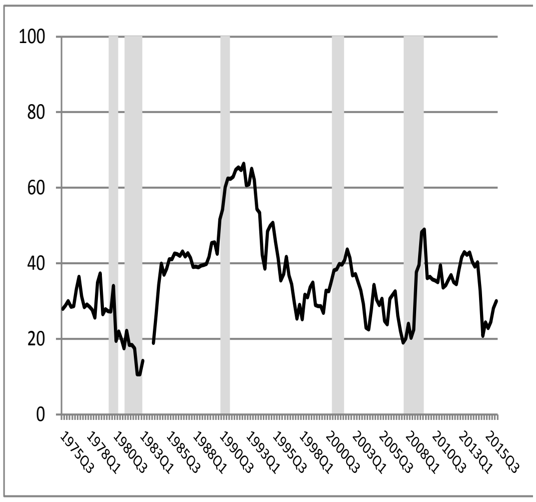
[115] When M2 is the money stock used, the velocity gap accounts for an average 21% of the inflation decomposition over all the windows, compared to 17% for the output gap. When MZM is used, the velocity gap has a 21% average share, while that of the output gap is 14%.

Fig. 3 Spillover to GDPD inflation (%)

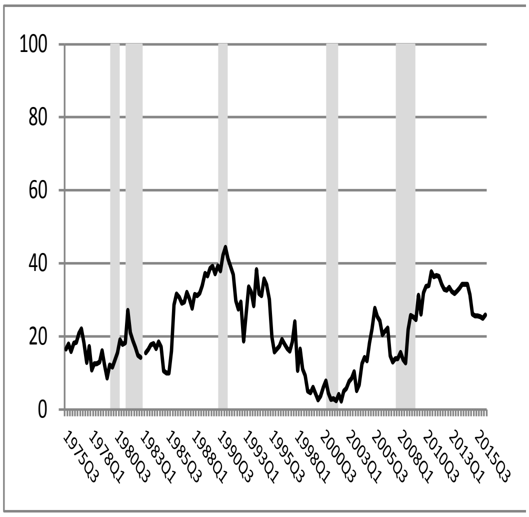
i. Monetary impulse



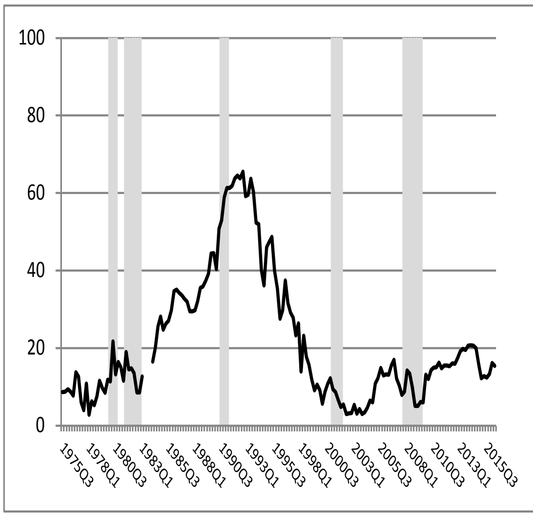
ii. Monetary impulse



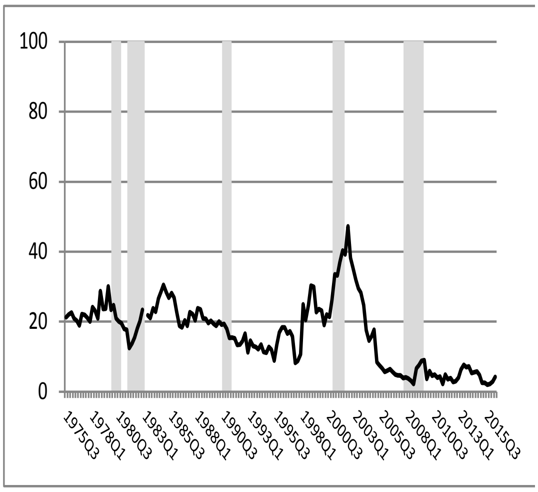
iii. from M2 velocity gap shocks



iv. from MZM velocity gap shocks



v. from output gap shocks



vi. from output gap shocks

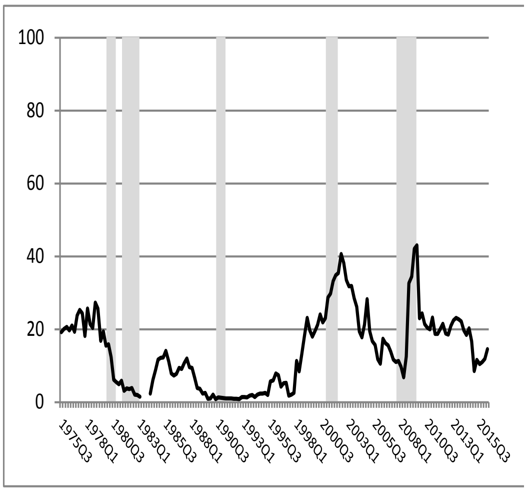
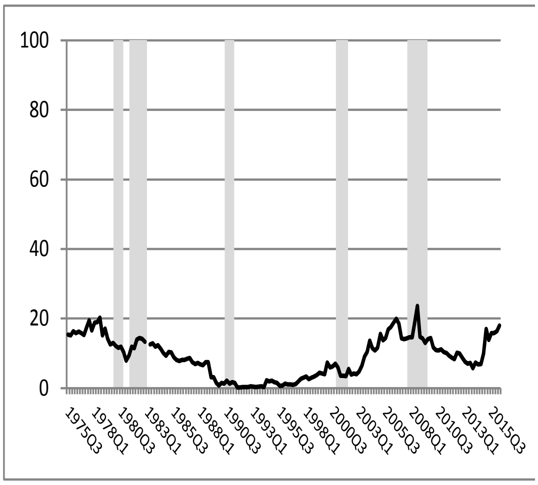
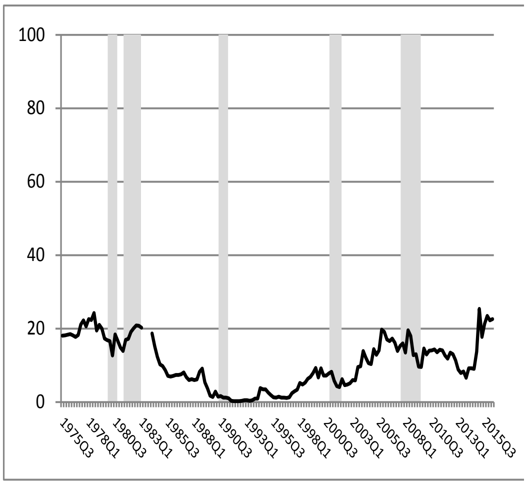


Fig. 3 (contd.)

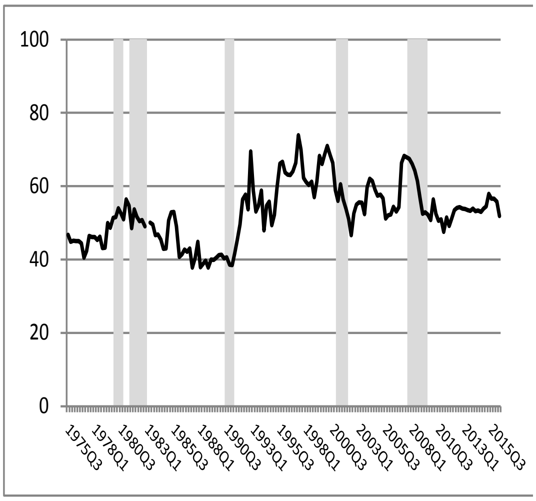
viii. ***from oil inflation shocks***



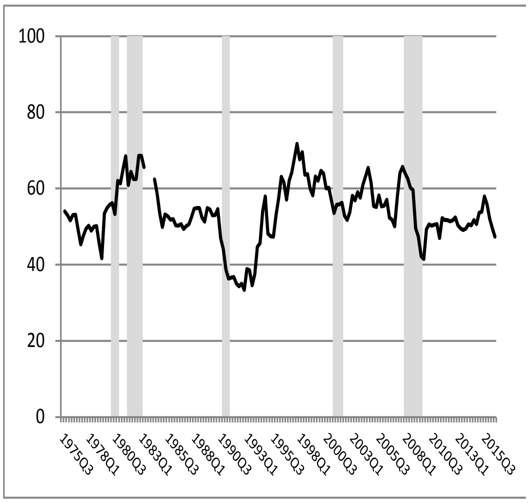
viii. ***from oil inflation shocks***



ix. ***from own shocks***



x. ***from own shocks***



The results then are supportive of the P-star model. In most rolling windows, velocity gap shocks account for a larger share of the inflation decomposition than the output gap's, thus indicating the money stock to be informative about price developments. The choice of money aggregate is important, however, to the velocity gap's share. This resonates with concerns that "missing money" can undermine the establishment of a link between money and inflation in practice and that the measurement of the money stock is thus important to that link.[116]

5.4 Spillover to oil price inflation

The other change-in-price variable included in the VARs is oil price inflation. Frankel (2008) argues that commodities, such as oil, are subject to monetary influences, while Browne and Cronin (2008, 2010) explain changes in their value over time by money supply shocks. Gattini et al. (2015) consider money demand shocks relevant to inflation and commodity prices. In their studies of 1970s stagflation, Barsky and Kilian (2000; 2002) contend that the rise in oil prices at that time was, at least in significant part, a result of an economic boom driven by monetary expansion. The decompositions of oil price inflation will indicate the effect that monetary conditions have on it. The spillovers from the two gap variables to oil inflation are shown in Figure 4 (with the panels being arranged in a similar manner to those in Figure 3). The share of oil inflation shocks attributable to GDPD inflation shocks are also shown in panels (vii) and (viii).

Panels (ix) and (x) of Figure 4 show the own-variance share of the decomposition for oil price inflation is high in comparison to that for GDPD inflation in the corresponding panels of Figure 3. Own-market developments then have considerable influence on changes in oil prices over time. Supply factors, in particular, are likely to be important, with the decision by oil exporters to increase or decrease supply having an impact on oil prices.

A smaller proportion of the decomposition here is then left to be explained by the cross-variance factors than in the case of GDPD inflation. The two gap variables, and their combined “monetary impulse”, can be seen to be less than 20% for most of the windows in panels (i)-(vi) of Figure 4. The initial windows in panels (i) and (ii), however, show the monetary impulse to oil prices being strong in the mid-1970s compared to many of the years that followed and being mainly accounted for by velocity shocks (panels (iii) and (iv)). After the 1970s, monetary influence declined slowly over time.

[116] The definition and refinement of the broad money stock has been an important feature of studies relating the real money to economic activity since, at least, Goldfeld (1976). The particular money stock affecting the results at different junctures here is then unsurprising.

The values in panels (i) and (ii) of Figure 4, however, have increased since the mid-1990s. The combined share of the two gap variables is at its strongest in recent years and is coming predominantly from the money channel (panels (iii) and (iv)) rather than the goods market (panels (v) and (vi)). One explanation of this development is the loosening of monetary policy in the wake of the 2008 financial crisis affecting commodity markets. Koo (2011) argues that these policy measures, including quantitative easing, forced fund managers to invest liquid balances in commodities in a search for yield and, thus, monetary policy is causing price developments in those markets.[117] This is not to deny that supply shocks have also likely been prominent in recent years. Azezki and Blanchard (2014) identify surprises in oil production and the publicly-announced intention by Saudi Arabia that it did not intend to counter the rising supply of oil from other producers as contributing to oil price developments in 2014.[118]

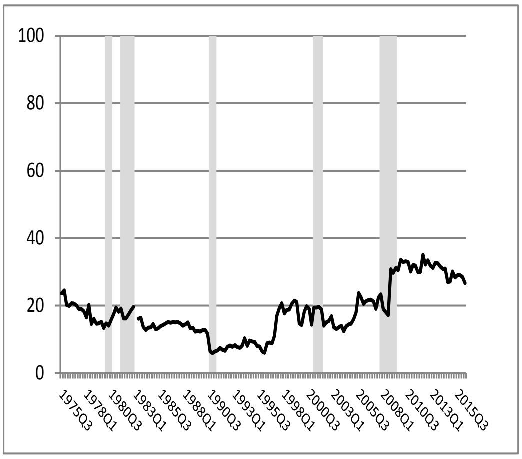
The strong monetary impulse to oil prices in recent years is also noteworthy in the context of the Bank for International Settlements and its staff (see, for example, Borio and Lowe 2002; Borio and White 2004; Borio 2014; Bank for International Settlements 2015) identifying a link between monetary and asset price developments. Its view is that financial liberalisation has strengthened the role of financial factors in the economic cycle and that excess liquid balances show up first in asset prices (including commodity prices) rather than consumer prices. The results here indicate monetary developments having a strong effect, by historical comparison, on oil prices in recent years, with that occurring in parallel to the P-star gap variables exercising continuing influence on final goods prices.

[117] The effects of quantitative easing on asset prices more generally is considered in Cronin (2014).

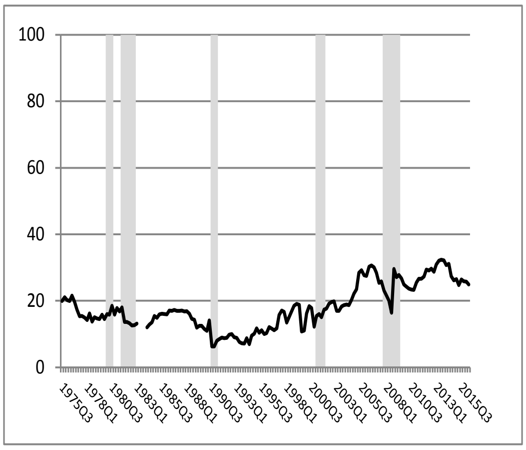
[118] The remaining two panels of Figure 4, (vii) and (viii), show the impact of GDPD inflation rate shocks to oil price inflation. It is generally low but does pick up in the windows ending in the 1990s and has a share of the forecast error variance decomposition of over 20% for most of the second half of that decade, before falling off thereafter.

Fig. 4 Spillover to oil inflation (%)

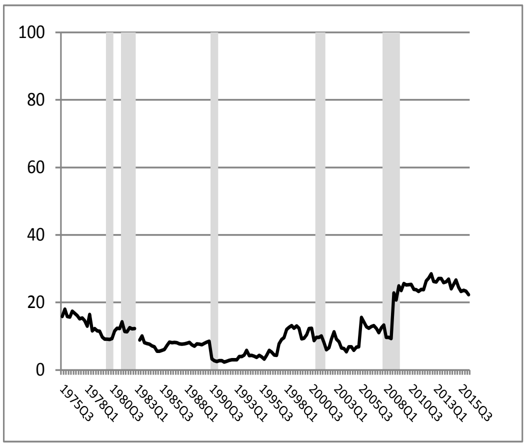
i. ***Monetary impulse***



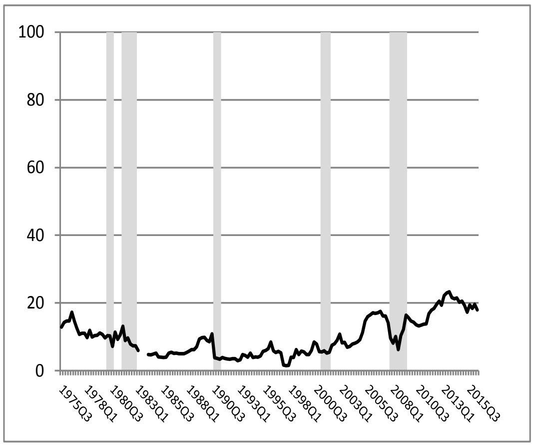
ii. Monetary impulse



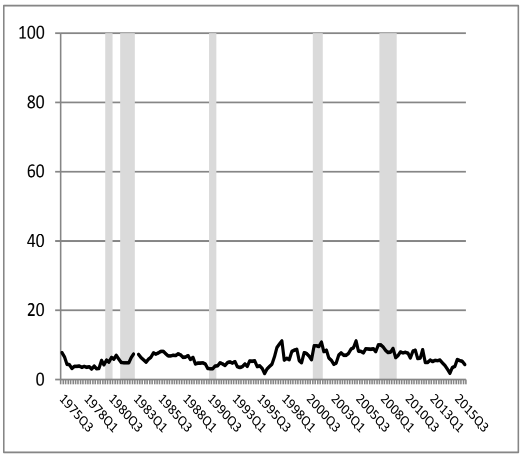
iii. from M2 velocity gap shocks



iv. from MZM velocity gap shocks



v. ***from output gap shocks***



vi. from output gap shocks

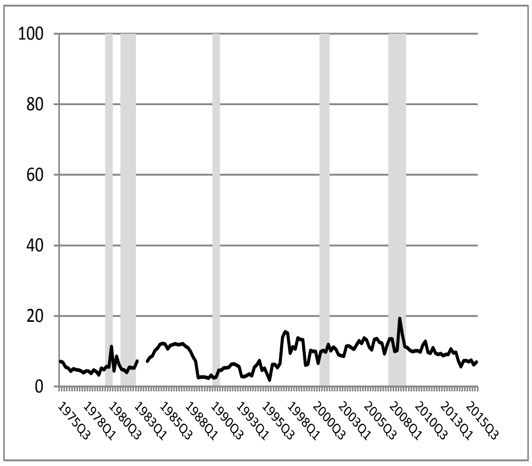
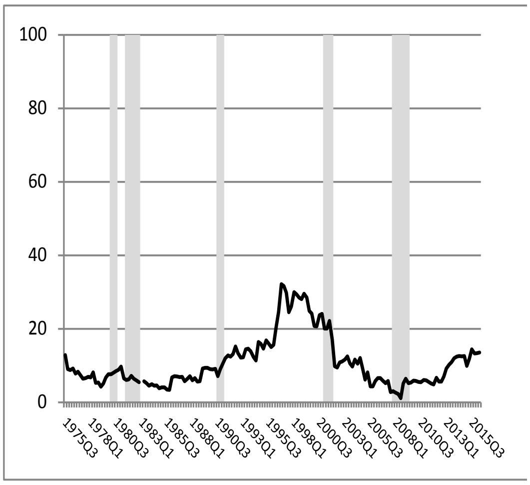
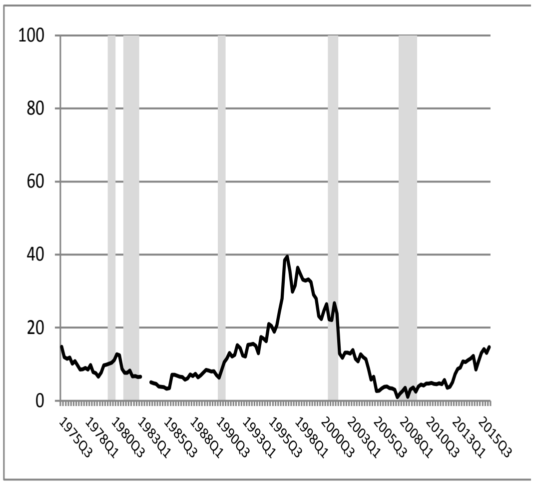


Fig. 4 (contd.)

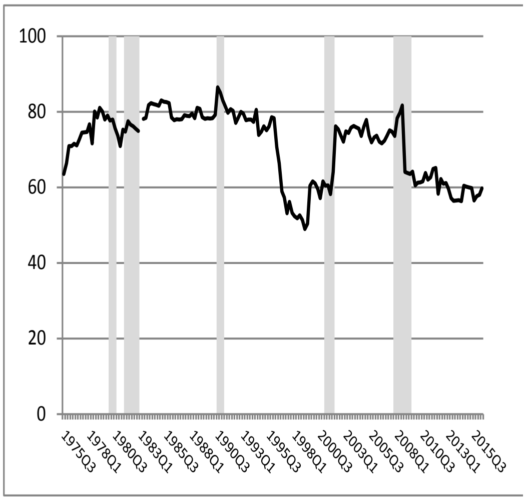
vii. from GDPD inflation shocks



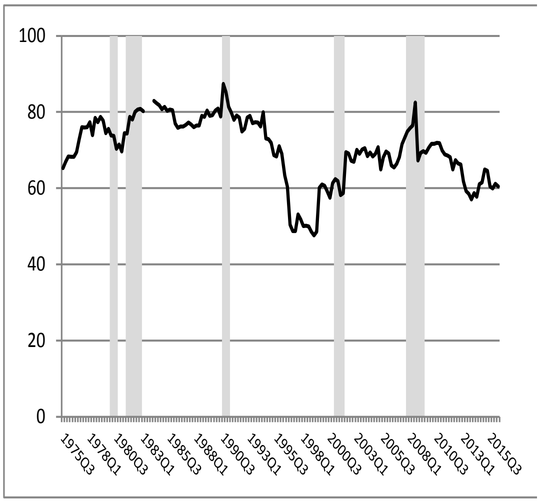
viii. from GDPD inflation shocks



ix. from own shocks



x. from own shocks



5.5 Spillover to the output gap

A final set of charts is presented in Figure 5, showing the spillover to the output gap from the other variables in the VAR, as well as its own-variance share. While the P-star theory is a model of inflation, it also indicates that changes in money aggregates are not neutral in their impact on output in the short run, with the output gap expanding or contracting in response to changes in the money supply. The extent to which the velocity gap accounts for the output gap's error variance decomposition over the forecast horizon is then of interest. The Diebold-Yilmaz approach and dataset employed here also allows the relative importance of GDPD inflation and oil inflation to output gap developments to be assessed.

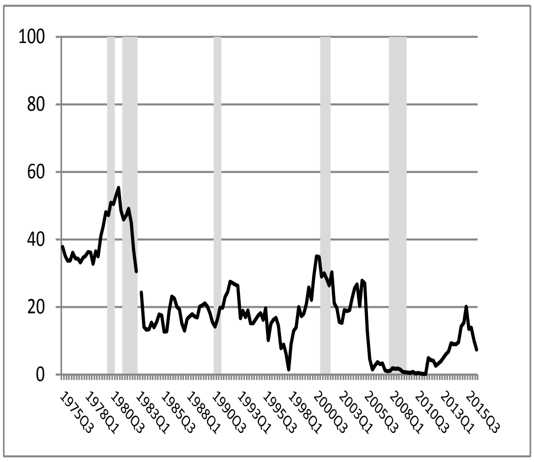
Panel (iii) of Figure 5 shows M2 velocity gap shocks having their highest share of the output gap's decomposition around the time of the 1990-1991 recession and during and just prior to the 2001 recession. The share for the MZM velocity gap (panel (iv)) is often much higher than for its M2 counterpart. As in the case of Figure 3 and the explanation of the decomposition of GDPD inflation, its effect is particularly strong in the late 1980s and early 1990s. Thus, the MZM velocity gap accounts more strongly for both inflation shocks and output shocks than the M2 velocity gap at that time. This may be because MZM captures transaction balances, or spending power, in that period more accurately and, thus, is more closely linked to developments in inflation and real activity. The results indicate money mattering to macroeconomic developments and the measurement of money balances being an important consideration in establishing and quantifying that relationship.

The 1970s and early 1980s was a time when both high and variable inflation and low or negative growth arose for much of the period. The economics literature has since debated whether the principal cause of that situation was monetary policy or aggregate supply shocks (with oil market shocks to the fore among the latter). A comparison of panel (iii) with panel (v) in Figure 5, and of panel (iv) with panel (vi), points to oil price shocks accounting for the greater share of output gap shocks up to the end of the 1981-82 recession. Inflation shocks (panels (i) and (ii)), however, have the largest cross-variance share of the three variables at that time. There is a sharp decline in inflation's influence at the end of that recession, when inflation rates were falling rapidly. The impact of oil price shocks on the output gap also declines and is quite low subsequently, even though episodes of rapid rises and/or falls in oil prices occurred in later years.[119] When inflation declined to lower and less volatile values after the Volcker disinflation – and policy shift - of the early 1980s, the influence of velocity shocks on the output gap increases with higher spillover values arising in the 1980s and 1990s in panels (iii) and (iv). In recent years, both inflation shocks and oil inflation shocks have a very low share of the output gaps' forecast error variance decomposition and most of the cross-variance share is from velocity gap shocks.

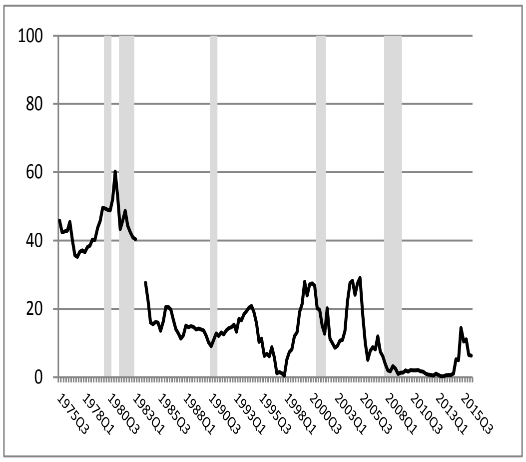
[119] For example, the price of West Texas Crude tripled between 1998Q4 and 2000Q3. It fell sharply from a value of $133 per barrel in 2008Q2 to €41 per barrel two quarters later. The lesser impact of oil market developments on the output gap in recent decades, however, should not be unexpected given its diminished role in economic activity compared to, say, the 1970s.

Fig. 5 Spillover to the output gap (%)

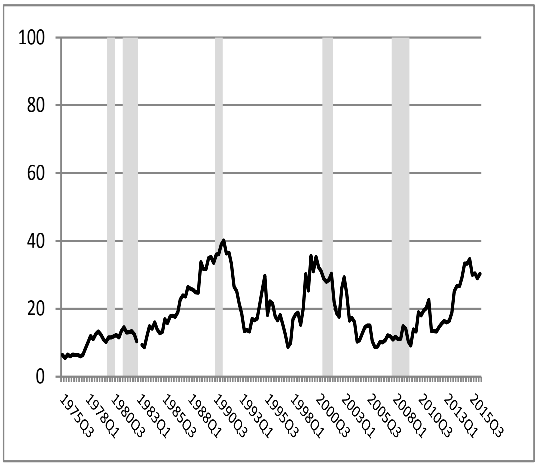
i. from GDPD inflation shocks



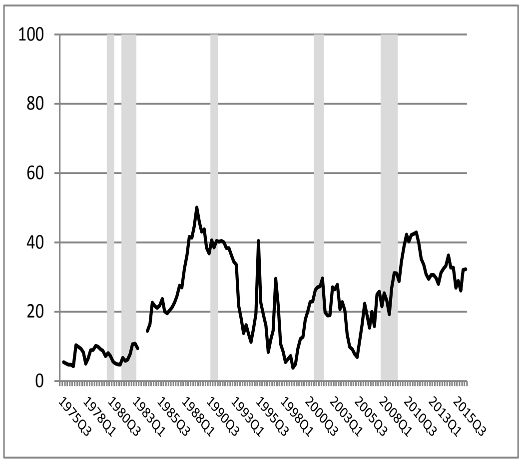
ii. from GDPD inflation shocks



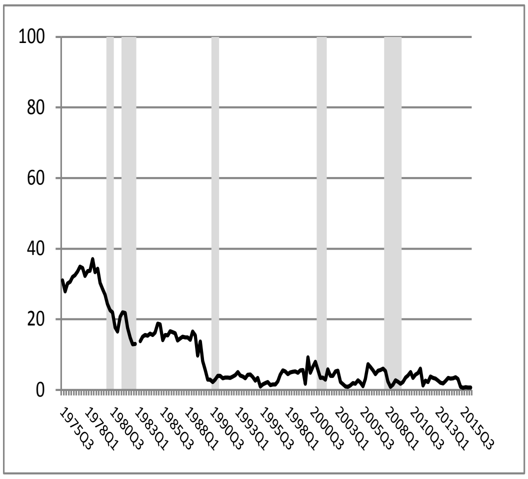
iii. from M2 velocity gap shocks



iv. from MZM velocity gap shocks



v. from oil inflation shocks



vi. from oil inflation shocks

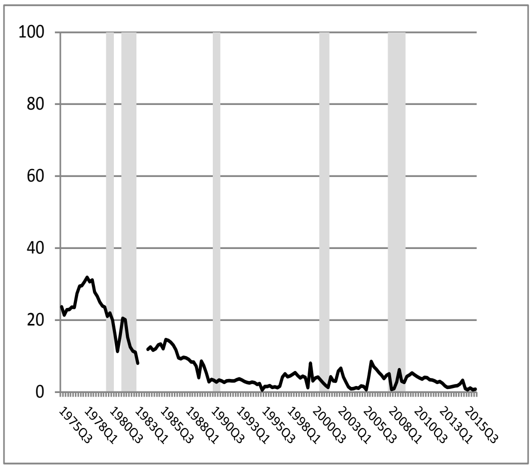
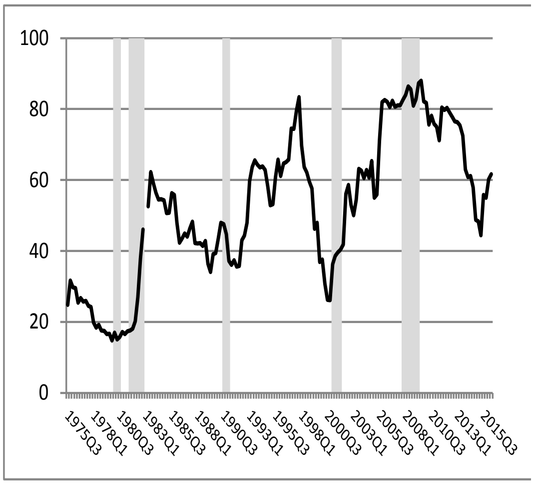
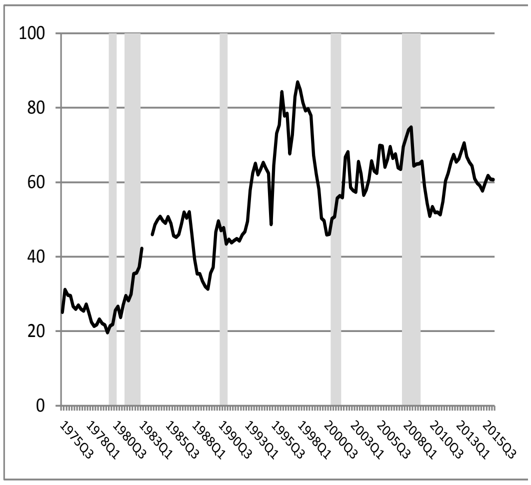


Fig. 5 (contd.) Spillover to the output gap (%)

vii. from own shocks



viii. from own shocks



The final pair of charts in Figure 5 (panels (vii) and (viii)) indicates the output gap's own-variance share trending upwards over time. Stock and Watson (2003) argue that an absence of large shocks has been part of output growth developments in recent decades. Blanchard and Simon (2001) emphasise structural changes in the economy systematically altering the propagation mechanism of shocks, which they view as not getting smaller. In other words, the economy is better able to absorb shocks and attenuate their effect on output. Whether arising from smaller shocks or an improved capacity of the economy to withstand their effects, the charts in Figure 5 point to inflation shocks and oil shocks having little influence on output since the 2007-2009 recession. Velocity gap shocks alone among the three seem to matter to output developments in recent years.

6 Conclusion

The econometric evidence presented in this article is supportive of a P-star model of inflation over a cost-push determination of price changes. The velocity gap, on average, has a greater influence on inflation over time than the output gap. Its explanatory power over both inflation and output developments is, however, sensitive to the choice of money aggregate used in the velocity gap, emphasising the relevance of how the stock of transactions balances is calculated to the establishment of a link between money, inflation and economic activity.

Looking at specific periods, the gap variables have a greater share of the inflation decomposition than oil price changes in the 1970s and early 1980s, a period often associated with events in the energy market contributing to high and variable inflation rates. The velocity gap, however, has little influence on output developments at that time, with inflation shocks and oil price shocks having a particularly high share of the output gap decomposition up to the end of the 1981-2 recession. The period after the 2007-9 recession is one where the monetary influence on inflation is high even though inflation rates are at low values. Alongside that, the gap variables' impact on oil prices is at its strongest in recent years. Overall, the results indicate monetary variables continuing to matter to price developments.

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Appendix: Robustness tests

Tests of the sensitivity of the TSI to the choices required in estimating the VAR model are reported in Figures 6, 7, 8, 9 and 10. In each figure, the solid line represents that found in the same column of Figure 2, where (a) the VAR lag length is 4, (b) the forecast horizon is 10 quarters, (c) the estimation window is 60 quarters, (d) the forecast error variance decomposition is of the orthogonalised form, and (e) there are four variables. In turn, each of these five settings is changed in turn in Figures 6, 7, 8, 9 and 10 while holding the other four unchanged.

The lag length of the VAR was allowed vary from 4 lags, to 3, 5 and 6 lags. The minimum and maximum TSI value at each window from the four lag options, 3 to 6, are then plotted in Figure 6. The TSI moves in a similar pattern for all three lines in that chart, albeit with some variation in values. Figure 7 reports minimum and maximum values where the forecast horizon varies between 8-quarters-ahead and 12-quarters-ahead. The TSI values are in a narrow range. This is reassuring as it indicates variance shares being broadly unchanging at longer forecast horizons.

In Figure 8, the rolling windows are 40 quarters, 60 quarters and 80 quarters in size. One feature of the 40-quarter rolling-window TSI series is that there are many windows where no TSI is generated. That arises when there is a lack of convergence in decomposition shares as the forecast horizon lengthens. This supports the selection of the longer, 60-quarter window (where only 1 or 3 windows out of the estimated 152 windows do not provide decompositions) over the shorter window. The differences in TSI values between the 60-quarter windows and the 80-quarter windows are relatively small. An advantage of using 60 quarters over 80 quarters for the window size is that with the latter the first TSI value is not provided until a sample period ending in 1980Q3, thus excluding the 1970s. Figure 9 shows that the TSI is not particularly sensitive to the choice of orthogonalised or generalised decompositions. Finally, in Figure 10, a comparison is made with a five variable system where the additional variable is a measure of the openness of the US economy. It is the quarterly change in a ratio, that of the sum of US exports and imports divided by US GDP (shown in panel (viii) of Figure 1). The addition of this variable does not have any noticeable effect on the pattern of the TSI over time.

Fig. 6 Total spillover index (%) – different lag lengths

i. M2 velocity as money variable ***ii. MZM velocity as money variable***

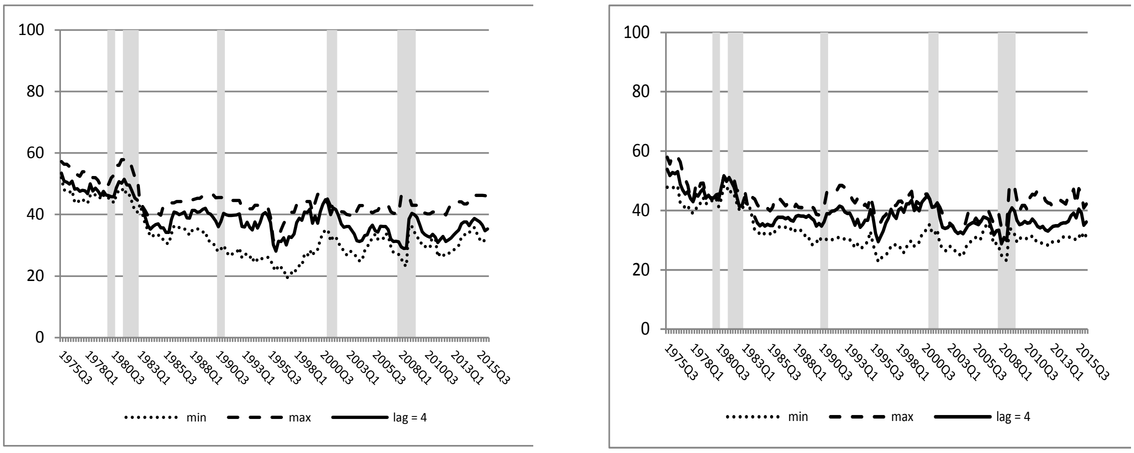


Fig. 7 Total spillover index (%) – different forecast horizons

i. M2 velocity as money variable ***ii. MZM velocity as money variable***

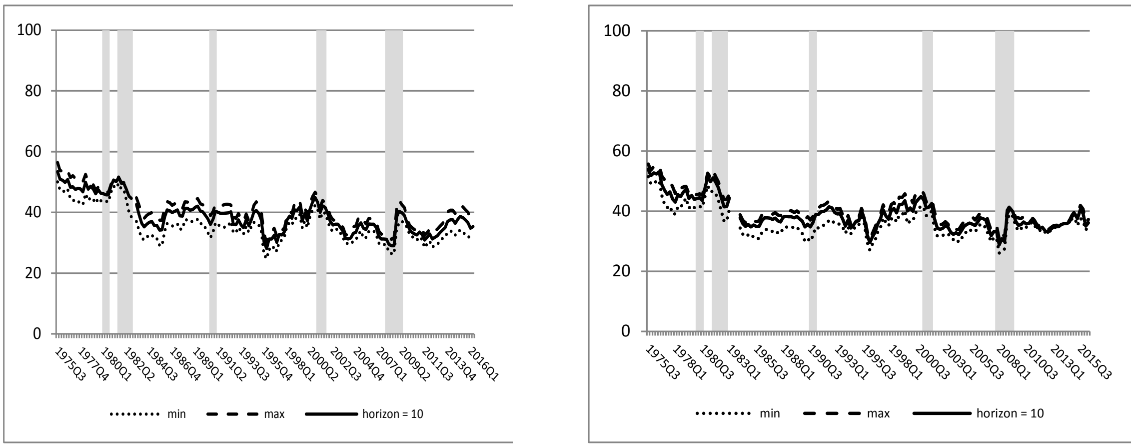


Fig. 8 Total spillover index (%) – different window sizes

i. M2 velocity as money variable ***ii. MZM velocity as money variable***

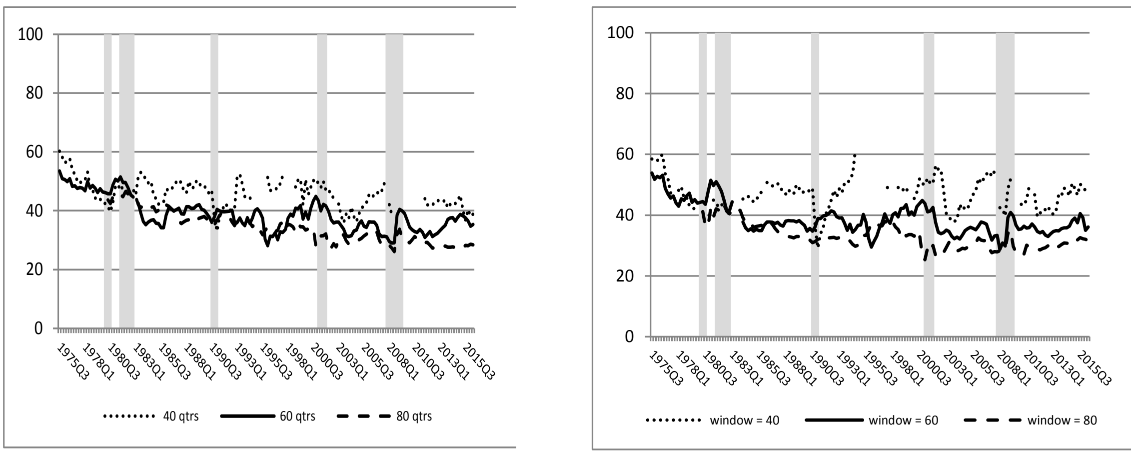
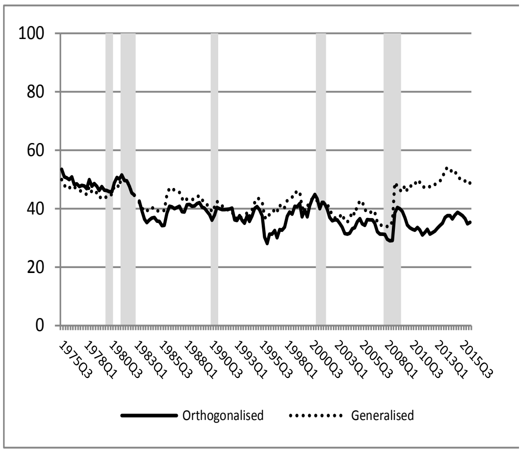


Fig. 9 Total spillover index (%) – orthogonalised vs. generalised decomposition

i. M2 velocity as money variable ***ii. MZM velocity as money variable***



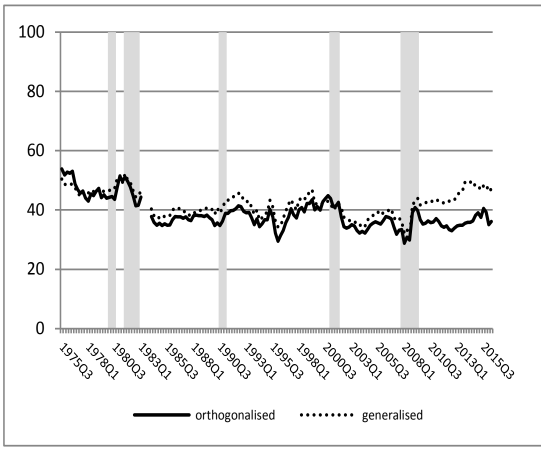
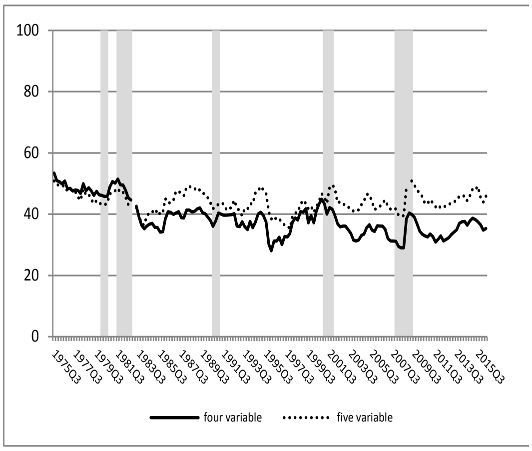


Fig. 10 Total spillover index (%) – four variable vs. five variable

i. M2 velocity as money variable



ii. MZM velocity as money variable