CAUSES OF THE GREAT MODERATION RE-STUDIED

GARCH APPROACH

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Abstract

The purpose of this paper is to perform a new study to add support for one of the three explanations of the Great Moderation; the explanation based on a change in monetary policy. The study focuses on the U.S., the U.K., and Australia during the period 1970 Q1-2013 Q3. The study is performed by exploring whether the Moderation (persistent decline in output volatility) was caused by volatility behaviors, namely; a reduction in Inflation volatility, Long-term Interest rate volatility and Stock prices volatility.

GARCH models are applied to study the correlation between these volatilities. Reduced volatility in inflation is discovered to be the cause of the decline in real output volatility. I could not reject the hypothesis of no significant relationship between inflation volatility and real output volatility in all the countries considered. The results lend considerable support to the change in monetary policy as the cause of the Great Moderation. The other two explanations for the Great moderation are believed to be structural and technological changes and "Good Luck" hypothesis. The basic interest of this study was on financial variables and their predicative power. It is believed that financial variables have less predicative powers in explaining these other two causes, therefore are not considered.

No significant correlation was found between interest rate, stock price volatility and output gap volatility.

Key words: The Great Moderation, Output gap, Volatility, GARCH, HP-Filter.

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1. Introduction

The marked and persistent decline in real output volatility in most, if not all, industrial countries that occurred in the mid1980s is commonly referred to as the Great Moderation. A considerable number of studies have provided evidence on the causes of the Great Moderation, but no consensus has yet been reached. The fact that no consensus has yet been found leaves room to further analyze the question.

It is not strange that researchers have not reached a consensus, as Bernanke (2004) commented in his speech on the causes of the great moderation; “Explanations of complicated phenomena are rarely clear cut and simple and each … probably contains elements of truth.” The main elements could have acted together in complicated ways. It is probably the case that the monetary policy that was adopted facilitated the use of advanced computer systems that improved inventory management. Or perhaps the lack of strong shocks made the new monetary policy successful, as Bernanke also points out. Nevertheless, all the suggested explanations of the causes of the Great moderation are doubtless part of the story.

The main aim of this study is to explore whether the reduction in real output volatility in the countries studied could be explained by volatility behaviors in some of the main financial variables, namely: inflation, long-term interest rates and stock prices. Statistically and theoretically, one can think of volatility in output as being dependent on the volatility of its components. Therefore, studying the behavior of inflation volatility, interest volatility and stock price volatility will help in understanding the behavior of output volatility, since inflation, interest rates and stock prices directly or indirectly affect the output components and thus affect output volatility. Moreover, to study output volatility the standard deviation of output gaps is studied.

The subsidiary aim of this paper is to earn support for one of the main causes adduced for the Great Moderation, namely; the explanation based on changes in monetary policy. The study uses quarterly time series data on real GDP which is used to calculate output gap, CPI, long-run interest rates and stock prices in three of the industrialized countries said to have experienced the Moderation, namely; the U.S., the U.K. and Australia, for the period 1970 Q1 to 2013 Q3. I use a three-step procedure, where in the first step the output gaps are calculated using the HP-filter method. In the second step the volatilities for the financial variables are estimated by demeaning using OLS regression, thirdly the estimated volatilities are used as input in a GARCH model to estimate output gap volatility.

The real output gap volatility behaviors for the three countries can be observed in Figures 4, 5 and 6 in the appendix. In the U.S. the sharp persistent decline (the Great Moderation) can be traced starting from 1983 Q4/1984 Q1 to 2009 Q1.This dating is consistent with both McConnell & Perez-Quiros and Kim & Nelson, who found the first quarter of 1984 to be the most likely time for the change in volatility. The magnitude of the decline in output volatility was substantial in the U.S., but not in the U.K. and Australia. The U.K. saw a sharp decline in output gap volatility in 1976-77 but this was interrupted; I would trace the origin of the persistent decline in output volatility to 1980 Q1. It was, however, interrupted in 1997-1998 and again in 2008. In Australia, the sharp decline in real output standard deviation was experienced as early as 1975 Q1 with interruptions in 1983, 1988 and 2008. Volatilities in the U.K. and Australia appear to swing from high and low; this raises a question as to whether the decline in output volatilities in the two countries should be termed “Great”. This has also been a concern for some researchers, for example David & Robert (2010) in their research paper on the Australian region found the so-called great moderation in Australia to have been less extensive than studies suggest.

I find that reduced volatility in inflation accounted for the decline in real output volatility. The results lend considerable support to changes in monetary policy being the cause of the great moderation.

The rest of the paper proceeds as follows: Section 2 briefly reviews the empirical background to the causes of the Great Moderation, the relationship between inflation, interest rates, stock prices and output. Section 3 introduces the data, Section 4 specifies the relevant model, and Section 5 reports the empirical results. Section 6 is the conclusion.

2. Background

2.1. Causes of the Great Moderation

As previously mentioned, there have been a number of studies of the causes of the Great moderation; with most of the research conducted on the U.S. and without any consensus being reached.

Summers (2005) gives a summary of the causes of the great moderation in the U.S. and the other G-7 countries. He states the causes to have been improved monetary policy, changes in inventory management, and good luck. Intuitively, the improved monetary policy can be considered to have reduced output volatility by improving the ability of the economy to absorb shocks through lower and more stable inflation. Many analysts argue that by achieving low and stable inflation monetary policy creates a favorable environment for economic activity. Lower inflation decreases nominal distortions, for instance those that arise from taxation. According to the literature, the Great Moderation in the United States occurred soon after several major changes at the Federal Reserve.

Richard Clarida, Galí, & Mark Gertler (1998) explore the role of monetary policy using a forward looking monetary policy reaction function for the U.S. economy, pre and post October 1979 and find the conduct of monetary policy to have changed significantly upon the appointment of Paul Volcker as chairman of the Board of Governors in 1979. They also find the pre-Volcker period to be characterized by greater macroeconomic instability. In the U.K., according to some analysts, Margaret Thatcher's monetarist and deflationary economic policies implemented in late 1980 are argued to have caused a significant cut in the inflation rate and established a ground for economic stability[1].

Romer & Romer (2002) believe that there was an evolution of economic understanding in the U.S. It was not a case of linear progress from less knowledge to more, but rather an evolution from a crude but fundamentally sensible model of how the economy worked in the 1950s to a more formal but faulty model in the 1960s and 1970s and finally to a model that was both sensible and sophisticated in the 1980s and 1990s.

The second explanation for The Great Moderation is based upon structural and technological changes which were permanent in nature and were not directly caused or controlled by macroeconomic policies. McConnell & Perez-Quiros (2000) analyze the sources of decreased volatility by decomposing GDP growth into expenditures on goods, services and structure. They fit AR models to both the growth contribution and the growth rate and later test for breaks in the residual variances and AR coefficients. Growth contributions are examined because a break in the growth contribution of an individual component is believed to signal a potentially causal role for that component in the aggregate decline in volatility. Growth rates are also examined because a break in the growth rate of a particular component indicates whether the break in the growth

[1] https://www.academia.edu/2536012/Literature_Review_Margaret_Thatchers_economic_policies_towards_industry_trade_unions_and_the_subsequent_effect_on_unemployment

contribution is due to increased stability within that sector. McConnell & Perez found a break in both the growth rate and growth distribution of the goods sector. They furthermore link the date of the decline in goods volatility with the date of the aggregate decline in volatility.

Khan, McConnell &Perez-Quiros (2002) argue that changes in inventory behavior resulting from improvement in information technology played a direct role in reducing real output volatility in the U.S. Basing their argument on McConnell & Perez-Quiros (2000), they explore the role of inventory behavior in explaining output volatility by using a simple growth-accounting framework whereby they decompose the variance of output growth in the goods sector into the variance of the growth contributions of sales and inventory investment along with their covariance, since output is a sum of final sales and inventory investment. They found that a change in inventory behavior contributed substantially to the drop in output volatility. Their findings, however, did not rule out the possibility that some exogenous change in the sales process had played some role. Steven & Kahn (2008) applied the same approach as Khan, McConnell & Perez-Quiros (2002), but instead used a rolling five year variance of the inventory investment term and the sales inventory covariance term. Both terms showed considerable downward trends, with the covariance term accounting for a very large drop in the output volatility. McCarthy & Zakrajsek (2003) are in agreement with the literature but do not, however, believe that better inventory management was the ultimate cause for the great moderation.

Another important structural change is related to worldwide economic integration through financial innovation and globalization. Dynan, Elmendorf, & Sichel (2006) employ a variety of simple empirical techniques to identify links between the observed reduction in output volatility and the influence of financial innovation on consumer spending, housing investment and business fixed investment. They found that financial innovation was likely to have contributed to mid-1980s stabilization and should be considered to be one of the causes. Cavallo (2007) backs up this argument; he highlights how trade openness has reduced output volatility, and how more open economies are also more stable. Cavallo's methodology of gravity estimates as instrumental variables for trade disproves the old view of how more openness exposes economies to volatility. Cavallo instead argues that more open economies have more opportunities to adjust to international shocks.

The third main explanation for reduced output volatility was the "Good Luck" hypothesis; the argument is based on the belief that the economic conditions in the 1980s were moderately benign. There were no severe unlucky events that hit the economies of these countries. Many analysts focus on oil price supply shocks as major examples of "bad luck". The two main large oil price shocks occurred about the time of the Arab oil embargo in 1973-74 and the Iranian Revolution in 1979-80. Large increases in the price of oil usually diminish economic activity significantly. Economic activity is more likely to be disrupted by large price hikes than by large declines or by stable (although possibly high) prices, as most analysts agree.

Stock & Watson (2003) analyzed G7 output data using a structural VAR to separately identify common international shocks, domestic effects of spillovers from idiosyncratic foreign shocks, and the effects of idiosyncratic domestic shocks. They found that the widespread reduction in volatility was in large part associated with a reduction in the magnitude of the common international shocks. They believe that the G7 business cycles would have been considerably more volatile, had the common international shocks in the 1980s and 1990s been as large as they were in the 1960s and 1970s.

Ahmed, Levin, & Wilson, (2002) applied both frequency-domain and vector autoregression (VAR) methods on GDP growth to distinguish among the three documented causes of the Great Moderation and found the good luck hypothesis to be the leading explanation for the fall in output volatility. Primiceri & Alejandro (2006), in their attempt to identify structural disturbances responsible for the volatility changes in the U.S economy, estimated a DSGE model in which the volatility of the structural innovation was allowed to change over time. The U.S. economy was found to have been hit by exogenous shocks with stochastic volatility and the volatility of output in the 1980s was found to have largely been driven by investment specific technology shocks. Gali & Gambetti (2008) showed in their study that the decline in U.S. output volatility was associated with large changes in the patterns of co-movements among output, hours worked and labor productivity, and that those shocks that occurred at that time were largely responsible for the decline in the correlation between hours and labor productivity, which was one of the immediate factors behind the decline in output volatility.

Giannone, et al, (2008) argue that the econometric models used in support for the good luck hypothesis are too simple. When more complex models were examined with a larger number of variables, it was found that the reduced volatility came from a change in the propagation of shocks rather than in the size of the shocks.

The timing of the Great Moderation still remains controversial. According to Kim & Nelson (1999), McConnell & Perez-Quiros (2000), Stock & Watson (2002), Chauvet & Potter (2001) and others the Great Moderation starts in the early to mid-1980s, whereas Smith & Summers (2002), Cecchetti et al (2006), and Shepherd & Dixon (2006) date the start from the mid-1980s to the early 1990s.

2.2. The role of Inflation and Interest rates in the form of monetary policy on real economy/ aggregate activity.

This approach is based on the idea that the economy´s monetary policy is ineffective due to the Central bank lacking full credibility. The issue is to demonstrate whether the economy will gain from improving this credibility by committing to a rule regarding policy. The baseline of the framework is grounded in goods market equilibrium theory and relates to the traditional IS/LM model in that the monetary policy affects the real economy in the short term.

The model is represented in three equations; the goods market equilibrium condition (GMEC), the aggregate supply curve (AS) and the social loss function (SL) due to the inefficiency of the policy.

GMEC: $$y - \bar{y} = -\alpha(r - \acute{r}) + v^{*} \qquad (1)$$ [2]

AS: $$\pi - \pi^{e} = \gamma(y - \bar{y}) + s \qquad (2)$$ [3]

SL: $$-a_d(\hat{y} - b\hat{}) + \frac{a_l(\hat{y} - b\hat{})^2}{2(1-\alpha)} + \frac{a_\pi}{2}\pi\hat{}^2 \qquad (3)$$ [4][5]

Where:

$\boldsymbol{y} - \bar{y}$ = output gap, the difference between actual ($\boldsymbol{y}$) and potential output ($\bar{y}$)

$r - \acute{r}$ = differential interest rate, the difference between short-run (r) and long-run interest rate ($\acute{r}$)

[2] Chap.17, pg. 480-505, Introducing Advanced Macroeconomics, *growth and business cycles* by Peter Birch and Hans Whitta, 2nd. Edition.
[3] "

[4] Chap 20, pg. 590 -601, "
[5] Explained more in the appendix

$\pi - \pi^e$ = Inflation gap, the difference between actual inflation (π) from target inflation (π^e), static expectations is assumed, $\pi^e = \pi^*$

$v^* = v + \alpha(g - \bar{g}) =$ Disturbance term in form of income growth expectations plus government spending gap or simply demand shocks

S = disturbance term or supply shocks.

Eq. (1) arises from the assumption of a closed economy and the assumption that for the goods market to clear aggregate demand must be equal to total output. Aggregate demand for goods therefore consists of the sum of real private consumption, real private investment and real government demand for goods and services. Eq. (1) also demonstrates that aggregate demand for goods is negatively related to the real interest rate and positively related to government spending and demand shocks. The negative effect of interest rate on output reflects the negative impact that high interest rates have on private wealth and consumption, since a rise in interest rate, *ceteris paribus* will push down stock prices as well as investment. Since monetary policy affects the short term real interest rate it therefore also affects aggregate demand.

Eq. (2) arises from the assumption that the firm sets prices depending on its cost function in order to maximize profits. It is further assumed that labor is the only input for the firm and the firm therefore only faces wage costs. Wages are given to the firm by a union in the same sector. Due to the firm being a price setter and the union being a wage setter they both face respective nominal rigidities. Unions set wages depending on their inflation expectations and firms set nominal prices depending on expectation of future marginal costs. Additionally, it is assumed that there is imperfect short term information and that therefore the firm and the union both make mistakes. Unemployment rises when unions overestimate the price level (expected inflation) and set a high wage. Increase in unemployment increases inflation, which further decreases aggregate goods demand. According to the expectations- augmented Phillips curve,[6] a rise in unemployment lowers inflation and vice versa. Not only do deviations in output cause deviation in inflation, but even supply shocks which are usually productivity shocks and price- and wage mark-ups cause deviations in inflation.

Furthermore; the model assumes nominal interest rate as the instrument of monetary policy, the so called Taylor rule.

$$i^p = r^* + \pi + h(\pi - \pi^e) + \mathrm{b}(\boldsymbol{y} - \bar{y})^7 \qquad (4)$$

Where; i^p = Monetary policy rule or the nominal interest rate

r^*= risk free rate

Eq. (4) indicates that the monetary policy can effectively change the short term interest rate by varying the nominal interest rate, and through this mechanism monetary policy gains leverage over real economic activity in the near future.

First, we look at the case when the central bank lacks full credibility, in other words, the central bank follows no policy rule. This is believed by many economies to have been the case before the great moderation. The objective of the central bank is to minimize the social welfare loss caused by gaps in output and inflation.

[6] Chap.16, pg. 480-505, Introducing Advanced Macroeconomics, *growth and business cycles* by Peter Birch and Hans Whitta, 2nd. Edition.

[7] Chap.16, pg. 460-461, "

Therefore the central bank faces a tradeoff between the output gap and the inflation gap. It makes sense to assume that the central bank assumes static inflation expectation ($\pi^e = \pi_{-1}$). The central bank chooses a desirable output gap (eq.1), inflation gap (eq.2) and a policy rule (eq.3) to minimize the social loss (eq.4). Given that the central bank has no rule or commitment to follow, it "goes with the wind", usually the "wind" is the adjustment mechanism of the aggregate demand – aggregate supply model[8]. The central bankwill therefore, increase/cut interest rates when the inflation gap increases/decreases and thus decrease/increase the output gap. This method could be ineffective if the central bank lacks perfect information about the type of shocks hitting the economy.

We assume now that the central bank is credible, that is, it is committed to a rule or target. It faces a tradeoff between stabilizing the output gap and the inflation gap but this time has a plan to deal with the situation. We assume that the policy aims at stabilizing the output gap. If we further assume that there is a negative output gap, the central bank will act by raising the interest rate to stimulate aggregate demand. A rise in interest rate simultaneously raises inflation.

$$\frac{\partial SL}{\partial \hat{y}} = \frac{\partial SL}{\partial \hat{y}} + \frac{\partial SL}{\partial \pi} * \frac{\partial \pi\hat{}}{\partial \hat{y}} \quad \text{(Optimal Social loss due to the negative output gap)} \quad (5)$$

Re-writing Eq. (6) $\frac{\partial SL}{\partial \hat{y}} = -a_d + \frac{a_l}{1-\alpha}(\hat{y} - b\hat{}) + a_\pi \pi\hat{} * \frac{\alpha}{1-\alpha}$ (5a)

Monetary policy aims at stabilizing output gap; the Central bank`s optimal output is when optimal welfare social loss is equal to zero: $\frac{\partial SL}{\partial \hat{y}} = 0$

$$\leftrightarrow -a_d + \frac{a_l}{1-\alpha}((\hat{y} - b\hat{}) + a_\pi \pi\hat{} * \frac{\alpha}{1-\alpha} = 0$$

$$\leftrightarrow \hat{y} = b\hat{} + (1-\alpha)\frac{a_d}{a_l} - \frac{\alpha a_\pi}{a_l}\pi\hat{} \quad \text{(Optimal output gap) (6)}$$

Eq. (6) is the optimal output gap the monetary policy aims at stabilizing. The inflation gap is inversely related to the optimal gap, and therefore efforts to reduce the output gap by the policy makers will come at a cost of an increase in the inflation gap.

2.3. Literature review

2.3.1. Inflation and Output

There has been a considerable amount of research on the nature of the relationship between inflation and economic growth. There is a consensus over a negative relationship between inflation and output. The effect of inflation on output has been studied in the context of models of economic growth in which the constant increase of per capita income is the outcome of capital accumulation together with technological progress.

[8] Chap.16, pg. 519-527, Introducing Advanced Macroeconomics, *growth and business cycles* by Peter Birch and Hans Whitta, 2nd. Edition.

De Gregorio (1994) suggested a robust negative relationship between inflation and growth when reviewing existing theory and evidence about inflation and growth. He argued that inflation limits growth mainly by reducing the efficiency of investment rather than its level.

Khan & Abdelhak (2000) also re-examined the nature of the relationship between inflation and growth. Basing on the mixed findings of the relationship between inflation and growth, they use new econometric models to estimate the existence of a threshold where the relationship between inflation and growth goes from positive to negative. They found an inflation of 11 % to be the threshold. Both industrial and developing countries showed a positive and significant relationship between inflation and growth below the threshold and a significant and robust negative relationship for inflation rates above the threshold. They also found a negative and significant indirect effect between inflation and growth through investment.

The costs associated with high and volatile inflation have been a concern of macroeconomists, policy makers and central bankers. High and volatile inflation leads to uncertainty which affects the rate of return which in turn lowers investments[9]. High inflation undermines the confidence of domestic and foreign investors about the future of the economy thus reducing its international competitiveness. Furthermore, inflation reduces total factor productivity[10] due to firms devoting more resources to dealing with the effects of inflation (high firm costs).

2.3.2. Real interest rate and Output

The relationship between real interest rates and output growth is of great importance for economists. Interest rates are negatively correlated to output as seen in the section above. High real interest rates cause households to save more and therefore consume less, which causes firms to cut down on their investments. This pushes down demand for goods which in turn reduces the supply of goods since in equilibrium demand must meet supply[11]. Furthermore, high interest rates make the cost of money more expensive which may crowd out private demand particularly when investments show a significant sensitivity to changes in interest rates. This could result in a decline in aggregate demand, either directly through investment or indirectly through a lower wealth effect in the private sector and subsequent lower consumption[12].

Julian Di Giovanni et al. (2009) studied the impacts that interest rates have on real output for several European countries and found that interest rates lower quarterly real growth only moderately. Using an ordinary least squares (OLS) methodology, their results showed that a 1 percentage point increase in the interest rate in the Netherlands resulted in a 0.094 percentage point decrease in the real growth rate, 0.015 points decrease in France and an average effect across countries of -0.043.

Using regression analysis to study the impacts interest rate has on real GDP for Jordan, Saymeh & Abu Orabi (2013) found a one period lagged interest rate had a significant impact on GDP, with a coefficient of -0.152.

2.3.3 Stock prices and Output

There has been wide debate on whether the stock market can predict an economy. Some authors support the market's predictive ability and thus argue that the stock market is forward-looking, and that current prices mirror the future earnings potential and profitability of corporations. Profitability is directly linked to economic activity, since stock prices mirror expectations about profitability, and fluctuations in stock prices are

[9] Pindyck and Solimano (1993)
[10] Javier and Ignacio (1997)
[11] Abel, Bernanke and Croushore.
[12] Abel, Bernanke and Croushore.

considered to predict the direction of the economy. For instance, the stock market will push down stock prices if there are signals of the economy entering a recession. Pearce (1983) argues that the economy can be forecast from the stock market since variations in stock prices directly affect aggregate spending.

When comparing financial variables according to their forecasting power in predicting the then Great Recession, Estrella &Mishkin (1995) provided evidence that stock prices played a significant role in predicting the Great Recession. Andersson et al. (2011) examined whether stock prices and stock market valuation metrics could help to predict real GDP, private consumption and investment growth for the U.S. and the Euro area. Using an out-of-sample forecast exercise over the period 1985 to 2009, they found Stock prices to have strong predictive power in both the U.S. and Euro Area.

2.4. GARCH Model

Many economic time series exhibit phases of relative tranquility followed by periods of high volatility and vice versa. Such series are said to exhibit volatility clustering features. Volatility clustering occurs when the current volatility of a series is conditional on its previous volatility. The GARCH process is an econometric term introduced by Bollerslev in 1986, whereby the conditional variance is allowed to be an ARMA process. GARCH process allows for both autoregressive and moving average components in the heteroskedastic variance.[13] In other words, a GARCH formula takes the weighted average of the unconditional variance (the long-run forecast of the variance), the squared residual for the first observation and the starting variance and estimates the variance of the second observation and so on.

Formulaically: GARCH ($h_t) = w + \sum_{t=1}^{q} \alpha \varepsilon_{t-i}^2 + \sum_{t=1}^{p} \beta h_{t-i} \qquad \varepsilon_t | \psi_t \sim$N (0,$h_t$)[14]

Where; h_t is the conditional variance (GARCH) in the present period, w is long-run forecasted variance, ε_{t-i}^2 is the squared residual for the last period, referred to as the ARCH term, $h_{t-i}$is last period`s variance of the observation, also referred to as the GARCH term, and $\psi_t$is the information set available at time t.

GARCH formulas only work when $\alpha + \beta < 1$ for the process to be stationary and only make sense when $\alpha > 0, \beta > 0, w > 0$, i.e. the weights should be positive. Note also, the GARCH formula implies that the next period's GARCH or variance is conditional on the current GARCH. This means that if today`s variance is high/low, tomorrow's variance will most probably be high/low. This is what makes GARCH an appropriate model to explain the behavior of the great moderation.

3. Data

The study is carried out for the United States, United Kingdom and Australia for the period 1970 Q1-2013 Q3, a time interval which is prior to and after the great moderation. As mentioned earlier, the great moderation is believed to have occurred in the mid 1980s and to have ended by the recession in 2008, so this time interval should be sufficient to trace the causes and provide a fair picture of the great moderation. Also, this specific time interval was chosen due to lack of data on earlier periods, for instance data on Australia`s interest rate is only available from 1969 Q3. The countries were randomly selected to represent economies sufficiently similar to give a hope of finding similar results. Differences in the results are interpreted as an indication of lack

[13] Applied Econometric Time Series, pg. 126 - 131
[14] "

or the moderation was of less degree. Or it is an indication of other factors playing a bigger role than financial variables in explaining the Great moderation.

The data set used in this paper consists of real Gross Domestic Product (GDP) for calculating GDP gaps[15], Consumer Price Index used to represent Inflation, long-run interest rates and Stock prices.

Real GDP data for the U.S. were collected from the Bureau of Economic Analysis (BEA), measured in billions of chained (2009) dollars, seasonally adjusted at annual rates, Australia`s real GDP data were from the Australian Bureau of Statistics (ABS), measured in millions chained volumes as percentage changes and real GDP data for the U.K. were obtained from the Office for National Statistics (ONS), as chained volume measures in millions, seasonally adjusted.

CPI data for all the countries were collected from the Organization of Economic Cooperation and Development (OECD) statistics and are measured as the quarterly percentage change from the same period of the previous year, and are therefore seasonally adjusted.

Interest rate and stock price data were also collected from Organization of Economic Cooperation and Development (OECD) statistics. Interest rates are long-term interest rates, measured as averages of monthly figures. Stock prices are monthly averages measured as indices with reference year 2010.

GDP and Stock price series are transformed into their natural logs due to the skewness of the series whereas Inflation (CPI) and Interest rate series are unchanged.

3.1. Data Description

For easy data analysis, the data are divided into two periods. Period 1 is the period before the great moderation (1970Q1:1984Q3) as the literature suggests, and period 2 is the period during and after the Great Moderation (1985Q1:2013Q4).

From Table 1, 2 and 3 we see a similar pattern in all the three countries. The countries experienced upward trending GDPs over the years with a few exceptions during the early 1980s, 1990s, 2000 and the crisis in 2008. Despite the crisis, the GDPs started picking up in 2010 and were at their all-time highs in 2013. This can be seen in the mean increase in period 1 and 2 in the tables and figures 1, 2 and 3.

The behavior of CPI and real interest rates in all three countries changed substantially during the period 1970 to 2013, in particular, the period from the mid-70s to 1983 stands out as a period of high and persistent inflation and nominal interest rates. Inflation peaks in late 1974 and early 1979 in the U.K, late 1974 and early 1980 in the U.S. and 1975 in Australia. Whereas the interest rate was at its peak in 1974, 1976 and 1981 in the U.K., in 1982 and 1990 in Australia, in 1981 and 84 in the U.S.

The countries experienced upward trending but, however, quite volatile stock prices with interruptions in 2002-2003 and during the financial crisis in 2008.

According to literature, many countries adopted changes in their monetary policies due to this stag inflation in the 70s. Could the monetary policies adopted in the U.S., U.K. and Australia have paid off in reducing volatilities in macroeconomic variables, particularly volatility in output, interest rate and inflation? Or was it the flourishing financial markets caused by favorable stock prices that stabilized output?

Figures 1, 2, 3, and tables 1, 2, 3 also show how GDP is negatively correlated to interest rate and Inflation, and positively correlated to Stock prices. This relationship is consistent with the literature as pointed

[15] GDP gap and Output gap will be used interchangeably.

out in the background section. This relationship is also the core for this thesis, which is to test the relationship between GDP, Inflation, Interest rate and Stock prices, but in terms of volatility.

Table 1: U.S. Real Output gap, CPI, Interest rate and Stock price

	GDP		CPI (Inflation)		Interest rate		Stock prices	
	Perid.1	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**
Mean	5883	11754	7.18	2.8	9.06	5.73	8.97	69.33
Max.	7388	15837	14.5	6.2	14.85	11.58	14	137
Min.	4703	7462	2.6	-1.6	5.89	1.64	5.4	15
SD	764	2625	3.2	1.25	2.56	2.18	2.19	36.61

Source: Bureau of Economic Analysis (BEA), OECD and Author`s calculations
Notes: Perid.1= period 1=1969Q3:1984Q3
Perid.2= Period 2=1985Q1:2013Q3
GDP is measured in billion of chained dollars

Figure 1.

Table 2: U.K. Real output gap, CPI, Interest rate and Stock price

	GDP		CPI (Inflation)		Interest rate		Stock prices	
	Perid.1	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**
Mean	159.62	296.74	11.44	3.08	11.76	6.57	9	76.13
Max.	183.66	392.78	26.6	8.4	16.02	12.32	21.3	119.5
Min.	133.72	185.95	3.8	0.6	7.13	1.67	2.7	23.3
SD	13.32	67.49	5.76	1.80	2.32	2.76	4.49	30.14

Source: Office for National Statistics (ONS), OECD and Author`s calculation.
Notes: GDP is measured in million chained pounds.

Table 3: Australia Real output gap, CPI, Interest rate and Stock price

	GDP		CPI (Inflation)		Interest rate		Stock prices	
	Perid.1	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**	**Perid.1**	**Perid.2**
Mean	110872	238706	9.45	3.65	10	7	9.28	64.31
Max.	135940	379456	17.7	9.6	16	14	16.2	141
Min.	88159	137448	2.1	-0.4	5.75	3	4.4	17.2
SD	1620.8	76050.4	3.82	2.47	3	3.25	3.32	30.62

Source: Australian Bureau of Statistics (ABS), OECD, and Author`s calculations.
Notes: GDP is measured in million chained dollars

Figure 1.

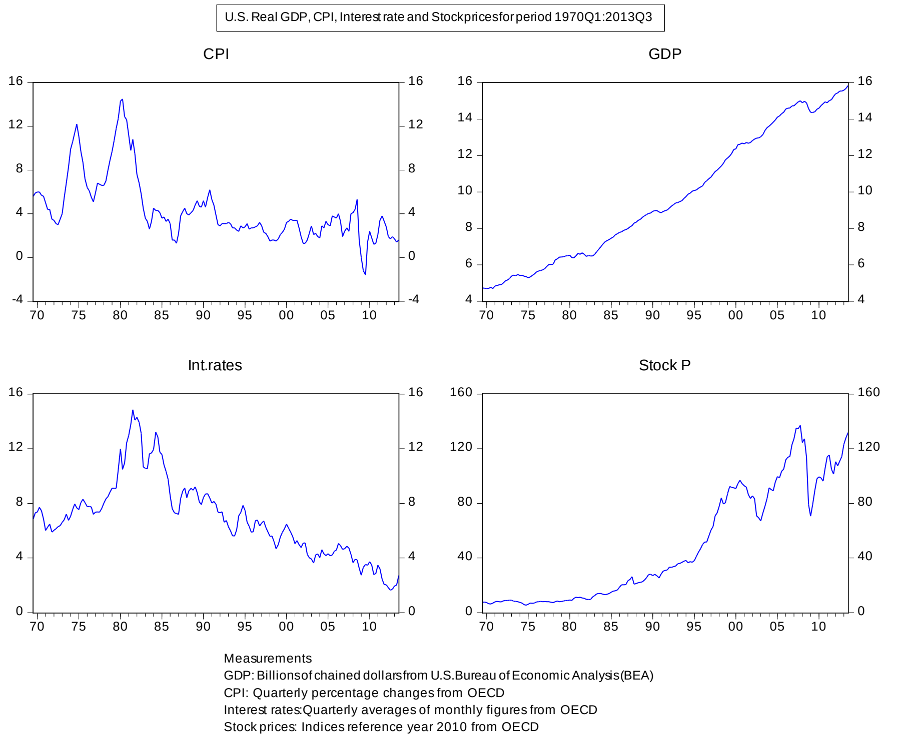


Figure 2.

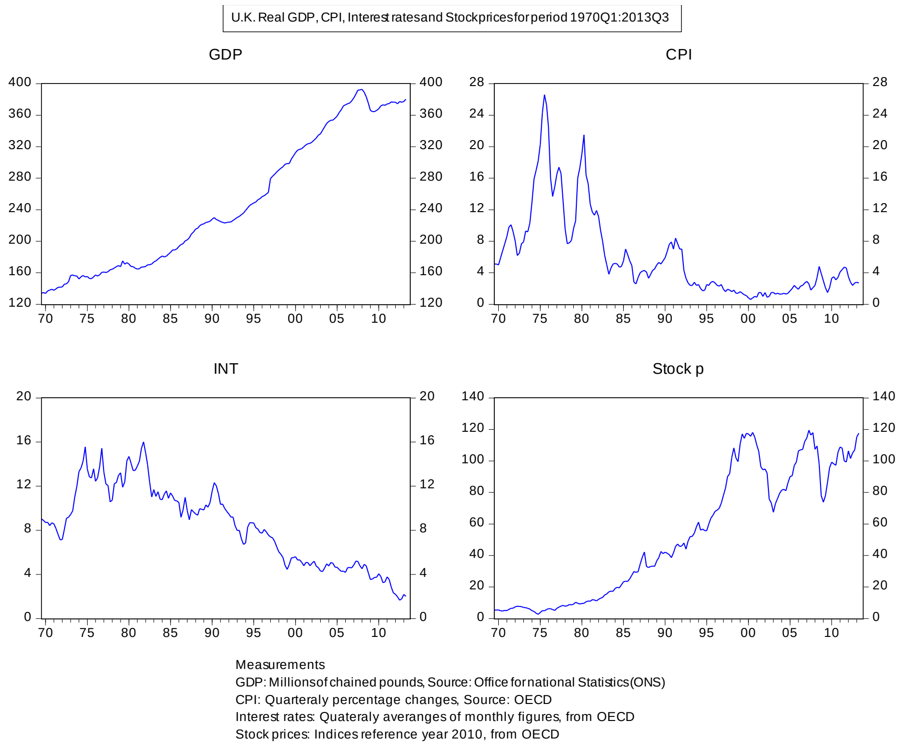
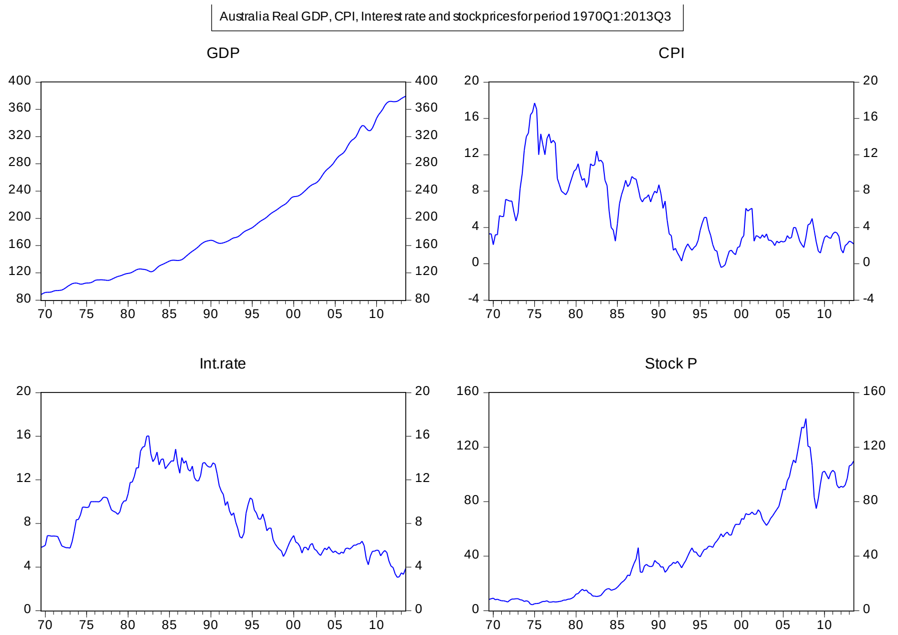


Figure 3.



Measurements:
GDP: Million of chained dollars
CPI: Quarterly percentage changes
Interst rates: Quarterly averages of monthly figures
Stock prices: Indices reference year 2010

4. Model specification

4.1. Ensuring the Stationarity of the Series

The series are tested for unit root using ADF unit root test, since time series data is prone to being non-stationary and therefore giving misleading regression results. All unit root test regressions are run with a constant and trend term. The null hypothesis for the ADF test is that there is a unit root and the optimal lag lengths selection is automatically chosen by the Schwarz Bayesian criteria. The results are detailed in Tables 4, 5 and 6 for each country. CPI in U.S. and Australia were found to be stationary with a drift and trend term. The remaining series were non-stationary. In other words, the tests were unable to reject the null hypothesis for the variables. However, the variables appear to be stationary at first difference, i.e. integrated at order 1. These results, therefore, imply that the series should be first differenced in order not to get spurious regression results.

Table 4. U.S. Unit Root Test Results

ADF test critical values	Variable	t-stat	P-value*
At level	CPI	-3.6516	0.0285
	Interest rate	-2.3671	0.3955
	Log Stock price	-2.7539	0.2166
At 1^{st} Difference	Interest rate	-10.3638	0.0000
	Log Stock price	-9.4453	0.0000

Table 5. U.K. Unit Root Test Results

ADF test critical values	Variable	t-stat	P-value*
At level	CPI	-2.3221	0.4192
	Interest rate	-3.1668	0.0946

	Log Stock price	-1.6658	0.7623
At 1^{st} Difference	CPI	-5.7968	0.0000
	Interest rate	-10.2233	0.0000
	Log Stock price	-9.9429	0.0000

Table 6. Australia Unit Root Test Results

ADF test critical values	Variable	t-stat	P-value*
At level	CPI	-3.6567	0.0280
	Interest rate	-2.2399	0.4641
	Log Stock price	-2.7826	0.2057
At 1^{st} Difference	Interest rate	-10.7729	0.0000
	Log Stock price	-11.0864	0.0000

*MacKinnon (1996) one-sided p-values
Note: GDP gap is not tested for unit root because it is by construction stationary.

4.2. Finding Output gap

Output volatility is studied through studying the standard deviation of the output gap. To obtain the output gap it is assumed that the output series is generated by a stochastic process that can be represented as the sum of trend and cyclical components, with additional noise or other irregular components (shocks). An idea borrowed from Stefan & Wensheng (2006).

$$y_t = y_t^{trend} + y_t^{cycle} + e_t \qquad \text{(a)}$$

Where the cyclical component, which is referred to output gap, is obtained by;

$$y_t^{cycle} = y_t - y_t^{trend} + e_t \qquad \text{(b)}$$

The output gap, or the cyclical component of output, is the difference between the natural logarithm of real output (y_t) and the Hodrick- Prescott (HP) trend which I shall explain briefly later.
The objective is to identify the cycle component (gap) for the real output series, and using the GARCH process to estimate the gap`s volatility whereby I shall later study its behavior depending on volatility behaviors in inflation, interest rate and stock prices, which are explanatory variables in the main model.

Components of (y_t) in (a) are not directly observable, only the joint outcome y_t is observed, therefore the task is to obtain components of the unobserved element. The Hodrick-Prescott (HP) filter method[16] is used on real output series to compute for y_t^{trend} component which I subtract from the observed (y_t) to obtain the gap. The HP filter has long been used as a de-trending method in the empirical business cycle literature, see Blackburn & Ravn (1992), Artis & Zhang (1997), Hess & Shin (1997) or Stefan & Wensheng (2006).

The HP filter decomposes actual output into a long-run trend and cyclical components, therefore, when the trend is obtained using HP filter, it is subtracted from the logarithm of real output series, giving me the output gap. Lambda, λ=1600 is used as the smoothing parameter in the Hodrick-Prescott filter, which is the recommended lambda for quarterly data.

[16] See Hodrick and Prescott (1997)

Hodrick-Prescott filter is chosen because of its advantage over other filters in that it considers both past and future data and because of its simplicity, whereas GARCH is employed because of its popularity in econometrics and finance as the best measure of time-varying volatility.

4.3. Finding Inflation, Interest rate and Stock price volatilities

After the series have been tested and transformed into stationary, they are de-meaned by running an OLS regression of each series on its mean as shown in step 1. The regression estimates are subtracted from the original series to obtain the residual (step 2), the residual (variation) is squared thus giving the series volatility (step 3). $Step\ 1\text{:}\ Run\ OLS\ regression;\ x = \beta_0 + \varepsilon_t$

$Step\ 2\text{:}\quad Obtain\ the\ residual; x - \ \beta_0 + \varepsilon_t = \epsilon$

$Step\ 3\text{:} square\ the\ residual;\ \epsilon_t^2\ \rightarrow \sigma_{\mathrm{x}}$

4.4. The Model

The model estimated is a GARCH (p, q) model with;

Mean equation:

$$y_t = \beta_0 + \beta_1 y_{t-1} - \beta_2 Inf._{t-1} + \beta_3 \Delta Int._{t-1} + \beta_4 \Delta Stoc.p_{t-1} + \varepsilon_t \qquad (1)$$

Variance equation:

$$\sigma^2{}_{y(t)} = w + \sum_{i=1}^{p} \alpha \varepsilon_{t-1}^2 + \sum_{i=1}^{q} \beta \sigma^2{}_{y(t-1)} + \alpha_1 \sigma_{\mathrm{Inf.(t-1)}} - \alpha_2 \sigma_{\Delta Int.(t-1)} + \alpha_3 \sigma_{\Delta lnStoc.p(t-1)} \qquad (2)$$

Where;

Eq. (1); y_t= Output gap

$Inf.$= Inflation

$\Delta Int.$= 1st differenced interest rate

$\Delta Stoc.p$= 1st differenced Stock prices

ε_t= classical error term

Eq. (2); $\sigma^2{}_{y(t)}$ = Output gap volatility

w= Intercept or long-run forecasted variance

ε_{t-1}^2= Squared residual for the last period, or the ARCH term

$\sigma^2{}_{y(t-1)}$ = Last period`s variance of the residuals, or the GARCH term

$\sigma_{\mathrm{Inf.(t-1)}}$= Lagged Inflation volatility

$\sigma_{\Delta Int.(t-1)}$= Lagged 1st differenced Interest rate volatility

$\sigma_{\Delta lnStoc.p(t-1)}$= Lagged 1st differenced log Stock price volatility

$\alpha_1, \alpha_2, \alpha_3 =$ Volatility coefficients to be estimated.

The thesis is interested in output volatility, not levels of output, and therefore only Eq. (2) is considered. Eq. (2) states that output volatility is a conditional variance depending positively on the realized volatilities of inflation, interest rate, stock price and other unobserved factors. If the magnitude of inflation, interest rate and stock price volatility, respectively, is large, the output volatility is expected to be large and vice versa. The nature of the model is such that increases/decreases in the previous period`s inflation volatility, interest rate volatility and stock price volatility increase/decrease the current output volatility.

The volatilities in the model are lagged since GARCH is an autoregressive process, implying it operates under the premise that past values have an effect on current values.

The GARCH model above is based on the tradeoff between the inflation gap and output gap presented in Eq.6, the tradeoff between interest rate gap and output gap presented in Eq.1, and the positive correlation between stock prices and output. The model assumes the economy has an efficient monetary policy that has managed to improve the gaps in inflation and output, a reason for the plus sign on the inflation volatility coefficient. According to Eq.6, if policy makers react vigorously to the inflation gap, they will narrow that gap but widen the output gap. Put in volatility terms, a decrease in inflation volatility will cause high output volatility, and vice versa. Furthermore, low volatility in inflation will lead to low volatility in the interest rate, because the Central bank will act by cutting down the interest rates when inflation falls, and vice versa.

This tradeoff could also mean that an inadequate monetary policy may fail to achieve this trade off and the outcome could be devastating, with excessive volatility of output and inflation. On the other hand, an efficient monetary policy may improve the trade-off in the event of of a situation with excessive output and inflation volatility, lowering it to a "normal tradeoff" or lower tradeoff, and thereby reducing volatility in both output and inflation. This is the case on which the main model of this thesis is based.

Later in this paper this relationship between volatilities will be tested. The null hypothesis is that there is no significant relationship between inflation volatility, interest rate volatility, stock price volatility and output gap volatility.

5. Regression results

The GARCH results are presented in table 7, 8 and 9 below.

	Table 7			
	U.S. GARCH (1,1) Model for period 1970Q1 – 2013Q3			
	Coef.	**Std.Error**	**Z-Stat**	**P-Value**
C	1.61E-06*	4.59E-07	3.504022	0.0005
ARCH(-1)	-0.082881*	0.014543	-5.698886	0.0000
GARCH(-1)	0.986083*	0.026248	37.56781	0.0000
Inflation Vol.(-1)	2.54E-07*	6.35E-08	3.996003	0.0001
Interest rate Vol.(-1)	-2.95E-06	1.80E-06	-1.644608	0.1001
Stock price Vol.(-1)	0.000871	0.000988	0.881801	0.3779

Table 8

	Australia GARCH (2,1) Model for period 1970Q1–2013Q3			
	Coef.	**Std.Error**	**Z-Stat**	**P-Value**
C	4.16E-06	1.72E-06	2.421807	0.0154
ARCH(-1)	0.182454*	0.085462	2.134921	0.0328
GARCH(-1)	0.607707*	0.131731	4.613242	0.0000

Inflation Vol.(-1)	-1.44E-07*	5.83E-08	-2.462527	0.0138
Interest rate Vol.(-1)	-1.29E-06	3.18E-06	-0.407271	0.6838
Interest rate Vol.(-4)	-6.22E-07	2.71E-06	-0.229680	0.8183
Stock price Vol.(-1)	0.036108	0.017610	1.577291	0.1147

Table 9

	U.K. GARCH (2,1) Model forperiod 1970Q1 – 2013Q3			
	Coef.	**Std.Error**	**Z-Stat**	**P-Value**
C	5.31E-05*	1.29E-05	4.122684	0.0000
ARCH(-1)	0.147282	0.138237	1.065432	0.2867
GARCH(-1)	0.588288*	0.132458	4.441306	0.0000
Inflation Vol.(-1)	-2.25E-06*	6.98E-07	-3.218419	0.0013
Interest rate Vol.(-1)	-1.60E-05	1.67E-05	-0.955218	0.3395
Stock price Vol.(-1)	-0.000284	0.000953	-0.298461	0.7654

Notes: Dependent variable: Y-gap
Sample (adjusted): 1970Q1 2013Q3
*Significant at 5% confidence level

Table 7, 8 and 9 above display estimates for the variance equation of the GARCH model for each country. The regressions are carried out using EViews 7. The coefficients in the variance equation are listed according to the GARCH model chosen. The coefficients are listed as C the intercept; ARCH (-1), the first lag of the squared residual, ARCH (-2) the second lag of the squared residual, GARCH (-1), the first lag of the conditional variance, Inflation Vol. (-1), the first lag of inflation volatility, Interest rate.Vol (-1) the first lag of interest rate volatility, and, lastly Stock price Vol. (-1), the first lag of Stock price volatility. The variables are lagged because GARCH is an autoregressive process and, therefore, operates under the idea that past volatility has an effect on current volatility.

The models were chosen on the basis of Akaike Information (AIC) and Schwarz model selection criterion and diagnostic tests. According to AIC and SIC, GARCH (1, 1) is chosen as the better fit for the U.S. and Australia data, whereas GARCH (2, 1) is a better fit for the U.K. data. Additionally, the models have quite high R-squares, 0.82 (U.S.), 0.83 (Australia) and 0.70 (U.K.), another indication for models to be a good fit. However, the Australia model has failed residual diagnostic test for serial correlation, ARCH test and normality test. Even when the Bollervslev-Wooldridge robust test was used to compute for standard errors, the model still contained some serial correlation and ARCH effect and is therefore not a correct model and probably spurious, so not much attention will be paid to it.

The sums of ARCH and GARCH parameters in the U.K. model are 0.73, 0.78 for Australia and 0.90 for U.S. All the sums are less than one, a criterion for a good GARCH model. The ARCH and GARCH sums are quite close to one; an indication that the variations in the output volatility were persistent. One can conclude that the volatility patterns were less persistent in the U.K. compared to the U.S.[17]

The models give different estimates with different signs, which makes it difficult to generalize the analysis. One result, however, was consistent, the significant correlation between inflation volatility and real

[17] Australia is not considered since the model is of no good fit.

output gap volatility. In the U.S. the correlation was positive, but it was negative in the U.K. and Australia models. The negative correlation between inflation volatility and output volatility in the U.K. and Australia models could be an indication of the tradeoff between inflation and output under a normal monetary policy or simply due to model misspecification, since the U.K. model failed diagnostic tests for normality of the residuals whereas Australia as I have already mentioned failed all the diagnostic tests and is therefore not a correct model for estimating the decline in output volatility. Or the models simply cannot correctly estimate the moderation because there was none in either of the two economies.

Interest rate volatility was found to be negative and insignificant to output volatility in all the models. To test for the lag effect between interest rate and output, interest rate was lagged 4 and 8 periods back, none of the lags were significant, and since the 8^{th} lag decreased the R^2 in the U.K. model and did not improve estimations in the other models, it was entirely dropped.

Stock price volatility was found to be positive but not significant to output gap volatility in the U.S. and Australia and negatively insignificant to output volatility in the U.K.

The null hypothesis of no significant relationship between the respective volatilities to real output gap volatility was rejected/not rejected at a 5% significance level.

The U.S. model seems to be the most correct model, and I am therefore basing my conclusions on it. The positive significant correlation between inflation volatility and output gap volatility suggests the reduction in inflation volatility accounted for the decline in real output volatility. This intuition rests on the assumption that the country improved the trade-off between the inflation gap and output gap through implementing better and more efficient policies. The result is in line with the literature, Olivier Coibion & Yuriy Gorodnichenko (2008) and other authors believe that the increased focus on fighting inflation under Volcker (1979 -1982) and Greenspan`s time as the chairmen of FED in the U.S. led to economic stability. Boivin & Giannoni (2006) found that the change in the systematic behavior of the Federal Reserve in the U.S. played an important role in decreasing macroeconomic volatility than did change in the size of the shocks. Shesadri Banerjee (2012) found that lack of inflation targeting in the policy framework was potentially a factor responsible for greater inflation volatility in developing economies.

The negative and significant relationship between inflation volatility and output volatility in the U.K. and Australia could be because the economies` monetary policy were not effective enough to improve both inflation gap and output gap and therefore, their aim to narrow inflation gap came at an expense of increased output volatility.

The tradeoff between the output gap and interest rate was not significant enough to have caused the moderation. Finally, stock prices did not seem to have played a major role in causing the great moderation.

The results lend considerable support to the explanation based on a change in monetary policy. The results also give answers to the two questions of this thesis. I believe the improvements in the monetary policies adopted by the U.S. contributed to obtaining not only stable and low inflation but also stable and high output. It is hard to say whether the favorable stock prices during the period studied had a positive impact on the reduction of output volatility in the countries studied.

6. Conclusion

This paper re-studies the documented causes of the Great moderation phenomenon in a simple manner. The phenomenon does not have one cause but many approximate causes, as seen in section 2; despite the large literature on the causes of the phenomenon no consensus has been reached. The author believes changes in monetary policy as the cause for the Great moderation and, therefore, re-studies the Great moderation in order to give more support to the explanation based on changes in monetary policy.

One of the key findings is that the Great Moderation was more evident in the U.S. than in Australia and U.K. One is tempted to conclude that the Great Moderation was primarily a U.S. phenomenon.

The main aim of this paper was to explore if the great moderation in the U.S., U.K. and Australia could be explained by volatility in financial variables, namely inflation, long-term interest rates and stock prices. The study was carried out from the both statistical and theoretical point of view that volatility of output depends on the volatility of its components and that the output components are directly and indirectly affected by inflation, Interest rates and stock prices.

GARCH models are used estimated under quasi-maximum likelihood for the data period 1970Q4 to 2013Q3. My findings suggest the Moderation or the persistent decline in output volatility was associated with, and may have largely been caused by, a decline in inflation volatility, resulting from the implementation of a more efficient monetary policy that must have led to lower and more stable inflation and to better output stabilization.

Another finding was that stock prices, though favorable, did not play a major role in stabilizing output from the 80s until the crisis in 2008.

The aim of this paper was to study the correlation, not the causality; perhaps it was the decline in output volatility that led to decline in inflation volatility, interest volatility and so on. The study of the causality between the volatilities could be a fruitful ground for further research.

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8. Appendix

Social Welfare loss function

Assume $Y = \beta L^{1-\alpha}$; Y: Actual output (Production function)

$\bar{Y} = \bar{\beta} * L^{-1-\alpha}$; $\bar{Y}$: Long-run/potential output (Long-run production function)

$y - \bar{y} = (b - \bar{b}) + (1-\alpha)(l - \bar{l})$ ↔lnY-ln$\bar{Y}$ Relative difference

$(l - \bar{l}) = \frac{(y-\bar{y})-(b-\bar{b})}{1-\alpha} \leftrightarrow \hat{l} = \frac{\hat{y}-\hat{b}}{1-\alpha}$ (Social loss related to fluctuations in labor)

$SL = -a_d(\hat{y} - \hat{b}) + \frac{a_l}{2(1-\alpha)}(\hat{y} - \hat{b})^2 + \frac{a_\pi}{2}\hat{\pi}^2$ (Social welfare loss re-written) ↔ Eq. (3)

Where;

$-a_d(\hat{y} - \hat{b})$: Measures the wedge between marginal product of labor and marginal rate of substitution between consumption and work.

$\frac{a_l}{2(1-\alpha)}(\hat{y} - \hat{b})^2$: Captures gains/losses from business cycle (output gap)

$\frac{a_\pi}{2}\hat{\pi}^2$: Measures fluctuations in employment (Inflation gap)

Effect of change in output gap on SL

$$\frac{\partial SL}{\partial \hat{y}} = -a_d + \frac{a_l}{1-\alpha}(\hat{y} - \hat{b})$$

Effect of change in inflation gap on SL due to change in output gap

$$\frac{\partial SL}{\partial \pi} = a_\pi \hat{\pi}$$

Total effect of change in output on SL

$$\frac{\partial SL}{\partial \hat{y}} = -a_d + \frac{a_l}{1-\alpha}(\hat{y} - \hat{b}) + a_\pi \hat{\pi}$$ Eq. (5) & (5a)

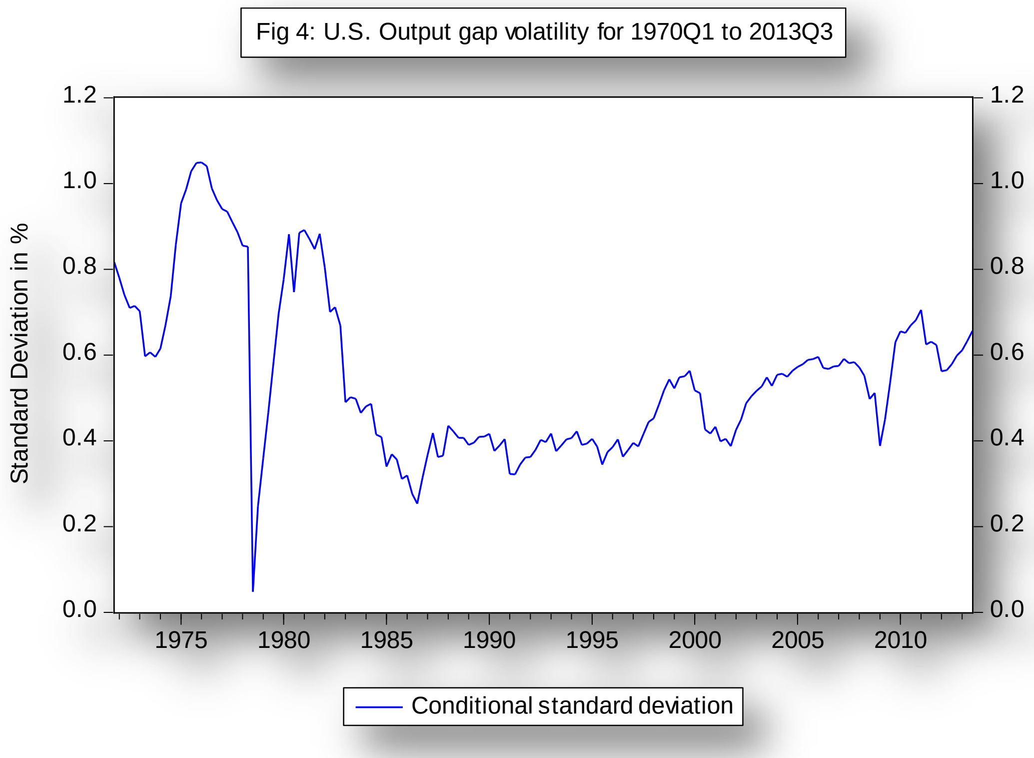


Fig 4: U.S. Output gap volatility for 1970Q1 to 2013Q3
Standard Deviation in %
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1975
1980
1985
1990
1995
2000
2005
2010
Conditional standard deviation

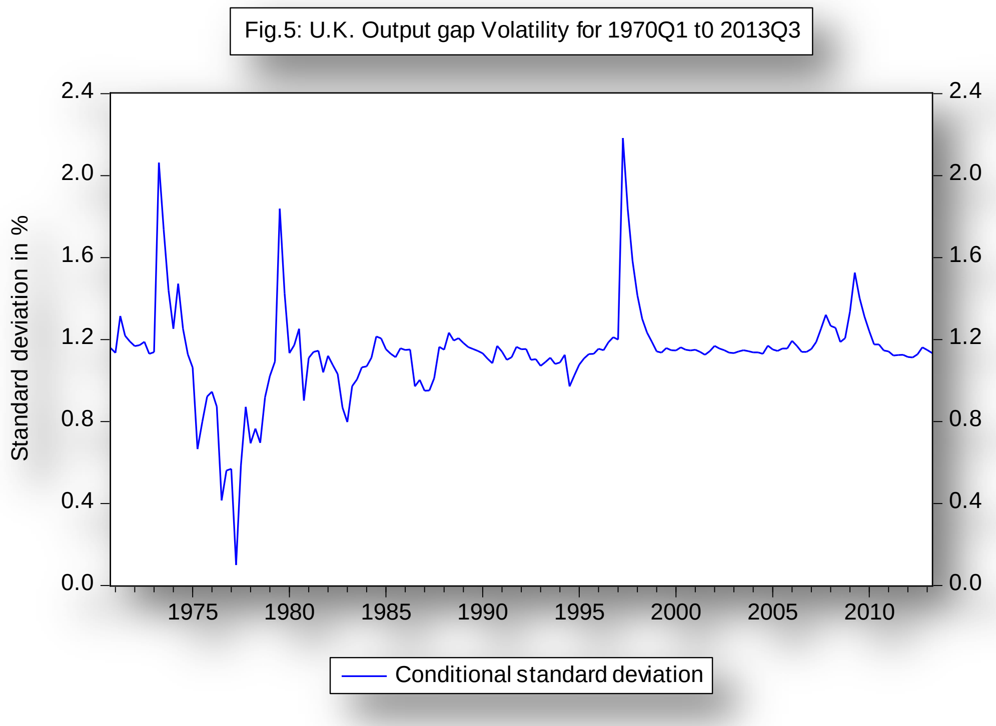
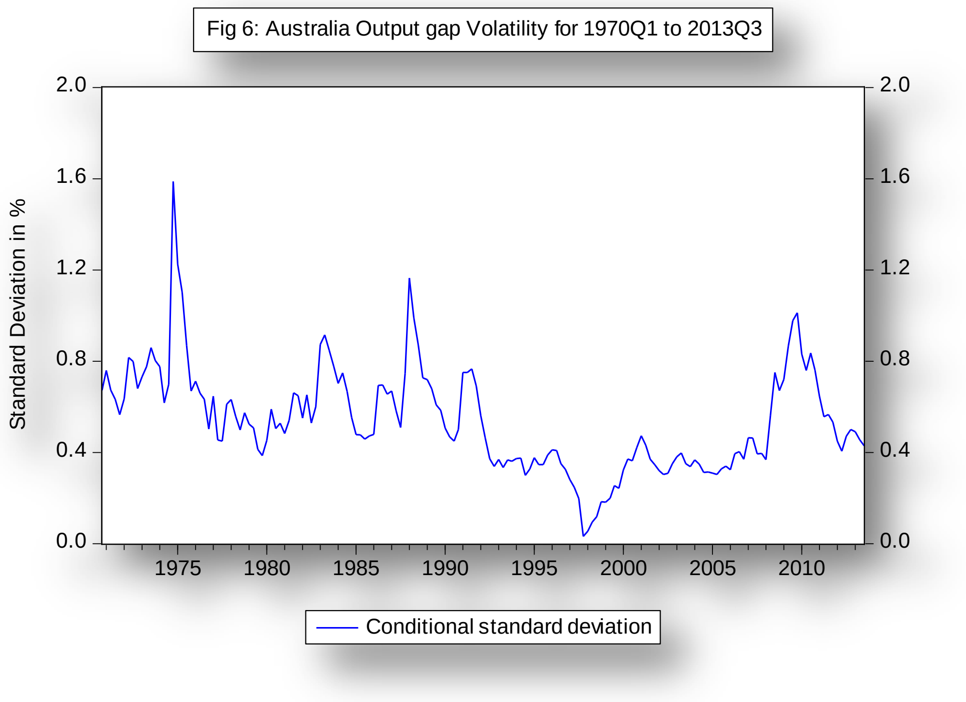


Fig.5: U.K. Output gap Volatility for 1970Q1 t0 2013Q3
Standard deviation in %
2.4
2.0
1.6
1.2
0.8
0.4
0.0
1975
1980
1985
1990
1995
2000
2005
2010
Conditional standard deviation



a) U.S. Estimates

Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/09/14 Time: 01:26
Sample (adjusted): 1970Q4 2013Q3
Included observations: 172 after adjustments
Convergence achieved after 29 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(8) + C(9)*RESID(-1)^2 + C(10)*GARCH(-1) + C(11)*CP_VOL(
-1) + C(12)*DINT_VOL(-1) + C(13)*STOCK_VOL(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000730	0.000910	0.802114	0.4225
Y_GAP(-1)	0.991529	0.030353	32.66670	0.0000
Y_GAP(-4)	-0.165229	0.039403	-4.193263	0.0000
CPI(-1)	-0.000232	0.000198	-1.170854	0.2417
DINT(-1)	0.001542	0.000822	1.876956	0.0605
DINT(-4)	0.000609	0.000777	0.783988	0.4330
DLOGSTOCK(-1)	0.100105	0.017357	5.767247	0.0000
		Variance Equation		
C	1.61E-06	4.59E-07	3.504022	0.0005
RESID(-1)^2	-0.082881	0.014543	-5.698886	0.0000
GARCH(-1)	0.986083	0.026248	37.56781	0.0000
CP_VOL(-1)	2.54E-07	6.35E-08	3.996003	0.0001
DINT_VOL(-1)	-2.95E-06	1.80E-06	-1.644608	0.1001
STOCK_VOL(-1)	0.000871	0.000988	0.881801	0.3779

R-squared	0.826435	Mean dependent var	-4.61E-05
Adjusted R-squared	0.820124	S.D. dependent var	0.015806
S.E. of regression	0.006704	Akaike info criterion	-7.427283
Sum squared resid	0.007415	Schwarz criterion	-7.189391

Log likelihood	651.7464	Hannan-Quinn criter.	-7.330764
Durbin-Watson stat	2.081578		

b) U.K. Estimates

Dependent Variable: Y_GAP
Method: ML - ARCH (Marquardt) - Student's t distribution
Date: 10/07/14 Time: 11:34
Sample (adjusted): 1970Q4 2013Q2
Included observations: 171 after adjustments
Convergence achieved after 12 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(7) + C(8)*RESID(-1)^2 + C(9)*GARCH(-1) + C(10)*DCPI_VOL(
-1) + C(11)*DINT_VOL(-1) + C(12)*STOCK_VOL

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-3.05E-05	0.001181	-0.025837	0.9794
Y_GAP(-1)	0.813659	0.069409	11.72268	0.0000
DCPI(-1)	-9.18E-05	0.000648	-0.141586	0.8874
DINT(-1)	0.003209	0.001612	1.991113	0.0465
DINT(-4)	0.000320	0.001205	0.265519	0.7906
DLOGSTOCK(-1)	-0.001997	0.021248	-0.094000	0.9251
Variance Equation				
C	5.31E-05	1.29E-05	4.122684	0.0000
RESID(-1)^2	0.147282	0.138237	1.065432	0.2867
GARCH(-1)	0.588288	0.132458	4.441306	0.0000
DCPI_VOL(-1)	-2.25E-06	6.98E-07	-3.218419	0.0013
DINT_VOL(-1)	-1.60E-05	1.67E-05	-0.955218	0.3395
STOCK_VOL	-0.000284	0.000953	-0.298461	0.7654
T-DIST. DOF	19.99996	17.64876	1.133222	0.2571

R-squared	0.700822	Mean dependent var	6.24E-05
Adjusted R-squared	0.691756	S.D. dependent var	0.017102
S.E. of regression	0.009495	Akaike info criterion	-6.362611
Sum squared resid	0.014876	Schwarz criterion	-6.123771
Log likelihood	557.0032	Hannan-Quinn criter.	-6.265700
Durbin-Watson stat	1.745092		

c) Australia Estimates

Dependent Variable: Y_GAP
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/09/14 Time: 01:25
Sample (adjusted): 1970Q4 2013Q3
Included observations: 172 after adjustments
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(7) + C(8)*RESID(-1)^2 + C(9)*GARCH(-1) + C(10)*CP_VOL(-1)
+ C(11)*DINT2_VOL(-1) + C(12)*DINT2_VOL(-4) + C(13)*STOCK_VOL(
-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.51E-06	0.000345	0.004388	0.9965
Y_GAP(-1)	0.921120	0.027825	33.10435	0.0000

DCPI(-1)	-0.000315	0.000367	-0.859175	0.3902
DINT2(-1)	0.002439	0.000483	5.053429	0.0000
DINT2(-4)	-0.001720	0.000504	-3.409439	0.0007
DLOGSTOCK_P(-1)	0.036108	0.017610	2.050424	0.0403
Variance Equation				
C	4.16E-06	1.72E-06	2.421807	0.0154
RESID(-1)^2	0.182454	0.085462	2.134921	0.0328
GARCH(-1)	0.607707	0.131731	4.613242	0.0000
CP_VOL(-1)	-1.44E-07	5.83E-08	-2.462527	0.0138
DINT2_VOL(-1)	-1.29E-06	3.18E-06	-0.407271	0.6838
DINT2_VOL(-4)	-6.22E-07	2.71E-06	-0.229680	0.8183
STOCK_VOL(-1)	0.004726	0.002996	1.577291	0.1147

R-squared	0.835111	Mean dependent var	-5.94E-06
Adjusted R-squared	0.830144	S.D. dependent var	0.015321
S.E. of regression	0.006314	Akaike info criterion	-7.453816
Sum squared resid	0.006619	Schwarz criterion	-7.215924
Log likelihood	654.0282	Hannan-Quinn criter.	-7.357298
Durbin-Watson stat	0.587777		