Global Liquidity, Money Growth and UK Inflation

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Abstract

This paper uses tools from the classical theory of inflation for UK Consumer Price Inflation from 1970Q1 to 2017Q4. In particular, we adopt augmented Phillips curve type equations within a linear and regime-switching framework where regimes are governed by previous inflation rates. Our non-linear models show that a monetary explanation of inflation is prominent during periods of high inflation. However our models imply that during periods of high inflation, The Bank of England should monitor monetary conditions in conjunction with monetary policy stance; as these can help dampen inflation persistence.

Keywords: Global Liquidity, Inflation, Divisia Money, Non-linear Model.

JEL Codes: C5, E5.

1. Introduction

The recent global financial crisis witnessed a detrimental shock to liquidity and credit conditions followed by a somewhat staggered recovery. In response to the financial turmoil, monetary policy-makers in major economies pursued an unprecedented path of interest rate cuts and repeated rounds of asset purchase facilities involving, predominantly, the purchase of long-term government bonds and other related assets (more commonly known as quantitative easing, QE). Preconditions for this global phenomenon, as observed by Goodhart and Hofmann (2008), consisted of inflated asset prices, surging money growth rates and low capital market yields; implying that asset markets were "awash with liquidity".

Common to other developed countries, the UK's experience of the financial trauma comprised of a prolonged recession followed by a fragile recovery. The UK's response to the financial crisis saw the government attempt to stimulate the property sector through schemes such as 'help to buy' (HTB) which provides equity loans of up to 20% of a property's value (on properties up to the value of £600,000) given the buyer has 5% of the value of the property as a deposit (with the remaining 75% requiring a mortgage). This is consistent with the view–alluded to by Bank of England (BoE) Governor Mark Carney in the June 2014 Financial Stability Report press conference–that historically recessions preceded by a property bust are more severe than those without[1].

In parallel with this, the UK's monetary policy response consisted of successive interest rate cuts which froze at 0.5% on March 5th 2009, and was lowered to 0.25% on August 4th 2016, following the UK's decision to leave the EU[2]. These rate cuts were implemented in tandem with three rounds of QE from March 2009–July 2012, and an additional round in August 2016 summing to £435bn. QE is thought

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[1]The UK housing market is thought to affect the economy through three channels: domestic demand (documented in the BoE's November 2013 Inflation Report as having prospects for medium term inflationary pressure); financial stability and debt levels and resource allocation.

[2]Subsequently the Bank rate was raised to 0.5% in 2017Q4.

to work via three main channels: the macro-policy/news channel; the signalling channel and the portfolio rebalancing channel (for a critical analysis see e.g. Martin and Milas (2012)). However, during the first round of QE, M4 growth (the usual monetary aggregate monitored by the Monetary Policy Committee) did not pick up. Yet, Divisia money did, thus raising the question as to what measure of money matters for inflation. Divisia money assigns weights to the component assets of M4 in accordance to their liquidity, such that those bearing higher interest payments (thought to be less useful for transaction purposes) are allocated a lower weight. With this in mind, Hancock (2005) argue that compared with M4, Divisia money has a closer relationship to expenditure[3].

A monetary explanation of inflation requires a classical approach toward inflation. The classical theory of inflation links the aggregate price level to the interactions of demand for and supply of money. This characterises inflation towards its appropriate definition; an erosion of the purchasing power of money. Our approach, however, utilises the classical theory alongside standard Phillips curve equations that attribute current inflation to expected inflation and the output gap. Another novelty in our approach is the inclusion of global money movements. It is reasonable to assume the UK is an open economy that is receptive to fluctuations in international capital flows and more integrated financial markets. As noted in Giese and Tuxen (2007), the integration of financial markets and fluctuations in the money supply of one country has the potential to be absorbed by demand elsewhere. More importantly, contemporaneous shifts in the money supply of major economies could result in spill-over effects into domestic rates of inflation. Furthermore, global aggregates are thought to embody cross-country movements in money aggregates as a result of capital flows between different regions. This can hinder dissemination of the link between inflation, money and output (Sousa and Zaghini, 2008). Belke et al. (2010) argue that domestic money aggregates/national liquidity have become more difficult to interpret due to the vast increase in volume of international capital flows. To the best of our knowledge, there are no studies examining (simultaneously) global and domestic liquidity effects onto a nation's inflationary dynamics.

The main contribution of this paper looks to offer a "classical" explanation of UK CPI inflation dynamics from 1970Q1-2017Q4[4]. We show that house prices exhibit wealth effects on the demand for money based upon the theoretical arguments in Friedman (1988) and Setzer and Greiber (2007) whilst also adding an international dimension to our approach by constructing proxies of global liquidity. Our approach combines the classical theory of inflation with traditional Phillips curve analysis by specifying models that allow inflation to be affected by spare capacity, oil prices, domestic and global liquidity conditions, and monetary policy stance. We model inflation using both linear, and regime-switching models where regimes are dictated by previous inflation rates. We employ non-linear models to allow for asymmetric adjustment of inflation, domestic and global liquidity, oil price growth, and spare capacity. This distinguishes our paper from previous UK inflation studies, namely Osborn and Sensier (2009) who consider regime-switching with respect to a time trend and past inflation (RPIX) and Milas (2009) who considers regime-switching with respect to M4 growth without allowing for the effects of the property sector and international liquidity effects.

[3]There are various theoretical motivations for the use of Divisia aggregates. For surveys advocating their attractiveness; see e.g. Barnett (1980); Belongia and Binner (2000); Drake and Mills (2005).

[4]We focus on the CPI measure of inflation because this is targeted (the target is 2%) by the Bank of England's Monetary Policy Committee (MPC). Other popular measures, such as the Retail Price Index (RPI), have also been used in the literature (and indeed in a previous version of our paper). Recently, however, Bank of England Governor Mark Carney has called to switching altogether the focus away from RPI on the grounds that they were known errors in its calculation by the Office for National Statistics (ONS); see `https://news.sky.com/story/carney-calls-for-govt-to-stop-using-discredited-rpi-inflation-measure-11229756`. This point has been repeatedly made by Economics Editor of The Financial Times Chris Giles who discussed in detail errors in the RPI formula (see `https://www.ft.com/content/b71eabae-6c7f-11e7-bfeb-33fe0c5b7eaa`). In March 2018, the ONS itself published a detailed note on the RPI shortcomings (`https://www.ons.gov.uk/economy/inflationandpriceindices/articles/shortcomingsoftheretailpricesindexasameasureofinflation/2018-03-08`).

Our results are summarised as follows: First, we find evidence that global liquidity yields inflationary pressures in the UK over and above the impact of domestic monetary conditions and spare capacity. Second, the demand for money is positively influenced by the property sector. Third, we find that when previous inflation rates are less than 3%, inflation is well specified by a standard Phillips curve augmented with global liquidity effects. Yet, when inflation surpasses this threshold, domestic monetary effects become prominent. We find that our conclusions are consistent across models using M4 and Divisia monetary aggregates and also reveal that are results are not driven by the zero lower bound.

Our estimated thresholds are consistent with the upper bound, of more than 1% above the inflation target, that requires the Governor of the Bank of England to write a letter to the Chancellor of the Exchequer explaining why inflation is too high[5]. Our models imply that during periods of high inflation, policymakers should utilise monetary policy, and indeed monitor monetary conditions. Specifically, monitoring monetary conditions through the growth of the money supply–as well as money demand conditions–could dampen inflationary pressures over the short-term. Over the medium-term, our models suggest that tightening monetary policy will hinder further inflationary pressures. With, at the time of writing, current CPI inflation (in 2018Q1) at 2.7%, our results indicate an imminent risk of the UK entering a high inflation regime. Having said this, in this very regime, a combination of monitoring money supply movements over the short term, and tightening monetary policy could aid the Bank of England in bringing inflation back to target. In light of substantial policy uncertainty surrounding Brexit negotiations weakening UK Sterling, and in turn, pushing up import prices, it should not come as a surprise if the Bank of England tightens monetary policy stance over the next two years at an increasing pace.

The rest of this paper is organised as follows. Section 2 provides a brief description of the data, money demand equations and global liquidity. Section 3 gives a discussion of the econometric methodology. Section 4 reports our empirical findings. Finally, section 5 provides a summary, discusses policy implications and outlines potential avenues for future research.

2. Data Description, Global Liquidity and the Demand for Money

2.1. Economic Data

We use quarterly economic data over the period 1970Q1 to 2017Q4 in our study. We obtain the Consumer Price Index from the Office for National Statistics' (ONS) database, spliced with the consumer price index provided by the Bank of England in their *Millennium of Macroeconomic Data* database. We use the Office for Budget Responsibility's (OBR) output gap measure as our proxy of spare capacity. We construct a break adjusted M4/M4ex series that splices conventional M4 with M4 excluding other financial corporations (OFCs); this is the preferred measure of the UK's broad money aggregate by the Bank of England, and data is obtained from the Bank of England's statistics database.

As an indicator of monetary policy stance, we obtain the Bank rate from the Bank of England. To overcome issues with the interest being at the zero lower bound, we use a shadow interest rate of the UK Bank Rate proposed in Wu and Xia (2016)[6]. This is estimated from an affine term structure model and allows the interest rate to cross the zero lower bound thereby providing further indication of monetary policy stance. We address this issue in Section 3.3. As a final control variable reflecting supply-side considerations, we obtain oil prices from the Federal Reserve Bank of St. Louis, converted into UK Sterling to account for oil price changes in our models.

[5]A letter must be written by the Governor of the Bank of England to the Chancellor of the Exchequer if inflation surpasses the target of 2% by more than +/-1%

[6]The Shadow Bank Rate is used in Ellington (2018) to assess the consequences of the zero lower bound in a time-varying parameter VAR model using UK data.

Figure 1 plots our economic data. All data are constructed as annual percentage growth rates; interest rates are left untransformed.

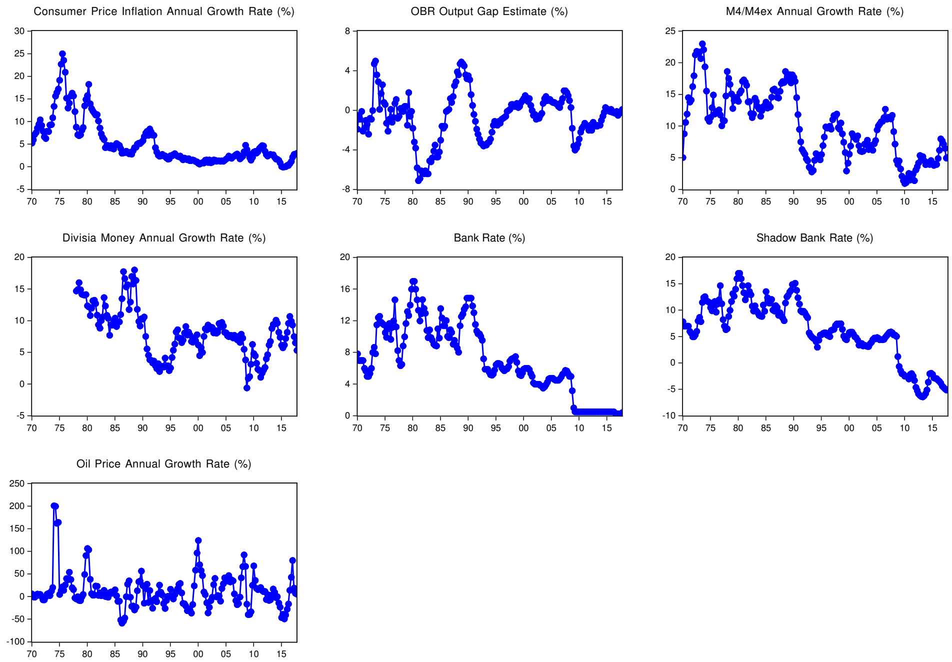

Figure 1: Economic data from 1970Q1-2017Q4
Notes: This figure plots the annual growth rates of economic data on CPI inflation, the OBR output gap estimate, Broad and Divisia money growth rates, the Bank Rate and Shadow Bank Rate, and Oil price growth.

2.2. Global Liquidity

To proxy global liquidity, we use two measures. The first is the US M2 broad money stock from the Federal Reserve Bank of St. Louis; converted into UK Sterling. Our second measure is the US Divisia M2 series (Barnett et al., 2013) available from the Centre for Financial Stability, also converted into UK Sterling[7]. Figure 2 plots the annual growth rate of our global liquidity proxies. As we can see, both series move extremely closely to one another and have a positive and significant correlation of 0.97.

2.3. Money Demand

Bernanke and Blinder (1988) characterise the "Achilles heel of Monetarism" as ambiguities in the stability of the money demand function. Conventional specifications for the UK such as Haldrup (1994) only amplify this issue. However, a stable money demand function implies that inflation targeting nations to extract information regarding both medium, and long-term price stability. Friedman (1988) and Setzer and Greiber (2007) offer theoretical underpinnings and motivate including other assets within the money demand function[8]. It is also well-known that an economy's housing market represents major assets within households' portfolios, from which direct utility is derived. Dreger and Wolters (2010) and Dreger and

[7]Using US data to add an international dimension to studies is implemented in Florackis et al. (2014). We also feel that this is the simplest, and most economically meaningful approach to take; whilst also maintaining consistency between our models. This, coupled with the fact that Divisia series are not made publicly available by the Euro Area or other advanced nations.

[8]There is no premise on the sign that these variables should influence the demand for money. The observed sign upon estimation indicates the net effect. If the sign is positive, it is a scale variable like income. If the sign is negative, it is an opportunity cost to holding money.

Wolters (2014) use these underpinnings to include housing variables with money demand equations for the Euro Area and show that housing enters the money demand function as a scale variable.

Our money disequilibrium terms are obtained from the Engle and Granger (1987) long-run regressions:

$$\text{diseq}_t^{\text{M4}} = (\text{m-p})_t + 16.43 - 1.97\text{y}_t + 0.01\text{R}_t - 0.07\text{h}_t \quad (1)$$

$$\text{diseq}_t^{\text{DM}} = (\text{m-p})_t + 15.34 - 1.25\text{y}_t + 0.01\text{R}_t - 0.25\text{h}_t \quad (2)$$

where $\text{diseq}_t^{\text{M4}}$, $\text{diseq}_t^{\text{DM}}$ denote the money disequilibrium terms using M4/M4ex and Divisia money respectively. $(\text{m-p})_t$ is the log-level of real money balances; y_t is the log-level of real GDP; R_t is the 10-year government bond yield; and h_t is the log-level of real house prices[9].

As we can see, GDP and interest rates enter the money demand equation with their expected theoretical signs. Note that the coefficient associated to GDP far exceeds the theoretical value of 1. This is an empirical phenomenon using UK data and is also found by Milas (2009). Real house prices enter UK money demand equations with a positive sign, and are therefore scale variables; consistent with Dreger and Wolters (2014).

Figure 3 plots our money disequilibrium terms. It is clear that both series fluctuate above and below 0 frequently. This suggest that money demand exhibits mean reversion over the medium term. Positive (negative) deviations indicate too much (little) liquidity within the economy, possibly providing inflationary (disinflationary) pressures.

Notice that the series move closely together until late 2010 where the Divisia money disequilibrium is persistently postive until the end of our sample; whereas the M4/M4ex disequilibrium is fluctuating just below its equilbrium value. This divergence coincides with the QE policies implemented by the UK. It is our conjecture that these stark differences arise from the ability of the Divisia index to capture purely internal substitution effects among the component assets of money Barnett and Chauvet (2011). We argue that what we are observing is the so called “portfolio rebalancing” effect associated to QE; for an explanation see Martin and Milas (2012). Taken together, this implies that the Bank of England’s decision to implement QE policies in response to the financial crisis in 2008-2009 are having their desired effects by stimulating the demand for money, and in turn, hindering the contractionary effects of the Great Recession. This observation is consistent with the findings of Kapetanios et al. (2012) who show that in the absence of the first round of QE, UK GDP would have been around a percentage point lower.

Table 1 reports a trio of stationarity tests on the residuals of our money disequilbria. Following Arghyrou et al. (2005), Martin and Milas (2004), and Martin and Milas (2010), we implement three tests with different null hypotheses. As advocated in Kwiatkowski et al. (1992) it is essential to subject series to an array of stationarity tests with different null hypotheses in order to deduce the order of integration. Table 1 reports results from the EGS test of Elliott et al. (1996), the KPSS test of Kwiatkowski et al. (1992), and the ERS point optimal test of Elliott et al. (1996). The EGS and ERS test statistics have a null hypothesis that the series has a unit root, and the KPSS test has the null hypothesis that the series is stationary.

For the M4/M4ex disequilbrium, both the EGS and ERS tests reject the null of a unit root at lags 4 and 6 at conventional leves (i.e. 5%). Similarly the KPSS tests are unable to reject the null that the series are stationary. However, ambiguities arise around the EGS and ERS test statistics for our Divisia money disequilbrium. As a form of robustness, we implement the Johansen (1988) and Johansen (1995) methodology. Both VAR models support evidence of cointegration, at conventional values, in favour of one cointegrating vector[10]. Therefore, on the premise that there is at least weak evidence in favour

[9]Nominal house prices available from Nationwide are deflated by the Consumer Price Index.
[10]For the sake of brevity, we refrain from reporting these results; they are available on request.

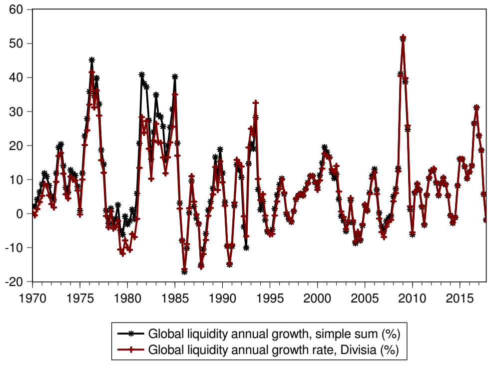

Figure 2: Global liquidity annual growth from 1970Q1-2017Q4
Notes: This figure plots the annual growth rate of our global liquidity measures. These are proxied by US M2 and US Divisia M2 converted into UK Sterling.

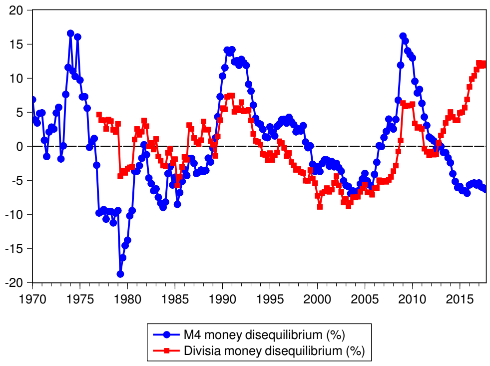

Figure 3: UK Money Disequilibria from 1970Q1-2017Q4
Notes: This figure plots UK money disequilibria terms that are constructed as the residuals from Engle and Granger (1987) long-run regressions, multiplied by 100, where (log) real money balances are regressed on (log) real GDP, 10-year government bond yields, and (log) real house prices. Money is proxied by a break adjusted M4/M4ex series (blue line) and by Divisia money for private non-financial corporations (red line).

of a stable money demand function, we treat our money disequilibrium terms as stationary or at least proceed under the working (and testable) assumption that some regime-switching form of stationarity exists; we explore this in the context of the non-linear models reported in Section 3.

Table 1: Stationarity Tests for Money Disequilibria

	M4/M4ex	Divisia
	Sample:	
	1970Q1-2017Q4	1977Q1-2017Q4
EGS, H_0 : Series has a unit root.		
Critical values: 10%=-1.61, 5%=-1.94, 1%=-2.58		
lag=0	-1.49	-1.21
2	-1.63*	-1.50
4	-2.14**	-1.63*
6	-2.16**	-1.26
KPSS, H_0 : Series is stationary.		
Critical values: 10%=0.347, 5%=0.467, 1%=0.739		
	0.08	0.21
ERS, H_0 : Series has a unit root.		
Critical values: 10%=4.31, 5%=3.16, 1%=1.91		
lag=0	5.83	7.17
2	4.62	4.67
4	2.29**	3.30**
6	1.94**	5.24

Notes: This table reports a battery of stationarity tests for the money disequilibrium constructions. EGS is a test developed by Elliott et al. (1996). This test implements generalised least squares detrending before running the ADF test regression. KPSS is the LM-type test in of Kwiatkowski et al. (1992). ERS, as in Elliott et al. (1996), is a point optimal test working from quasi-differenced data before running two test regressions. The test statistic is computed as the difference between sum of squared residuals scaled by an estimator of the residual spectrum at frequency zero. *, **, and *** indicate rejection of the null hypothesis at 10%, 5%, and 1% levels respectively.

3. Modelling Inflation Dynamics

3.1. Empirical Methodology

Our analysis begins with linear models specified as:

$$\pi_t = \beta_0 + \beta_i^{'} X_{t-l} + \nu_t \tag{3}$$

where π_t is the annual rate of CPI inflation, X_{t-l} is a vector of control variables including lagged inflation, the OBR output gap estimate, money growth (either M4/M4ex or Divisia), the Bank of England Bank Rate, global liquidity (either simple sum or Divisia), oil price changes, and a money disequilibrium estimate. $\beta_i^{'}$ denotes the coefficient associated to i^{th} control variable[11].

[11] To capture expectations of inflation in our model we also relied on the Bank of England's CPI inflation forecasts (average inflation assuming constant interest rates) one and four quarters ahead (available from successive Inflation Reports). Forecasts for CPI inflation measures are only available from 2004 onwards. Prior to 2004 (i.e. from 1993 to 2003), inflation forecasts are for RPIX inflation. This both reduces our sample size considerably, and also means we model CPI inflation, based on RPIX inflation forecasts. In using these forecasts, we estimate both linear and non-linear models of CPI inflation. Doing so resulted in qualitatively similar results and consistent conclusions to the ones we report.

Upon rejection of parameter constancy in favour of smooth parameter evolution, we consider non-linear models that allows for asymmetric adjustment to a 'transition' variable. More specifically, inflation follows a regime switching process of the form:

$$\pi_t = \beta_0 + \left(\beta_{i,1}^{'} X_{t-l}\right) \alpha_{t-l}^{\delta} + \left(\beta_{i,2}^{'} X_{t-l}\right) \left(1 - \alpha_{t-l}^{\delta}\right) + \eta_t \tag{4}$$

$$\alpha_{t-l}^{\delta} = 1 - \left[1 + \exp\{-\gamma(\delta_{t-l} - \tau)/\hat{\sigma}_{t-l}^{\delta}\}\right]^{-1} \tag{5}$$

where $\alpha_{t-l}^{\delta} \in [0\ ,\ 1]$ is the logistic function as in van Dijk et al. (2002). When $\delta_{t-l} < \tau$, $\alpha_{t-l}^{\delta} \to 1$ such that the inflationary impact is given by $\beta_{i,1}^{'}$. Similarly when $\delta_{t-l} > \tau$, $\alpha_{t-l}^{\delta} \to 0$ and the inflationary impact is given by $\beta_{i,2}^{'}$. The parameter γ ($\gamma > 0$), determines how sharp the transition from one regime to another is, and is made scale free by dividing by the standard deviation of the transition variable, $\hat{\sigma}_{t-l}^{\delta}$. X_{t-l} are the same regressors as in the linear specification. δ_{t-l} is the transition variable, and η_t is an error term.

This model allows us to assess the impact of spare capacity, domestic and global monetary conditions, oil prices and monetary policy stance during a 'low' and 'high' regime. We allow regimes to be defined by previous inflation rates, so this model can be thought of as a self exciting smooth tranisition autoregression (SESTAR)[12].

In general, our models might be thought of as augmented Phillips curve type equations. In particular, our non-linear models allow for asymmetric adjustment of parameters based on observable variables. The benefit of our SESTAR models is that they can be used to predict future regimes, whilst also providing an idea of how sharp the transition is. This implies that policymakers are able to concentrate on variables conditional on the regime the process is in. Building on this, the speed of transition informs policymakers on how quick they should change their policy strategies; if any.

3.2. Results

In Table 2, we report four specifications of linear models in (3). Models i) and ii) report linear models of CPI inflation using M4/M4ex, and models iii) and iv) report linear models of CPI inflation using Divisia money. In models i) and iii) we include 6 dummies to account for Value-Added-Tax (VAT) changes in the UK throughout our estimation sample. This helps us capture additional supply-side factors that may influence inflation[13]. Models ii) and iv) are analogous to models i) and iii) respectively, but do not include VAT dummies. The lag length of each control variable is chosen to achieve significance (or at least near significance). For instance, a lag length of eight for the Bank rate is consistent with the notion that monetary policy can take up to two years to affect inflation.

Across all models, inflation is highly persistent with coefficients of at least 0.94 across all models[14]. Specifications using M4/M4ex report insignificant coefficients for the output gap which contrasts our linear specifications using Divisia money. Money growth is significant at 1% with a coefficient of around 0.09 when using M4/M4ex, and coefficients of around 0.04 for our Divisia specifications; For the latter, money growth is significant at a 10% level.

[12]We tested for, and estimated models that allow inflation to be governed by domestic money growth as in Milas (2009); money disequilibrium; and interest rates. We abstain from reporting these models as regimes were not well defined, with the majority of observations falling in only one regime.

[13]Specifically, in 1973 purchase tax was replaced by a VAT rate of 10%. In June 1974 VAT was reduced from 10% to 8%. Then, in June 1979 VAT was increased from 8% to 15%. Norman Lamont further increased VAT to 17.5% in 1991. VAT remained at this level until December 2008 when it was reduced to 15%. There were two further increases in VAT following the Great Recession to 17.5% and 20% in January 2010 and January 2011 respectively. We thank an anonymous reviewer for this comment. As an extra source of robustness, we also estimate models using VAT levels in the UK yet find no significance for this variable.

[14]Removing inflation from these regressions produces $\bar{R}^2$ values of at least 0.47 for all estimated models. This suggests that our information set does contain information regarding UK inflation dynamics.

Table 2: Linear models of UK Inflation

$$\pi_t \quad = \quad \beta_0 + \beta_\pi \pi_{t-1} + \beta_{\text{gap}}\text{gap}_{t-1} + \beta_M \text{M}_{t-2} + \beta_{\text{oil}}\text{oil}_{t-1} + \beta_{\text{i}}\text{i}_{t-8} + \beta_{\text{G}}\text{G}_{t-8} + \beta_{\text{diseq}}\text{diseq}_{t-3} + \nu_t$$

where π_t is CPI inflation; gap_{t-1} is the OBR output gap estimate; M_{t-2} is a measure of domestic money growth; oil_t is the annual growth rate of oil prices; i_{t-8} is the Bank rate; G_{t-8} is a measure of global liquidity (for M4/M4ex specifications this is US M2 growth, and for Divisia money specifications, this is US Divisia M2 growth); and diseq_{t-3} is a money disequilibrium construction consistent with the measure of domestic money growth used in each regression.

	Sample: 1972Q1-2017Q4		1978Q3-2017Q4	
Money Measure:	M4/M4ex		Divisia	
	i)	ii)	iii)	iv)
β_0	-0.21(0.14)	-0.17(0.14)	-0.11(0.13)	-0.09(0.13)
β_π	0.94(0.05)***	0.94(0.05)***	0.99(0.06)***	0.99(0.05)***
β_{gap}	0.04(0.05)	0.03(0.05)	0.11(0.04)***	0.10(0.03)***
β_{M}	0.09(0.03)***	0.08(0.03)***	0.03(0.02)	0.04(0.03)*
β_{oil}	0.006(0.002)***	0.005(0.002)**	0.002(0.002)	0.002(0.002)
β_{i}	-0.07(0.02)***	-0.07(0.02)***	-0.02(0.02)	-0.03(0.02)
β_{G}	0.008(0.006)	0.008(0.006)	0.007(0.005)	0.007(0.005)
β_{diseq}	0.03(0.02)	0.03(0.02)	0.02(0.01)	0.02(0.01)*
VAT Dummies	yes	no	yes	no
$\bar{R}^2$	0.960	0.960	0.949	0.948
AIC	2.94	2.90	2.33	2.32
Stability F-stat	2.58***	3.04***	7.74***	4.86***
VAT dummies F-stat	110.67***	-	46.47***	-

Notes: This table reports linear models of UK CPI inflation from 1972Q1-2017Q4 for models using M4/M4ex, and 1978Q3-2017Q4 for models using Divisia money. In parantheses are Newey-West Heteroskedasticity and autocorrelation consistent standard errors. *, **, and *** indicate statistical significance of coefficient estimates at 10%, 5%, and 1% levels respectively. $\bar{R}^2$ denotes the adjusted R-squared of the regression and AIC is the Akaike Information Criterion. Stability F-stat is a test for parameter stability proposed by Lin and Teräsvirta (1994) that tests the statistical significance of the cross product of regressors with 1) a time trend, 2) a quadratic trend, and 3) a cubic trend. VAT dummies F-stat is an F test that tests the joint significance of the VAT dummies within the regressions of model i) and iii).

We find coefficients of similar magnitudes for oil price growth and the Bank rate across all models. However, these coefficients are only significant within models using M4/M4ex growth. It is noteworthy to mention that the economic significance of oil prices is negligible. Similarly the coefficients associated to global liquidity and our money disequilibrium constructions are qualitatively similar across models, yet statistically insignificant. Furthermore, note that our F-tests for the joint significance of VAT dummies is rejected which indicates supply side factors captured by VAT changes influence inflation dynamics.

On the whole, our linear models of inflation indicate that movements in domestic monetary conditions exert both a statistically and economically significant impact on CPI inflation; thereby pointing toward a monetary explanation of inflation dynamics. For instance, a 5 percentage point increase in M4/M4ex money growth implies inflation increases by 0.45 percentage points. In general these models suggest that money matters for inflation over and above controlling for: demand side factors, supply side factors (i.e. oil price and VAT changes), and indeed monetary policy stance.

However, all models reject the null hypothesis of constant parameters, in favour of smooth parameter evolution. The implication of parameter instability suggests that adequate policy recommendations cannot be made. Therefore, we proceed by estimating SESTAR models of inflation. We follow the procedure in Eitrheim and Teräsvirta (1996) and van van Dijk et al. (2002) to set the lag length of the transition variable, as well as form of the transition function. Inflation is our transition variable and tests favoured a lag length of 6. For the sake of brevity, we do not report these results, however they are available on request.

In Table 3, we report SESTAR models of inflation as in (4) and (5); one model using M4/M4ex, and one using Divisia. Note that both models endogenously determine statistically significant threshold values of around 3%. Therefore, our model captures periods of high and low inflation. Our model using M4/M4ex shows that when inflation is below 3%, the dynamics are governed by past inflation, global liquidity movements, and (regime independent)oil prices. Note also that in the low regime, inflation persistence is substantially lower than in the high regime. This suggests that inflation has the potential to overshoot the target (of 2%) much more often than undershooting. However, when UK inflation surpasses the threshold of 3%, there is a gradual transition to the high inflation regime (γ=5.41). In this regime, domestic liquidity conditions and monetary policy stance start to dominate inflation dynamics. More specifically, the inflationary impact of a 5% increase in M4/M4ex money growth yields a 0.45 percentage point increase to inflation.

Turning our attention to our model using Divisia, when inflation is lower than 3.33%, inflation is given by past inflation, oil price changes, the output gap, and global liquidity. Once CPI inflation exceed 3.33%, the transition to the high inflation regime is sharp with γ=200 (imposed)[15]. Again, in the high inflation regime, domestic monetary conditions captured by Divisia money growth and the Divisia money disequilibrium ($\beta_{2,\mathrm{M}}$=0.12 and $\beta_{2,\mathrm{diseq}}$=0.11, both are statistically significant) and monetary policy stance (a statistically significant $\beta_{2,\mathrm{i}}$=-0.09) govern inflation dynamics.

Note also that we are unable to reject the null hypothesis that parameters are constant throughtout time. Adding to this, we conduct an F-test with the null hypothesis that the parameters in each respective regime are equal to one another. This type of test is used in Arghyrou et al. (2005) to deduce whether the model simplifies to the linear specification. As both models reject the null, at 1% and 10% levels respectively, we provide further evidence against modelling inflation using linear models.

In general, our SESTAR models deduce that UK inflation follows a regime switching process governed by past values of inflation. In particular, when inflation is in the low regime, the process is dictated by a modified Phillips curve augmented by oil price growth and global liquidity conditions. During

[15]We initially estimated γ at around 210. Our results and conclusions are not sensitive to estimating the value, with estimates of around 210. We then ran a grid search on values of $\gamma \in [0,\ 250]$.

Table 3: Self Exciting Smooth Transition Autoregressive (SESTAR) models of UK Inflation

	Sample:	
	1972Q1-2017Q4	1978Q3-2017Q4
Money Measure:	M4/M4ex	Divisia
β_0	0.17(0.21)	0.07(0.10)
β_π		0.96(0.04)***
β_{oil}	0.006(0.003)**	0.002(0.002)
β_{gap}		0.07(0.02)***
Regime when	π_{t-6} <3.02%	π_{t-6} <3.33%
$\beta_{1,\pi}$	0.77(0.09)***	
$\beta_{1,\text{G}}$	0.02(0.01)*	0.001(0.004)
Regime when	π_{t-6} >3.02%	π_{t-6} >3.33%
$\beta_{2,\pi}$	0.92(0.05)***	
$\beta_{2,\text{gap}}$	0.08(0.08)	
$\beta_{2,\text{M}}$	0.09(0.04)**	0.12(0.05)**
$\beta_{2,\text{i}}$	-0.08(0.04)*	-0.09(0.04)**
$\beta_{2,\text{diseq}}$	0.03(0.03)	0.11(0.05)**
γ	5.41(2.92)*	200 (–)
τ	3.02(0.73)***	3.33(0.13)***
VAT dummies	Yes	Yes
$\bar{R}$	0.961	0.954
AIC	2.93	2.23
Stability F-stat	1.14	1.57
Linear F-stat	225.7***	1.99*

Notes: This table reports SESTAR models of UK CPI inflation from 1972Q1-2017Q4 for the model using M4/M4ex, and 1978Q3-2017Q4 for the model using Divisia money. In parantheses are Newey-West Heteroskedasticity and autocorrelation consistent standard errors. *, **, and *** indicate statistical significance of coefficient estimates at 10%, 5%, and 1% levels respectively. $\bar{R}^2$ denotes the adjusted R-squared of the regression and AIC is the Akaike Information Criterion. Stability F-stat is a test for parameter stability proposed by Lin and Teräsvirta (1994) that tests the statistical significance of the cross product of regressors with a time trend. Linear F-stat is an F-test of the null hypothesis that the model can be simplified to a linear specification.

persistently high periods of inflation, domestic monetary policy stance and monetary conditions take over.

Interestingly, our estimated thresholds are consistent with the upper bound, of more than 1% above the inflation target, that requires the Governor of the Bank of England to write a letter to the Chancellor of the Exchequer explaining why inflation is too high. Therefore, our models imply that during periods of high inflation, policymakers should utilise monetary policy, and indeed monitor monetary conditions. Specifically, monitoring monetary conditions through the growth of the money supply–as well as money demand conditions–could dampen inflationary pressures over the short-term. Over the medium-term, our models suggest that tightening monetary policy will hinder further inflationary pressures.

To illustrate the impact of monetary conditions and monetary policy stance throughout time, we plot the regime switching impact of M4/M4ex money growth, the M4/M4ex money disequilibrium, and the Bank rate from our SESTAR model of inflation in Figure 4. We can see that during the 1970s and 1980s, the impact of domestic money conditions had a persistent impact on CPI inflation. Then, during the Great Moderation, monetary conditions, and indeed monetary policy stance, had no influence on inflation as this was a period of time where inflation was around its target of 2%.

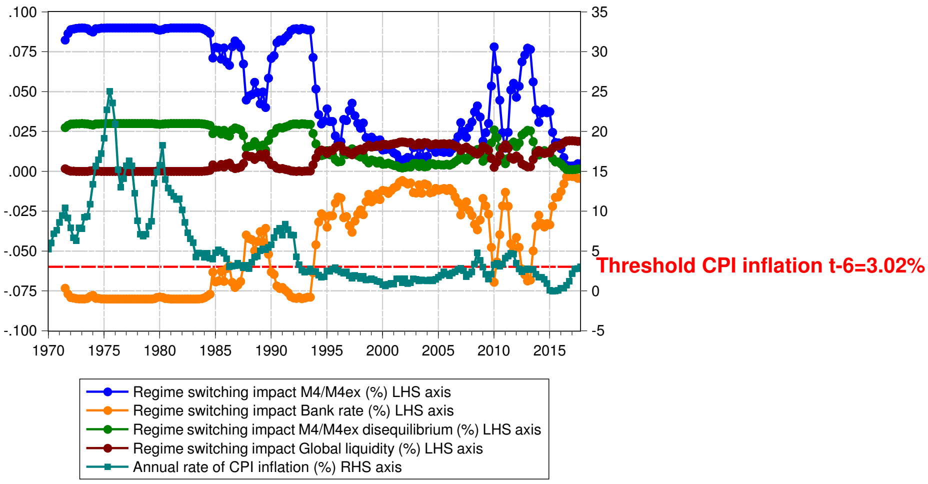

Figure 4: Regime Switching Impact of M4/M4ex growth, the M4/M4ex money disequilibrium, the Bank rate, and Global liquidity from 1972Q1-2017Q4

Notes: This figure plots the regime switching impact of monetary conditions and monetary policy stance for UK inflation from 1972Q1-2017Q4. The regime switching impact of M4/M4ex money growth is calculated as $\beta_{1,\mathrm{M}}\alpha^{\pi}_{t-6} + \beta_{2,\mathrm{M}}\alpha^{\pi}_{t-6}$ with $\beta_{1,\mathrm{M}}$=0 (imposed), $\beta_{2,\mathrm{M}}$=0.09. The regime switching impact of the money disequilibrium term is given by $\beta_{1,\mathrm{diseq}}\alpha^{\pi}_{t-6} + \beta_{2,\mathrm{diseq}}\alpha^{\pi}_{t-6}$ with $\beta_{1,\mathrm{diseq}}$=0 (imposed), $\beta_{2,\mathrm{diseq}}$=0.03. The regime switching impact of the Bank rate is given by $\beta_{1,\mathrm{i}}\alpha^{\pi}_{t-6} + \beta_{2,\mathrm{i}}\alpha^{\pi}_{t-6}$ with $\beta_{1,\mathrm{i}}$=0 (imposed), $\beta_{2,\mathrm{i}}$=-0.08. The regime switching impact of global liquidity is given by $\beta_{1,\mathrm{G}}\alpha^{\pi}_{t-6} + \beta_{2,\mathrm{G}}\alpha^{\pi}_{t-6}$ with $\beta_{1,\mathrm{G}}$=0.02, $\beta_{2,\mathrm{G}}$=0 (imposed). The threshold τ=3.02% and the speed of transition from one regime to the other γ=5.41. All coefficient estimates are from the model of CPI inflation using M4/M4ex in Table 3.

In the period following the Great Recession, inflation was fluctuating close to the threshold of 3% which causes inflation to be dictated by a combination of domestic and global money movements. This suggests that in response to the financial crisis, global coordination in terms of unconventional monetary policies is necessary to move, at least, the UK economy out of prolonged disinflation when required[16].

With, at the time of writing, current CPI inflation (in 2018Q1) at 2.7%, our findings suggest that

[16] An interesting avenue of future research would be to assess the connectedness of unconventional monetary policies implemented by nations such as the US, UK and Euro Area, and their ability to stimulate an economy in response to financial crises.

there is a risk of the UK entering a high inflation regime. However, in this very regime, a combination of monitoring money supply movements over the short term, and tightening monetary policy could aid the Bank of England in bringing inflation back to target. In light of substantial policy uncertainty shrouded around Brexit negotiations weakening UK Sterling, and in turn, pushing up import prices, it should not come as a surprise if the Bank of England increases the pace at which it raises its policy rate. In fact, the Bank of England's February 2018 Inflation Report predicted that modal (i.e. most likely outcome for) inflation would only fall to 2.2% (and yet remain above the 2% target) in 2020Q1 under the assumption of the policy rate going up from 0.5% in February 2018 to 1.0% in 2020Q1[17].

3.3. Assessing the Consequences of the Zero Lower Bound

With interest rates hovering around their zero lower bounds in many economies including the UK, it is necessary to examine whether our results are driven by nearly a decade of constant interest rates. Therefore, we repeat our analysis by replacing the Bank rate with an estimate of the Shadow Bank rate as proposed by Wu and Xia (2016). Replacing the Bank rate with the Shadow Bank rate has been implemented in Ellington (2018) within a time-varying parameter VAR framework. The Shadow Bank rate, stemming from an affine term structure model, allows the interest rate to fall below zero and hence does not suffer from this constraint. Therefore the Shadow Bank rate provides information on monetary policy stance when conventional interest rates are at their respective zero lower bounds (Wu and Xia, 2016).

In Table 4, we report the SESTAR models of CPI inflation that replace the Bank rate with the Shadow Bank rate. As we can see, the parameter estimates from models using Shadow Bank rate are similar to analogous baseline models. Therefore our results and conclusions are not sensitive to the zero lower bound.

[17]See: `https://www.bankofengland.co.uk/inflation-report/2018/february-2018`

Table 4: Self Exciting Smooth Transition Autoregressive (SESTAR) Models of UK Inflation: Replacing the Bank Rate with the Shadow Bank Rate (Wu and Xia, 2016)

	Sample: 1972Q1-2017Q4	1978Q3-2017Q4
Money Measure:	M4/M4ex	Divisia
β_0	0.10(022)	0.03(0.10)
β_π		0.96(0.03)***
β_{oil}	0.006(0.003)**	0.002(0.002)
β_{gap}		0.09(0.03)***
Regime when	π_{t-6} <3.49%	π_{t-6} <3.28%
$\beta_{1,\pi}$	0.84(0.08)***	
$\beta_{1,\text{G}}$	0.01(0.01)*	0.004(0.007)
Regime when	π_{t-6} >3.49%	π_{t-6} >3.28%
$\beta_{2,\pi}$	0.92(0.05)***	
$\beta_{2,\text{gap}}$	0.10(0.08)	
$\beta_{2,\text{M}}$	0.09(0.04)**	0.11(0.02)***
$\beta_{2,\text{shad}}$	-0.06(0.04)*	-0.08(0.03)***
$\beta_{2,\text{diseq}}$	0.03(0.03)	0.10(0.03)***
γ	5.62(3.30)*	200 (–)
τ	3.49(0.71)***	3.28(0.09)***
VAT dummies	Yes	Yes
$\bar{R}^2$	0.96	0.953
AIC	2.94	2.25
Stability F-stat	1.73*	1.67
Linear F-stat	224.8***	6.29***

Notes: This table reports SESTAR models of UK CPI inflation from 1972Q1-2017Q4 for the model using M4/M4ex, and 1978Q3-2017Q4 for the model using Divisia money. In parantheses are Newey-West Heteroskedasticity and autocorrelation consistent standard errors. *, **, and *** indicate statistical significance of coefficient estimates at 10%, 5%, and 1% levels respectively. $\bar{R}^2$ denotes the adjusted R-squared of the regression and AIC is the Akaike Information Criterion. Stability F-stat is a test for parameter stability proposed by Lin and Teräsvirta (1994) that tests the statistical significance of the cross product of regressors with a time trend. Linear F-stat is an F-test of the null hypothesis that the model can be simplified to a linear specification.

4. Conclusion

This paper uses tools from the classical theory of inflation and assesses the impact of both domestic and global liquidity conditions for UK consumer price inflation from 1970Q1 to 2017Q4. We specify linear and non-linear Phillips curve type equations augmented with domestic monetary conditions, global liquidity and oil price growth. We provide economically meaningful and statistical significant evidence that liquidity conditions influence inflation over and above spare capacity, monetary policy stance and supply side factors. Our non-linear models show that when UK inflation is greater than 3% (i.e. more than 1% above the target), domestic monetary conditions dominate inflation dynamics.

From a policy perspective, our results suggest that the Bank of England should monitor growth in the money supply, along with money demand conditions, in conjunction with monetary policy stance. More specifically during periods of high inflation, monitoring monetary conditions and tightening monetary policy may lead to price stability in the medium term. With, at the time of writing, current CPI inflation (in 2018Q1) at 2.7%, our findings suggest that there is a risk of the UK entering a high inflation regime. However, in this very regime, a combination of monitoring money supply movements over the short term, and tightening monetary policy could aid the Bank of England in bringing inflation back to target. In light of substantial policy uncertainty shrouded around Brexit negotiations weakening UK Sterling, and in turn, pushing up import prices, it should not come as a surprise if the Bank of England increases the pace at which it raises its policy rate.

Our work may be extended in a number of different directions. First, although the focus of our model is on UK inflation dynamics, our model may prove attractive for other countries. Second, it would make sense to allow UK inflation to be modelled as a function of economic policy uncertainty to reflect the ongoing Brexit negotiations as well as the so-called "transition period" of some two years into the future (the specifics of this transition period are not yet known). Third, it would be interesting to examine the ability of our non-linear models to forecast inflation out-of-sample. All these issues are left for future research.

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