

A Historical Causality Analysis of Inflation  
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## A Historical Causality Analysis of Inflation

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I, Ishita Ghoshal, hereby declare that this thesis on the topic entitled, "*A Historical Causality Analysis of Inflation*" is submitted for the award of Degree of Doctor of Philosophy in Economics to the Gokhale Institute of Politics and Economics, Pune 411004.

It is an original contribution and has been completed during my tenure as a research scholar at Gokhale Institute of Politics and Economics, Pune .

This thesis has not been submitted by me elsewhere for the award of any degree or diploma-part or full. The information gathered by me elsewhere for the thesis is original, true and factual. Such material as has been obtain from other source has been duly acknowledged in the thesis. I hereby request, to consider the thesis for the award of the degree of 'Doctor of Philosophy'.

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## List of Abbreviations

- ACF – Autocorrelation Function
- AD – Aggregate Demand
- AR – Autoregression
- ARIMA – Autoregressive Integrated Moving Average
- ARMA – Autoregressive Moving Average
- AS – Aggregate Supply
- BK Filter – Baxter-King Filter
- BW Filter – Butterworth
- CF Filter – Cristiano-Fitzgerald
- CPI – Consumer Price Index
- CRR – Cash Reserve Ratio
- DGP – Data Generating Process
- EME – Emerging Market Economy
- FEVD – Forecast Error Variance Decomposition
- FRED – Federal Reserve Economic Data
- GARCH – Generalised Autoregressive Conditional Heteroskedasticity
- GC – Granger Causality
- GDP – Gross Domestic Product
- HEGY – Hylleberg, Engle, Granger and Yoo
- HP Filter – Hodrick-Prescott filter
- IMF – International Monetary Fund
- IRF – Impulse Response Function
- LAD – Longrun Aggregate Demand
- LAS – Longrun Aggregate Supply
- LIC – Life Insurance Corporation
- MA – Moving Average
- MOSPI - Ministry of Statistics and Policy Implementation
- NSSO – National Sample Survey Office
- OEA – Office of the Economic Adviser
- OECD – Organisation for Economic Co-operation and Development
- OLS – Ordinary Least Square
- OPEC – Organization of the Petroleum Exporting Countries
- RBI – Reserve Bank of India
- SAD – Shortrun Aggregate Demand
- SAS – Shortrun Aggregate Supply
- SLR – Statutory Liquidity Ratio
- SVAR – Structural Vector Autoregression
- USA – United States of America

- VAR – Vector Autoregression
- VMA – Vector Moving Average
- WPI – Wholesale Price Index

## 1 Chapter 1. Introduction

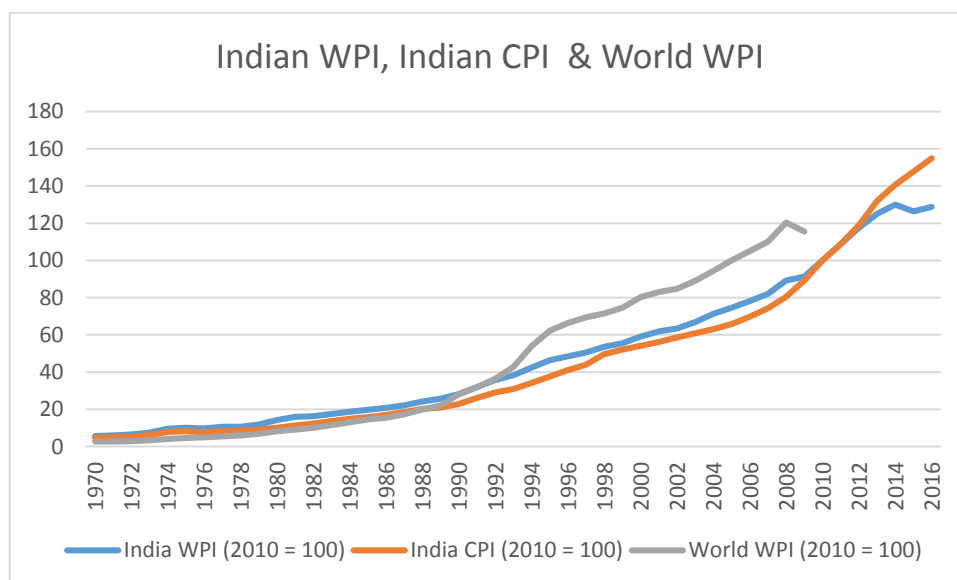
Inflation, which is a sustained rise in the overall price level or a persistent rise in the general price level rather than a once-for-all rise in it, has been a matter of interest to many groups of people since time immemorial. The main reason for such interest is the fact that inflation leaves individuals (particularly the poor) worse off, taking away the previous level of well-being and the opportunity to consume as much as was being consumed earlier. A bunch of goods and services walk out of the consumption basket simply because they are now out of reach. Inflation eats away purchasing power, raises cost of living and lowers the real value of saving making it one of the most closely monitored macroeconomic indicators of any economy. Imbalance between demand and supply of money, changes in production and distribution cost or increase in taxes on products are some of the factors that lead to inflation. When the price level of goods and services rise, the local currency loses its value and strength; the purchasing power of the currency falls, which means that now each unit of currency buys fewer goods and services in the world market.

The consumers of the economy lose out the most due to rise in prices. It becomes more and more difficult for consumers to afford even the basic commodities in life with continuous rise in prices. Thus, the only solution to tackle this (from the perspective of a consumer) is to demand for hike in income. In order to avoid this, the government tries to keep inflation under control.

Inflation paves the way for rising costs, making the exports less competitive in the global marketplace. Fluctuations in inflation, such as a large increase in prices followed by a decrease, can cause decreases in economic growth, reduce spending, decrease investments and increase interest rates.

Despite all the negative effects, a moderate level of inflation is the reflection of a good economy. Dornbusch & Fischer (1993) consider an inflation rate between fifteen and thirty percent prevailing consistently for at least three years to be of moderate nature. Very low

rates of interest at the times of extremely low inflation may again, be a deterrent for the economy. Hence, the government and the central bank try to maintain a limited level of inflation that would encourage buying and borrowing to keep the economy running smoothly. According to the Statistical Yearbook (2014), Ministry of Statistics and Policy Implementation (MOSPI), during 2000 to 2007 India has fared comparatively well with respect to its inflation figures vis-à-vis other countries. India's average inflation (Wholesale Price Index WPI 5.2% and Consumer Price Index CPI 4.6%) has been below the average of emerging and developing economies (6.7%) during the period. In 2008-09 inflation went up to 8.1% and had remained in double digits during and 2010-11 and 2011-12.



**FIGURE 1-1: INDIAN WPI, CPI & WORLD WPI – SOURCE: WORLD BANK**

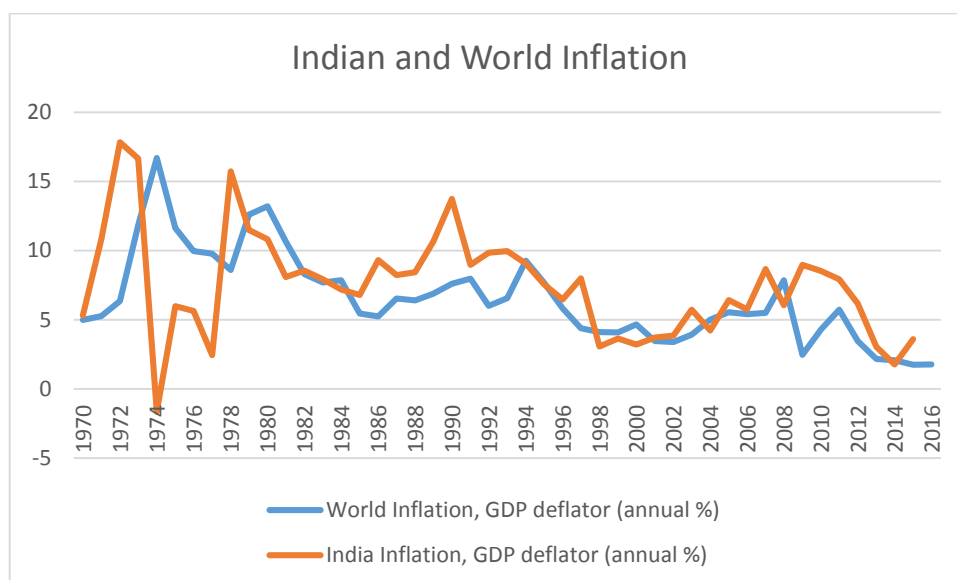


FIGURE 1-2: INDIAN & WORLD GDP DEFLATOR - SOURCE: WORLD BANK

Statistical Yearbook (2014), Ministry of Statistics and Policy Implementation (MOSPI) states the main reasons for the consistent rise in inflation are crude oil and global commodity price trends (due to increased deregulation and liberalization) and also exchange rate changes. The report further notes that the demand for food products have been seen to increase even though the production has remained stagnant. With rise in per capita income, protein based food products have been gaining on its demand providing protein inflation with a structural character. The rise in demand for food, in general, has also gone on to further diverge WPI from CPI. Strong demand factors in periods of high inflation and low supply elasticities, have led to further rise in inflation. National Sample Survey Office (NSSO) 68th Round survey shows per capita consumption expenditure has increased in both rural (average 1.4% during 2004-09 to 8.7% during 2009-12) and urban (2.4% to 6.7% for the same period) areas of the country. High food prices have been followed by subsequent rises in nominal wages. This in turn, has also fed into higher demand for necessary goods. Moderation in the recent inflation is attributable to lowering inflation of non-food articles, non-administered petroleum products (leading to a moderation of inflation in fuel and power sectors) and manufactured products. In the past, several macroeconomic factors like consistent increase in salaries, supply-demand imbalance and high import prices have been reported to cause inflation in the Indian



economy. Increased average salary forces the prices of goods and services to go up, which in the Indian scenario of excessive income-inequality, spell out as a problem of affordability of basic staples for the majority of the Indian population that survive below the poverty line. For several years, volatility in weather conditions leading to bad crops coupled with infrastructural constraints have caused shortages in food, pushing food prices up as a consequence. In the absence of sufficient production of manufacturing goods within the country, imports of expensive imported goods increases which in turn raise food prices. Raising interest rates have been one of the most relied upon strategies to curb inflation in India. However, several economists have been of the opinion that working towards improvement of supply in the economy by way of increased agricultural production is likely to help control inflation in the long-run.

## **1.1 The Social Costs and Effects of Inflation:**

Inflation not only decreases the purchasing power of the income of the people it also inflicts few other social costs. To further explain inflation's social cost, we need to first distinguish anticipated inflation from unanticipated inflation. In the case of anticipated inflation, the future rise in prices is considered when making decisions about economic transactions, like, negotiating the wage rate etc.

### **1.1.1 Costs of Anticipated Inflation:**

According to Mankiw (2003) in an economy where there is a particular inflation rate for an extended time period people speculate the inflation rate to exist at the same rate. In this situation all decisions made by the people like, wage contracts with labour, loan agreements with borrowers and property lease contracts among others will account for the same per cent annual rise in the interest rates, rent and wages so as to compensate for inflation. If interest rates, wages, rent etc. rise at the speculated rate of inflation, then there will exist no cost of

inflation apart from the two following types of costs – shoe-leather costs and menu costs which are not massive.

#### Shoe-leather Costs

When rate of inflation increases, nominal rate of interests on deposits held by banks rises, the interest foregone by keeping currency is thus on the rise. In such a situation people will hold relatively less money with them and keep a larger amounts of money in bank deposits for as long as possible. Accordingly, they will opt to withdraw lesser money than withdrawing a large amount of currency from banks at a time, which is enough to meet daily expenses for a week. This will lead to the people making more trips to the banks for cash withdrawal resulting in larger costs. These costs include wear and tear of the car, expenditure on petrol and wastage of time. This is metaphorically known as shoe-leather costs of inflation, as more often walk to banks leads to wearing-out of one's shoes leading to expenditure on new shoes.

Menu Cost is the other type of anticipated inflation, derived from the cost incurred by restaurants for printing a new menu. They occur due to high inflation which requires the restaurants to change their printed prices more regularly. Constantly increasing prices tends to be more expensive as firms are required to print new catalogues listing the new prices and re-distribute them among the public. They also spend money on new advertisements to educate the public about their change in prices.

Another inflation cost emerges due to firms experiencing menu costs and failing to update their prices frequently enough. Given this lack of update in prices, the higher rates of inflation, and leads to a greater variance in relative prices of firms. Therefore when because of inflation the relative prices of firms during a year are variable when compared to overall level of prices, this leads to a distortion in production of output and thus leads to microeconomic inefficiencies in allocating resources (Mankiw, 2003).

Inconvenience of Living Lastly, changing price levels leads to an inconvenience in terms of living which is another social cost of inflation. The value of transactions is measured by

money. When there exists inflation in the economy money changes, which causes it to become hard to calculate the real value of transactions every time a transaction is carried out during the year.

The steadily increasing price level making it harder to make decisions optimally regarding saving and investment and therefore do rational financial planning over an extended time period. In the words of Mankiw (2003), “A dollar saved today and invested at a fixed nominal interest rate will yield a fixed dollar amount in the future. Yet the real value of that dollar amount – which will determine the retiree’s living standard – depends on the future price level. Deciding how much to save would be much simpler if people could count on the price level in 30 years being similar to its level today.”

### **1.1.2 Cost of Unanticipated Inflation:**

Anticipated inflation has a less significant and disruptive effect than the cost of unanticipated inflation rate. The substantial effect of unanticipated inflation is that it arbitrarily re-distributes wealth among individuals. Take for example the fixed nominal value of assets.

In the period 1995 and 2006, in India, the price level increased by approximately 100 per cent. Implying that people holding assets fixed in nominal terms in 1996, would face a substantial decline in their purchasing power in real term. A government bond maturing in 10 years with a Rs. 1000 face value and a nominal interest rate (in 1996) of 8 per cent will have a much lower value in 2006 when the bond mature and Rs. 1000 is returned to the holder than when purchased in 1996.

Accordingly, unanticipated inflation has a harmful effect on the individuals, who retire on fixed nominal pensions. In a couple of years due to inflation, the purchasing power of the pension will fall drastically and thus bringing down his standard of living. This is how unanticipated inflation hurt people with fixed nominal pensions. Many private companies agree upon fixed nominal pension for their employees which harm them greatly when inflation is greater than expected.

Workers and the private firms often agree on fixed nominal pension payable to the workers after retirement. Workers are greatly harmed when inflation is higher than anticipated. Similarly, greater than expected rate of inflation harms creditors thus; inflation redistributes wealth in favour of debtors.

## **1.2 Inflation and Long-term Economic Growth**

Mankiw (2003) argues that inflation especially in developing economies has detrimental effects on long run growth. Some economists argue that creeping inflation or mild inflation has a positive effect on the long-run economic growth. In reference to their argument they used the example of the industrialized countries of today, in the eighteenth and nineteenth centuries when they experienced rapid growth rate of output which was seen in the long periods of inflation in these economies.

The main force behind the process of economic growth has seen to be higher profits caused by inflation. It has been argued that the lag in wages to the increase in price levels creates a larger profit margin for the firms and industries. This increases the share of profit in the national income.

Those receiving these profits in the form of income are the higher income class who tend to save more than the workers. Resulting in an increase in savings in turn ensures higher investment rates. With higher investment there is more accumulation of capital, rapid capital accumulation leads to a greater rate of economic growth in the long run.

An alternative perspective is, when wages lag behind the increase in prices, inflation leads to a large diversion of resources away from producing consumer goods for wage earners to producing capital goods. There is then a rise in the growth of the productive capacity in the economy and its productivity of labour bought about due to the increased rate of expansion in capital stock generating rapid economic growth.

A widely accepted fact is that inflation retards the rate at which capital accumulates in an economy, which may be due several reasons. Firstly people are eager to spend the money

whose value is falling due to rapid inflation in hopes to spend it before its value further depreciates. There then follows an increase in consumption which lowers savings. People then observe that such inflation depletes the purchasing power of their savings discouraging them to save.

The increase in the general price levels causes a larger portion of people's income to be used for consumption to sustain their previous standard of living, thus further eroding savings. Thus, inflation is not only a disincentive to save but also curbs the ability to do so.

Secondly, increasing prices result in unproductive investment, for instance, investment in gold, jewellery, real estate, construction of houses etc. These investments fail to add to the productive capacity of the economy and are deemed useless from the economic growth perspective. Although, inflation may result in higher investment much of it is unproductive. Inflation in such ways wastes economic surplus in unproductive investment.

Thirdly, inflation sharpens the problem of poverty in countries, predominantly in developing countries and is considered the foremost enemy of the poor. Because of increasing prices the poor are unable to maintain the basic standard of living and as a consequence putting more people below the poverty line. Inflation also pushes the consumption of the poor below the standard required to maintain health and efficiency or the productive consumption. In India the quick and successive inflation of the past years is equally responsible for the rise in the number of people operating below the poverty line as is the shortage of job opportunities.

Fourthly, inflation harmfully influences the balance of payments hampering the economic growth. When the domestic good prices because of inflation, they are unable to compete in international markets and as a result there is lesser incentive for exports.

Alternatively, when prices increase domestically in relation to foreign goods prices, imports increase. This fall in the exports accompanied by a rise in imports leads to an emergence of a state of disequilibrium in the balance of payments which may result in a foreign exchange crisis in the long run.

The lack of foreign exchange limits the countries imports including the need for fundamental materials and capital goods required in the process of industrial growth of the economy. The India in the period of 1988-92 experienced a drop in foreign exchange reserves to critically low level and there emerged in the economy a state of proving the argument.

There is a lack of clear agreement regarding the effect of moderate or mild inflation, whether it encourages saving thus ensuring increased rates of capital accumulation and growth. Although, there exists unanimity that rapid inflation is a disincentive to saving and curbs economic growth.

In the case of hyperinflation, the influence of savings on inflation depends upon the existence of a lag in wages. The industrial economies such as the U.S.A., Great Britain, France etc., saw an emergence of a lag in wages during before World War II, though for the years after it there exists no such substantial evidence. Presently wages catch up quickly to the increasing price levels.

Though there is sufficient evidence showing and decrease in the share of profits in the national income in a few developed economies accompanied by an increase in wages has years following World War II. Thus, "To the extent that rate of long-run economic growth depends on the rate of capital accumulation, a major basis for the conclusion that inflation promotes rapid economic growth is undermined given that wages no longer lag during inflation as they apparently did in time of past."

Although, it should be mentioned that some developing countries of the world like India in which there exists largely unorganised labour and weak trade unions of labour and also a shortage of information causing a lag in wages when the economy faces inflation.

Indian businessmen tend towards making unproductive investment like, gold, jewellery, property and palatial houses which see a rapid increase in prices during inflation. This form of investment leads to retard productivity and growth and as it further promotes disparities in the distribution of wealth and income which makes it an enemy of social justice.

Following the arguments above, holding the goal of monetary policy as an increase in price levels lead to a detrimental situation in the economy and the citizens of the country. Such monetary policy goals are not feasible for the economy as the increasing price levels are hard to control and often lead to hyperinflation.

Emergence of inflation in any economy is not a welcome phenomenon as it reduces the standards of living and purchasing power of the people. Inflation rates have decided the future of the incumbent prime ministers and governments to the extent that few presidential candidates have called it the number one enemy of America. Rising general price levels work against the poor making them anti-poverty.

It leads to unequal distribution of income and wealth making the wealthy wealthier and pushing the poor deeper into the poverty web working against the general justice prevailing in the society. Consistently rising price levels or inflation reduces the national production and employment and curbs economic growth in the long run, this phenomenon is seen most in developing countries like India.

### **1.3 Inflation and policies**

In India, the responsibility of monitoring and controlling inflation lies in the hands of the Reserve Bank of India (RBI). The RBI usually functions as an independent and autonomous organisation, far away from the reach of the Central Government. The primary reason for this is the existence of the two channels to control an economy – the fiscal policy and the monetary policy. It is through the fiscal policy that the Government controls and adjusts its expenditure and taxes in order to keep a track and/or to steer the economy. The tax and expenditure programmes of the Government are the realisations of the fiscal policies. On the other hand, the monetary policy lies in the hands of the central bank of the economy (RBI in the case of the Indian economy). The monetary policy is steered to keep money supply under control and hence ensure price stability and higher economic growth. The primary instruments of the central bank, in order to do so, are the rates of interest.

If the RBI lowers the interest rates, the money supply will increase faster as a result of which there will be more money in the economy for people to spend. This will lead to increased consumption of goods and services putting an upward pressure on aggregate demand which leads to a rise in prices of commodities resulting in inflation. Similarly an increase in interest rates by the RBI reduces money in the economy and thus reduces consumption pulling down the aggregate demand and prices charged by producers so as to clear their inventories. This phenomenon in turn leads to deflation.

A fall in interest rates inclines the economy to grow faster. In times where the economy faces disinflation and a steady currency, lowering interest rates is a reliable option to increase the growth rate of the economy. However the central bank under the leadership of Raghuram Rajan believed in investing heavily in the economic assets along with an expansionary fiscal policy. They looked towards lowering operating costs of companies by reducing the interest rates. A reduction in operating costs will lead to higher investments and put an upward push on consumption.

To maintain standard of livings in light of inflation, the incomes of people have to rise simultaneously. The rise in prices is battled with increasing the dearness allowance of government employees and after a slight time lag the wage and salaries of those employed in the private sector are too increased. The ones to suffer are the self-employed and those with a fixed income who find it hard to increase their prices. The poor suffer tremendously with consistent inflation especially in the prices of essential item, like food grains. India in the period of 1970-80 experienced high inflation rates as compared to the rates before then. For the period of 2010-2013, the CPI was calculated to be in double digits. The CPI and WPI prior to January 2013 were relatively high which lead the RBI to follow a rigid monetary policy.

According to the Reserve Bank of India's Annual report (2016-17), in May 2016, the Reserve Bank of India (RBI) Act, 1934 was amended to provide a statutory basis for the



implementation of the flexible inflation targeting framework. The amended RBI Act also provides for the inflation target to be set by the Government of India, in consultation with the Reserve Bank, once in every five years. Accordingly, the Central Government has notified in the Official Gazette 4 per cent Consumer Price Index (CPI) inflation as the target for the period from August 5, 2016 to March 31, 2021 with the upper tolerance limit of 6 per cent and the lower tolerance limit of 2 per cent. Prior to the amendment in the RBI Act in May 2016, the flexible inflation targeting framework was governed by an Agreement on Monetary Policy Framework between the Government and the Reserve Bank of India of February 20, 2015. The current monetary policy framework aims at setting the policy (repo) rate based on an assessment of the current and evolving macroeconomic situation; and modulation of liquidity conditions to anchor money market rates at or around the repo rate. Repo rate changes transmit through the money market to the entire the financial system, which, in turn, influences aggregate demand – a key determinant of inflation and growth. Once the repo rate is announced, the operating framework designed by the Reserve Bank envisages liquidity management on a day-to-day basis through appropriate actions, which aim at anchoring the operating target – the weighted average call rate (WACR) – around the repo rate. The operating framework is fine-tuned and revised depending on the evolving financial market and monetary conditions, while ensuring consistency with the monetary policy stance. The liquidity management framework was last revised significantly in April 2016. The RBI uses multiple direct and indirect instruments for conducting monetary policy such as, repo rate, reverse repo rate, liquidity adjustment facility, bank rate, cash reserve ratio, statutory liquidity ratio, open market operations, to name a few.

**Measures to Control Demand-Pull Inflation:**

Inflation caused by the existence of a surplus demand over the supply of goods and services at the existing price level, is known as demand-pull inflation. A number of fiscal and monetary measures can be used to manage this inflation. We discuss below the effectiveness

of the various policy measures and tools to check demand-pull inflation as caused by surplus aggregate demand.

a) **Fiscal Policy: Reducing Fiscal Deficit:**

The budget is the framework of how the government raise money to fund its activities. A fiscal deficit arises due to an excess of the government expenditure over revenue.

It should be mentioned here that a government budget is made of two parts, the revenue budget and capital budget. The revenue budget has on its receipts side revenue raised from taxes, interests, fees, profits from public undertakings and on the expenditure side consumption expenditure by the government on goods and services which are made to meet the requirements of defence, civil administration, education and health services, subsidies on food, fertilizers and exports, and interest payments on the loans taken by it in the previous years are important items. In the capital budget, the significant receipts are market borrowings by the government from the banks and other financial institutions, foreign aid, small savings (i.e., Provident Fund, National Savings Schemes etc.). The important expenditure on the capital budget is that of defence, funding of public enterprises for developmental purposes, especially those relating to infrastructure projects and loans to states and union territories.

The fiscal deficit can be financed in two ways, firstly, by the central bank lending to the government against its own securities resulting in the expansion of money supply thus adding to inflationary pressure in the economy. This was considered the main factor behind the demand pull inflation which emerged in India. This form of financing formerly known as deficit financing is now popularly known as monetisation of the fiscal deficit. Of late, India finances its fiscal deficit through the sale of bonds by the government usually bought by banks, insurance companies, mutual funds and corporate firms.

The rise in total expenditure resulting from the budget deficit leads to excessive total demand and tends to push inflation rates higher, especially if the economy has an inelastic aggregate supply of goods.

A rise in the aggregate demand may not result in demand-pull inflation in case the aggregate output rises essentially of the dominant consumer goods like food grains, cloth, the excess demand resulting from an increase in spending would be met by an increase in the supply of output. But if the economy is operating at full capacity and an increase in expenditure occurs, it tends toward the emergence of demand pull inflation. So if we have, to curb this inflation the fiscal deficit has to be brought down.

The International Monetary Fund (IMF) has advised India to check their fiscal deficit to 3% of the Gross Domestic Product (GDP) if inflation has to be curbed. To further reduce the fiscal deficit more revenue can be raised by increasing taxation. In a country like India the scope of raising funds from taxes is wide as in both personal and corporate income taxes as there exist a lot of irrelevant exemptions resulting in a low effective rate of income tax. For this reason a corporate income tax of 33% the effective rate of tax on corporate income is only 24% due to these unnecessary exemptions. Removing these tax exemptions will raise the tax revenue by a significant amount.

Tax evasion a widespread problem in India, leads the generation of black money on a large scale while it can be used to finance the fiscal deficit or curb it by reducing irrelevant expenditure especially ill targeted subsidies. Another frequent argument in India is the extent of the non-planned expenditure on defence, police and general administration and subsidies for food, fertilizers and fuel oil, though it has been hard to implement any cutback in this expenditure by the government.

There seems to exist inefficiency on a large scale in the way resources are utilised widespread corruption on the government's part in the process of spending the money. Therefore, both the problems of inefficient resource allocation along with mobilisation accompanied by

cutting back the irrelevant government subsidies and other expenditure will help in curbing inflation.

**b) Monetary Policy to Control Inflation: Monetary Tightening:**

Monetary policy refers to the adoption of appropriate policy with respect to interest rate and credit availability. It is a significant tool in decreasing aggregate demand to curb inflation. As a tool for regulating demand, monetary policy can work in two ways.

Firstly, it can influence the cost of credit and secondly, it can affect the availability of credit for private business firms. A look at the first factor, cost of credit, reveals that a rise in the rate of interest rates increases the cost of borrowing from financial institutions thus acting as a dis-incentive to private firms from creating more credit by borrowing. This acts against inflation and helps control it. Lower interest rates or what is known as the cheap credit policy is fitting when the government wants to promote private investment to augment growth. For this specific reason up till 1972 India maintained low credit rates. The higher rate of interest or dear money policy has been used as an instrument to control inflation in India.

There are several other tools that can be used to manage demand like repo rate and reverse repo rate. The Repo rate is rate at which Reserve Bank of India lends funds to the commercial banks for a short period. To control inflation repo rates are increased, this hike in interest rate leads to a rise in cost of funds which if the bank has low reserves it compensates by charging higher interest rates. The followed hike in interest rates brings down the demand and thus generation of bank credit for investment and auto loans, housing loans. Banks then to mobilise funds raise their deposit rates to attract people to deposit more money. Consequently, the increase in interest rates of bank deposits induces higher savings by households and reduces the total expenditure on consumption. Higher rates of interest discourage firms from holding larger inventories and consumer durables and thus, move towards reducing aggregate demand.

The monetary transmission system only works if liquidity of banks is curtailed, which can be done by the central government increasing the cash reserve ratio by sale of government securities. The banks are required to have low levels of reserves for the tool of repo rate to work because if banks hold excess reserves they will not need to compensate by raising their lending rates RBI increases the repo rate.

It is worth mentioning a relatively new monetary theory which lays emphasis on the fluctuations in the availability of credit over the rate of interest or the cost of credit. It believes the former is more efficient to regulate demand. There are several ways to reduce credit availability. Firstly, through open market operations the RBI can reduce the availability of credit in the economy. In the open market operations the government sell securities which are usually purchased by financial institutions which pay for them using cash reserves, thus controlling the amount of credit they can create. Resulting in the decrease in the generation of credit thus, curbing demand. These have however not played an important role as a tool against inflation as it was narrow although this is no longer a problem post the financial reforms.

Presently the RBI uses open market operations to manage the liquidity levels of the banking system. Not more than a fraction of the government securities are sold to the public, it is the financial institutions like commercial banks, LIC and Provident Funds for who it is mandatory to invest a share of their funds.

In India the Cash Reserve Ratio (CRR) is as a tool in controlling inflation. It is mandatory for banks to keep a share of their cash money as reserves against their demand and time deposits. This is called the cash reserve ratio. To decrease the liquidity of banks and reduce credit availability RBI can increase the CRR.

### **Statutory Liquidity Ratio (SLR):**

The other tool of the Reserve Bank of India for managing credit availability is the statutory liquidity ratio (SLR). Apart from CRR, banks are required to keep a particular minimum

percentage of money against their deposits in specified liquid assets predominantly government securities. To reduce credit availability the private firms the RBI has often increased the SLR to reduce the liquid assets held by banks.

### **Limitations of Tight Monetary Policy:**

Tight monetary policy for controlling inflation has its own limitations. First and foremost, monetary transmission mechanism may be lacking and increasing short-term interest rates (CRR or SLR) may not actually lead to the curbing the availability of credit as they might have with them an excess of liquid reserves not requiring them to increase their lending rates. Due to which credit availability is not reduced. Secondly, if the economy is operating in a boom period then aggregate demand is relatively high and thus credit demand may not be influenced by an increase in the interest rate at which commercial banks lend money. According to Keynes (1940), expected rate of return or marginal efficiency of capital is more important a factor in influencing investment than interest rates. Thirdly, presently in India external commercial borrowing is widely prevalent even more so when the foreign countries are facing low interest rates. Thus, RBI fiscal policy will be ineffective until the debt capital inflow or external commercial borrowing is curbed. Fourthly, when the stock market prices are rising and aggregate demand is quite high, the corporate sector is able to raise funds itself more easily from the capital market. This will also offset the impact of tight monetary policy of the RBI to control inflation.

If private corporations hold sufficient internal funds from retained profit earnings, they can be utilised to fund further expenditure and thus contribute further to the aggregate demand hence, countering the tools under the monetary policy to curb inflation.

In India, despite the repo rate has being increased a total of 13 time since March 2010 till November 2011 from a 4.75% to 8.50%, inflation as calculated by the WPI was still high. It was estimated at 10% in September 2011, 9.73% in Oct. 2011 and 9.11% in Nov. 2011.

Post Nov. 2011 inflation as calculated by WPI fell due to the drop in food inflation because of two factors, the base effect and easing of the supply position of some food articles. Hence tight monetary policy was unable to control inflation in spite of 3.75 points hike in the repo rate. The RBI blamed the large fiscal deficit for the inefficiency of the tight monetary policy in controlling the rise in prices. The large budget deficit was accompanied by a rising aggregate demand which was augmenting inflation. The RBI held the view that only when the fiscal deficit is curbed can a tight monetary policy work in reducing inflation. Besides, the RBI blamed supply-side factors responsible for food inflation which played a large role in the general increase in inflation.

Lastly, If the supply side factor of the economy are responsible for the inflation like there is a shortage in the production of food grains and other essential food articles such as milk, vegetables, fruits etc. and fails to meet the demand for reasons such as production bottlenecks there will emerge demand-supply disparities or inequalities resulting in inflation. This form of inflation cannot be checked by manipulating interest rates. We saw such a situation in the fiscal year 2010-11 when there was a lack of food grains due to irregular rainfall and inflationary pressures emerged in the economy increasing the price of food grains to approximately 20% by the end of 2009. These rise in prices prevailed well in to the FY 2010 and the tight monetary policy was ineffective in curbing inflation.

Similarly, in the fiscal year 2010 and 2011 there was a lack of protein-based food products like fish, eggs, meat, fruits and vegetables, pulses, milk, which largely led to persistent food inflation. Only post October 2011, the food-inflation began to fall, and inflation as estimated by WPI also fell.

Consequently, supply-side inflation can also be due to increase in the prices of petroleum products which are demanded by consumers and the tools of tight monetary policy are inefficient. If the production in major industries (steel, cement, coal) decreased as seen in

India during the period 2011-12, there will emerge supply-side bottlenecks resulting in supply side inflation in these industries.

If food inflation has to be curbed, long term measures need to be undertaken which will increase the productivity of the agricultural sector and hence of food grains. This can be done by introducing new technologies and land reforms. While in the short run food grains need to be pumped into the economy through the public distribution system keeping in check the possibilities of arising black markets. Food grain inventories need to be tapped into and made available for the general public for sale assuming there exist a surplus of food grains and if not they should be imported.

When the public anticipates a rise in price levels or shortage in supply of these fundamental goods there emerges a tendency to hoard for future use. Increasing interest rates may be implemented to prevent speculative hoarding or as mentioned earlier credit control can be an effective tool to curb hoarding of these items.

#### **1.4 Measures of inflation:**

The indices that are most widely used in the Indian economy are the Wholesale Price Index (WPI) and four measures of Consumer Price Index (CPI). WPI and CPI vary widely with respect to their composition. To begin with, food item prices receive larger weightage under CPI (ranging from 46%-69% across the 4 measures) vis-à-vis a 14% weight in WPI. Also, services are not incorporated in WPI at all whereas they enter the CPI in various weights (because of the same reason WPI has been losing its representativeness). Hence it can be gathered that CPI is more sensitive to food price changes and service price inflation. On the other hand, the fuel group gets a 15% weight in WPI vis-à-vis a 5.5%-9.5% in the various CPIs. Thus international crude oil prices affect WPI more than CPI. The latest revision faced



by the WPI was in the year 2010 when its base-year was changed from 1993-94 to 2004-05<sup>1</sup>.

The table below shows the progression of the change in base-years for WPI.

<b>Base</b>	<b>Year of Introduction</b>	<b>No. Of Items</b>	<b>No. Of price quotations</b>
Week ended 19 <sup>th</sup> August, 1939	10 <sup>th</sup> January, 1942	23	23
End August, 1939	1947	78	215
1952-53 (1948-49 as weight base)	1952	112	555
1961-62	July, 1969	139	774
1970-71	January, 1977	360	1295
1981-82	July, 1989	447	2371
1993-94	April, 2000	435	1918
2004-05	September, 2010	676	5482

**TABLE 1.1: EVOLUTION OF WPI BASE YEAR - SOURCE: MOSPI (2014)**

The WPI essentially depicts the changes in the prices of manufactured products as they exit the factory. For a very long time, the Reserve Bank of India (RBI) has used the WPI to measure inflation in the Indian economy. However, during the tenure of Dr. Raghuram Rajan as the Governor of RBI, the central bank has adopted CPI to measure inflation henceforth (as per suggestions of the Urjit Patel Committee Report, April 2014). The WPI in the country has been known to prove to be a comparatively more real-time indicator of inflation than the CPI (CPI has been tagged as the ‘lagging indicator’ of inflation). Taking cue from most of the developed economies around the world (who have been using CPI as their primary measure of inflation), the RBI decided to make the move mentioned above.

<sup>1</sup> Result of a Working Group set up with Prof. Abhijit Sen (Member, Panning Commission) as the chairman

However, the WPI has a more comprehensive and economy-wide coverage and the weights in the commodity basket are based on the value of quantities traded in the domestic market (Statistical Yearbook 2011, Ministry of Statistics and Program Implementation (MOSPI)). The study hence uses WPI to represent inflation for the causality analysis.

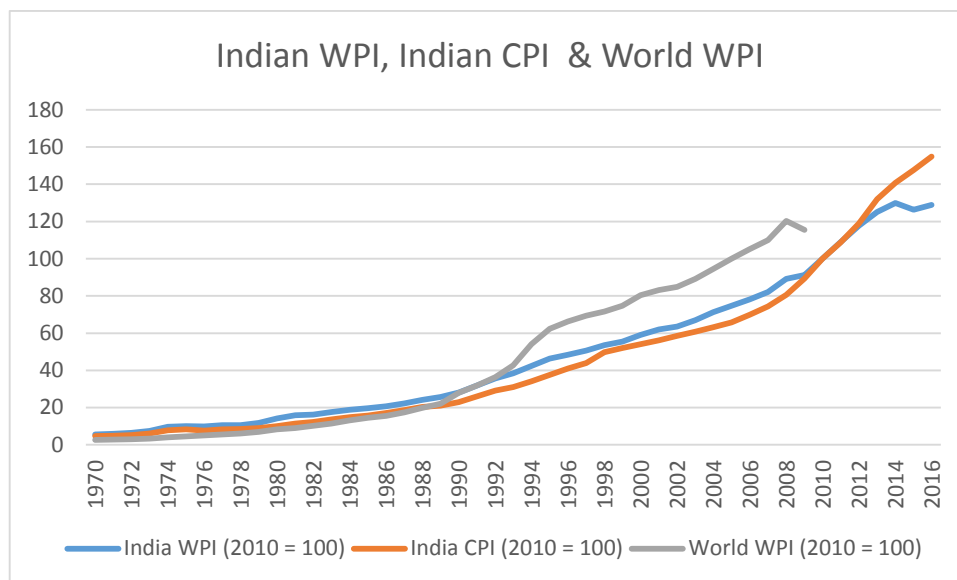
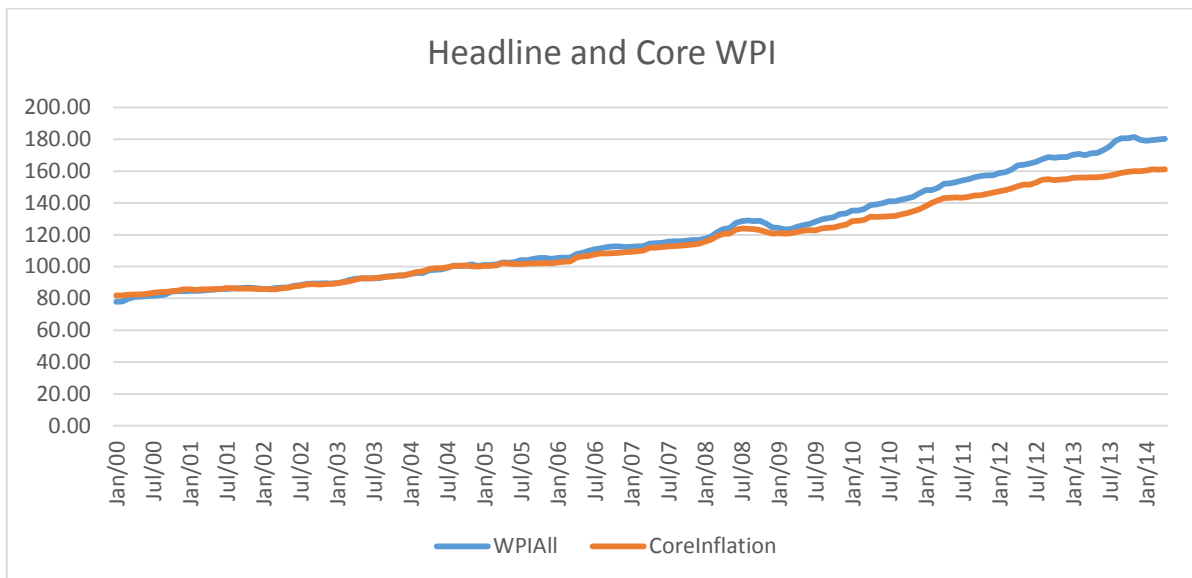


FIGURE 1-3: INFLATION COMPARISON - SOURCE: WORLD BANK

The figure above shows the movement of the Indian CPI and WPI for a period of over three decades. The two measures of inflation are found to be closely linked and moving towards a convergence over time. However, in the recent times the two series are seen to diverge (mainly due to the difference in the components of the two and contribution of the service sector). The correlation coefficient between the two series is found to be 0.99, revealing the strength of the linear relation between the two measures. The two series being so highly correlated with each other, it may be said that the results depicted by using one of the measures for the causality analysis will not be greatly deviated from the results expected by using the other.

A commonly used way to analyse inflation data is to use the ‘core inflation’ instead of the headline inflation. Within WPI, non-food manufactured inflation is considered as core inflation which is a measure of inflation excluding the volatile components of food and

energy prices. Including food and energy prices may misguide the representations as it may seem that overall prices are increasing or decreasing more rapidly than they actually are. According to Motley (1997) “although these prices have substantial effects on the overall index, they often are quickly reversed and so do not require a monetary policy response”. Hence the current study uses core inflation for the analysis.



**FIGURE 1-4: HEADLINE AND CORE WPI – INDIA SOURCE: OFFICE OF ECONOMIC ADVISER AND AUTHOR’S CALCULATIONS**

The above figure plots the headline and core WPI for India for the chosen period of study. The divergence between the two series that is found to have begun from 2005 approximately, sets the stage for relying on the core version of WPI over the headline version.

### 1.5 Motivation for the Study

This sets the stage for the necessity of understanding causality of inflation not only in the time domain but also in the frequency domain and trying to model it effectively so that targeting the same becomes easier. It is also evident that effect of dis-aggregated prices on the core inflation should play a vital role and hence modelling core inflation as a function of the various dis-aggregated components along with some other macroeconomic variables should be able to shed better light on the general behaviour of inflation in the economy. However, a time domain analysis may not be sufficient since it ignores the cyclical effects (if any).

Hence, it is imperative to look as the spectral analysis to ascertain the cyclical or frequency wise nature of the causality. The theories of inflation address the time domain dependence of inflation on various factors but none of them explore the frequency domain causality to determine the long run and short run causality effects of such variables on inflation. The current study attempts to address this gap by conducting causality analysis in the frequency domain and then constructing SVAR models (based on the results received from the causality analysis) to represent inflation. The study also conducts innovation analysis to establish the effect of shocks in the selected macroeconomic variables on core inflation to understand whether the effects are shortlived or longlived and the significance of the effects.

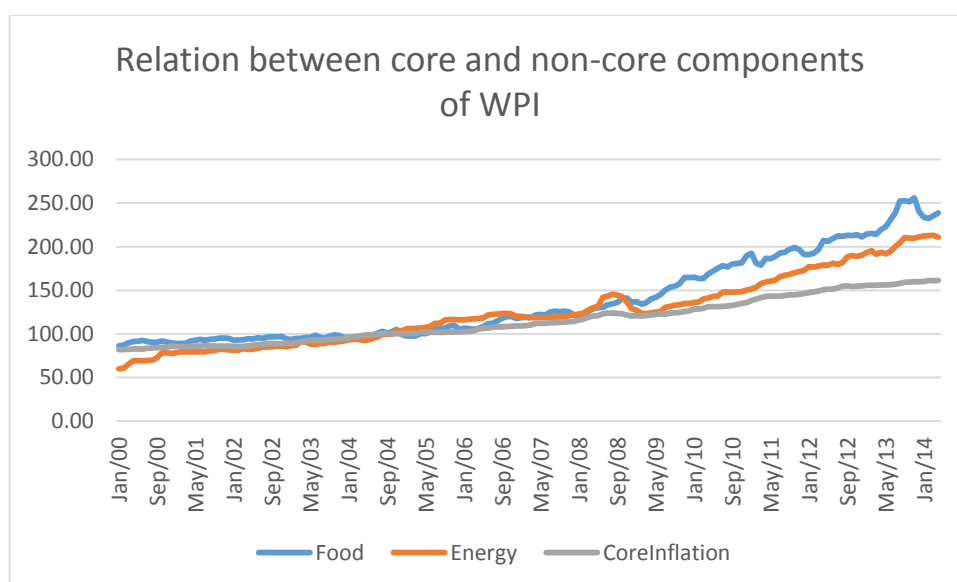


FIGURE 1-5: CORE & NON-CORE WPI – SOURCE: OFFICE OF ECONOMIC ADVISER AND AUTHOR’S CALCULATIONS

The figure above shows how core WPI is related with food and energy WPI (non-core components of WPI). Food inflation and energy inflation being two of the strongest reasons for driving overall inflation in the country (as cited by many studies), the study considers the two series while checking causality and modelling core inflation.

The other variables chosen for the study are international energy prices, money supply (all the four measures) and output gap as a measure of excess demand (computed through four filters: Hodrick- Prescott, Baxter-King, Butterworth and Cristiano-Fitzgerald).

## 1.6 The objectives and hypothesis of the study

### The objectives:

- a) To test whether the selected macroeconomic variables have significant causal effect on inflation
- b) To establish the direction and strength of the relationships
- c) To construct a model for inflation prediction

The hypotheses used for achieving the above-mentioned objectives are listed as follows:

- a) Domestic food price causes core WPI significantly
- b) Domestic energy price causes core WPI significantly
- c) Domestic output gap causes core WPI significantly
- d) Domestic money supply causes core WPI significantly
- e) International energy price causes core WPI significantly
- f) All the five macroeconomic variables have a positive effect on core inflation
- g) All the five macroeconomic variables (together) are able to explain core inflation in a statistically significant manner
- h) Each of the variables (individually) have statistically significant effect on inflation

## 1.7 Chapter Scheme

The study is divided into the following parts:

### Chapter 1 – Introduction

This chapter provides an overview of the incidence of inflation along with the effects on expected and unexpected inflation followed by the role of policies in tackling inflation and its relation with economic growth. The chapter also touches upon the trend of inflation and notes various measures of inflation and their interrelations. The chapter also provides the rationale of the study along with the research questions and a schema for the entire thesis.

## **Chapter 2 – Literature Review**

This chapter reports the literature available on the various variables that cause inflation. The section begins by discussing the existing theories that exist in the literature followed by discussion of studies that highlight various causal factors of inflation in India and otherwise moving on to studies related to each of the causal factors considered for the current study. Each sub-section contains literature for a particular variable, first from the global perspective and then in particular relation to studies on the Indian context (if any). The chapter notes the absence of a spectral analysis for causality of inflation for the selected variables for the current study.

## **Chapter 3 – Data and Methodology**

This chapter spells out the data and methodology used for the study. Some of the variables had to be constructed manually from the reported data. The process of doing the same is the primary focus of the chapter followed by the econometric methods used to test causal relations among the variables. The chapter begins by citing the significance of using core inflation instead of headline inflation as the measure of inflation for the study and explains the methodology used to construct core inflation series from the wholesale price index available from the Office of the Economic Adviser. Next, the section discusses various literature on use of filters for calculating output gap and highlights in particular the four filters used for the study, namely, Hodrick-Prescott, Baxter-King, Butterworth and Cristiano-Fitzgerald filters. The methodology for constructing the filters and extracting the cyclical component and further constructing the output gap series are discussed thereafter. The sources of the variables chosen for the study are discussed. Next, the methodology for the econometric tests are discussed. The discussion begins with tests for stationarity and seasonality, in particular the HEGY test, followed by ARIMA model used to filter the data to extract the residuals to be used for causality analysis. A discussion on Granger causality in

the frequency domain follows next ending with explanation of the method for innovation analysis – impulse response function and forecast error variance decomposition methods.

#### **Chapter 4 – The model**

The chapter reports the model constructed to check for causality effects of the chosen variables on core WPI. The section begins by highlighting all the variables used in the study followed by the structural VAR models constructed to test dependence of core WPI on each of the other five variables. The chapter includes the sixteen models being considered for the analysis – each model has one variant of output gap measure and one variant of money supply measure.

#### **Chapter 5 – Results and discussions**

This chapter of the study reports and explains the results for spectral causality and SVAR modelling with innovation analysis. The results show that only international energy prices have a long run causal effect on core inflation, food prices do not cause core inflation at any of the frequencies and domestic energy prices, output gap and money supply cause core inflation in the short run. The SVAR and innovation analysis shows that an unprecedented change in each of the variables (a shock) has significant effect on core inflation for subsequent periods of time and the variability of core inflation is explained significantly by each of the variables (except food inflation).

#### **Chapter 6 – Conclusions and policy implications**

The last chapter summarises the findings and points out the implications of the results. The results clearly show the endogenous nature of Indian core inflation and highlight the differences in demand side and supply side transmission mechanisms along with domestic and international effects on Indian inflation. This may be considered as a new way of looking at monetary policy making. The section also highlights the probable extension of the study.

## **2 Chapter 2. Literature Review**

This chapter reports the literature available on the various variables that cause inflation. The section begins by discussing the existing theories that exist in the literature followed by discussion of studies that highlight various causal factors of inflation in India and otherwise moving on to studies related to each of the causal factors considered for the current study. Each sub-section contains literature for a particular variable, first from the global perspective and then in particular relation to studies on the Indian context (if any). The chapter notes the absence of a spectral analysis for causality of inflation in the existing studies for the identified variables.

### **2.1 A glance through the existing theories of inflation**

In practice, it is not always easy to decompose the observed inflation into its monetary, demand-pull, cost-push and structural components. The shocks experienced by the prices are attributed to various factors. It has also been seen that inflation causes further inflation. The theories of inflation differ with the different views of why inflation occurs and how it should be corrected and also due to the wide range of economic disparities existing in the global economy. In developed economies the cause of inflation is largely attributed to the increase in money supply while in developing countries, it is not seen as a purely monetary phenomenon.

Inflation, based on where it originates from can be divided into the following types:

- a) Demand Pull Inflation
- b) Cost Push inflation
- c) Monetary inflation
- d) Structural Inflation
- e) Rational expectations driven inflation



### **2.1.1 Demand-Pull Inflation**

This form of inflation arises when the aggregate demand increases at a faster rate than the aggregate supply, that is, when aggregate supply is comparatively inelastic in nature. This phenomenon typically occurs when the economy grows faster than its long run trend rate of growth. The aggregate demand comprises of consumption, investment and government expenditures. When the demand grows faster than supply the firm responds by pushing up prices. A common example of such inflation was seen during the Lawson boom of the late 1980's in the United Kingdom when the economy was growing at a rate of 5% a year largely fuelled by increasing house prices and consumer confidence. This caused supply bottlenecks and led to increased prices.

John Maynard Keynes was one of the pioneers of this field and his followers emphasized that it is the increase in aggregate demand which causes demand pull inflation. The sources of demand were seen as multiple, that is, consumers could demand more goods and services for consumption or business men demanded more inputs for production. The larger gap between aggregate demand and aggregate supply the more rapid is the inflation. Increase in money income will lead to an excess of aggregate demand over aggregate supply and a consequent inflationary gap. Thus Keynes (1940) used the concept of inflationary gap to show an aggravated rise in prices. This may be looked upon as a phenomenon where the basic factor at work is the increase in aggregate demand for output either from the households or the entrepreneurs or government. This results in a situation where the currently available supply of output is insufficient to meet the rising demand.

For instance, given full employment when private investment or public expenditure rises, an inflationary pressure builds in the economy. According to Keynesian theory, inflation is when an inflationary gap exists in the economy when the total demand exceeds total supply or total output at full level of employment. The rise in price is a natural consequence of the excess of aggregate demand over aggregate supply which leads to inflation.

This gap may exist for a number of reasons. Aggregate demand consists of the sum of consumer spending, government expenditure on goods and services and probable net investment as decided by entrepreneurs. A rise in price levels is seen when the aggregate demand, consumption, government and investment exceeds the aggregate output at current price levels. Inflation is a result of continuous increases in price levels and thus requires a continuous increase in aggregate demand.

Contemporary macroeconomics explains inflation with the AD-AS model. Here inflation can be caused by either a demand shock i.e. an increase in aggregate demand or a fall in the aggregate supply or a supply shock i.e. a rise in production costs. In the absence of supply shocks, demand pull inflation occurs when aggregate demand shifts upward. Thus, demand pull inflation occurs when any component of aggregate demand rises and goes unmatched by an increase in taxes (that is, deficit spending by the government financed by either creation of new money by the central bank or borrowing by the government from the market).

To further examine the cause of demand pull inflation, we assume that the government opts for expansionary fiscal policy which leads to an increase in expenditure without increasing taxes to finance the increase by borrowing from the central bank, the RBI in the case of the Indian economy. This results in an increase in the aggregate demand.

If the supply of output does not meet the rise proportionately in the short run, then a demand–supply imbalance arises which leads to demand pull inflation and an increase in the general price level. Similarly, if firms see an opportunity to make profits and begin to increase their investments, and finance these new investments by borrowing from banks because they were unable to finance it through their savings out of profits, and savings invested by the public in them. The new investment by the business firms increases the aggregate demand for goods and services. Inflation will only occur when the total output or supply fails to increase adequately to match the rise in demand.

Demand pull inflation is seen to occur in an economy working at natural rate of unemployment or the full employment level of resources. This is because when the aggregate demand rises above the natural rate of unemployment level of output, output cannot be increased sufficiently without a significant increase in cost.

Many developing countries like India face problems in quantifying employment, unemployment and full employment of the nation. For this reason in the context of India we assume that the full capacity level of output is the one above which the supply cannot be increased. Note that Keynes (1940) in his booklet “How to pay for the War” distributed amid the Second World War, illustrated inflation with respect to abundance of demand for goods over the total supply of the output (full-employment output). This inflationary gap, as indicated by him, prompts a rise in costs. According to Keynes the aggregate supply curve at full-employment level, is vertical. Along these lines, Keynes clarified inflation as a demand-pulled force. Hence, the theory of demand-pull inflation is related with Keynes.

Inflation in India: Causes, Effects and Curve. (2017) explains how modern macroeconomics differentiates between long run and short run supply curve. The long run supply curve is vertical at full employment level or full capacity output level for developing countries. This full capacity level is called potential output. On the other hand, the short run aggregate supply (SAS) curve, is upward sloping because with a rise in employment we see diminishing return to labour which in turn increases the marginal cost of production.

The SAS curve beyond potential level of output continues to slope upward to the right, because due to various factors as some amount of unemployment exists even at the full employment level. Thus, the employment of labour may rise with a fall in the natural levels of unemployment under the pressure of aggregate demand.

If the government decides to increase expenditure on goods and services, and finances this increase by borrowing from the RBI, it would require the RBI to print more money to fund them. With the rise in government expenditure the aggregate demand also increases and the

AD curve shifts to the right which then in turn results in a rise in price levels and the real GDP.

The price level rises due to the shift of the aggregate demand curve because the aggregate supply fails to rise proportionately to the rise in aggregate demand and thus creates an imbalance between demand and supply.

If the SAS curve was to be horizontal then the total supply would have risen proportionate to the increase in the total demand when the AD curve shifts. Due to demand supply imbalances the aggregate demand rises relatively more than the increase in the aggregate supply.

The response to the initial rise of aggregate demand is not restricted to a particular equilibrium point. The wage rate is kept constant when we draw the SAS curve. The shift in the aggregate demand curve caused an increase in price levels and the real GDP level.

Keeping the wage rate constant, an increase in the price levels will cause a fall in the real wage rates of workers. Workers will begin to demand higher wages when they see that a rise in price levels caused by increased total demand has reduced their real wages.

Also, the equilibrium level to the right of the potential GDP shows that the unemployment level has reduced to a level below that of the full employment level and thus causes a shortage in the labour supply implying a rise in the wage rates. The wage rate at the new equilibrium in this case, rises by an amount which is equal to the increase in the level of prices. Thus, real wage has been restored at the level prior to increase in aggregate demand.

It is important to note that the shift of the equilibrium and wage rate will not be achieved in a single shift but by various adjustments of the short run aggregate supply curve over a period of time. The SAS curve shifts upward to restore the level of wage rate existing prior to the increase in demand and also to restore the real GDP to the potential level of GDP.

### **Demand-Pull Inflation Process to Cause Continuous Rise in Price Level:**

Demand pull inflation is when due to increased demand, price level of the economy rises and the wages increase enough to bring the real wage rate to the old levels prior to the rise in

demand to the full employment level. For a continuous rise in aggregate demand the government has to maintain a persistent and large budget deficit which it finances by borrowing from the Reserve Bank of India or from the market year after year. This will ensure a continuous rise in the aggregate demand and hence the price levels and thus causes inflation.

If the Central bank of the country consistently increases the quantity of money, a continuous rise in the total demand will occur and so will the price levels.

Inflation in India: Causes, Effects and Curve. (2017) shows a continuous increase in price levels in which it is assumed that the government has a deficit budget every year, which it finances by borrowing from the central bank of the country. As a result of which the aggregate demand rises every year bringing about a continuous increase in the general price levels.

Assuming that the rise in government spending is financed by borrowing from the Central Bank, with the rise in the price level there will be fall in the real wages of labour which will result in them demanding a higher wage.

Now, if in the following year the government incurs once again a budget deficit and finances this additional increase in spending by borrowing even more from the country's central bank. This causes the aggregate demand curve to shift right and results in a further rise in price level.

### **Inflationary Expectations:**

An important factor in bringing about inflation is the inflationary expectations. In the event that a firm expects that its opponent firms will raise their costs, it might likewise bring its own particular cost up in expectation. The expectations of future price levels play a crucial role in the firm's decision making.

According to Case and Fair (2007) in their book titled "Principles of Economics", "Expectations can lead to an inertia that makes it difficult to stop an inflationary spiral. If

prices have been rising and if people's expectations are adaptive, that is, if they form their expectations on the basis of past pricing behaviour – that firms may continue raising prices even if demand is slowing.” Therefore, to control inflation, steps ought to be taken to break the inflationary expectations.

### **2.1.2 Cost-Push Inflation**

This theory has been observed since medieval times but only became widely known post the Second World War and was termed the “New Inflation”. This theory states that prices are pulled up by not only a rise in demand but also pushed up due to the rise in costs of production. This increase in costs of production is seen due to rise in cost of raw materials largely, wage increases enforced by unions also, an increase in profit margins by the employers. A demand by unions to increase wages pushes producers to increase prices. This increase in prices leads unions to demand even higher wages and the wage cost spiral continues. This may also be termed wage push inflation. When prices rise due to increase in profit margins is known as profit push inflation. This occurs when the oligopolistic and monopolistic firms increase the profit margins to offset the rise in production and labour costs. Since in such an economy there exists imperfect competition and the firms are able to charge higher prices for their products.

The basic cause of such inflation is the rise in money wages faster than the increase in the productivity of labour. The inflationary pressure builds up on the supply side rather than demand and spreads throughout the economy.

Now looking at cases where without an increase in aggregate demand there still is a rise in prices. This may occur when there is an initial rise in the costs irrespective of a rise in the total demand.

Inflation in India: Causes, Effects and Curve. (2017) notes the four main autonomous increases in costs which generate cost-push inflation have been suggested as follows:

- i. Oil Price Shock
- ii. Farm Price Shock
- iii. Import Price Shock
- iv. Wage-Push Inflation

#### **2.1.2.1 Oil Price Shock:**

The seventies experienced an increase in marginal costs due to supply shocks which became a significant factor in bringing about cost push inflation. The rise in the price of energy inputs like a hike by the OPEC in the crude oil prices which caused an increase in petroleum products prices. These supply shocks in the 1970's produced cost push inflation. The sharp hike in oil prices resulted in inflation through all countries importing oil. The rise in oil price also occurred in 1990, 1999-2000 and again in 2003-08 leading to an increase in the rate of inflation countries like India which imported oil.

Of late a substantial amount of fluctuations have been seen in the oil prices going up or down. An increase in the oil prices not only increase the rate of inflation but also have adverse effects on the balance of payments which results in the rise of current account deficits of countries like India which import oil.

#### **2.1.2.2 Farm Price Shock:**

A rise in prices of other raw materials, of which the most important may be those of farm products can cause cost push inflation in economies of India. In India when monsoon may be insufficient or be delayed or weather conditions are not suitable, the supply of agricultural products falls and their prices rise.

Farm items are crude materials for different enterprises, for example, sugar industry, other agro-preparing ventures, cotton material industry, jute industry and accordingly when costs of homestead items rise they prompt ascent in costs of merchandise which utilize the homestead

items as crude materials. This is farm price shock causing cost-push inflation. Indeed, even an ascent in prices of food or what is called food inflation is created by supply-side elements, for example, insufficient rainfall or unscheduled monsoons and other unfriendly climate conditions and lacking accessibility of fertilizers which prompt diminishing output of food grains is an example of supply-side inflation or cost-push.

### **2.1.2.3 Import Price Shock:**

These days currencies of most countries of the world are flexible, that is, determined by demand for and supply of a currency and they can appreciate or depreciate every month in terms of the US dollar. For example, when the Indian rupee depreciates, more rupees are required to buy one US dollar and therefore in terms of rupees, imports become costlier.

Nowadays monetary standards of most nations of the world are adaptable, that is, controlled by demand for and supply of the national currency and they can appreciate or devalue each month with respect to the US dollar. For instance, when the Indian rupee deteriorates, more rupees are required to get one US dollar and along these lines as far as rupee is concerned, imports end up noticeably costlier.

Indian citizens who for industries such as petroleum products, coal, machines and other equipment, oilseeds, fertilizers, Indian consumers who imports gold, cars and other final products have to pay higher prices in terms of rupees whose value falls against US dollar.

This raises the cost of production of the producers who in turn raise the prices of final products produced by them. This inflation is the result of import price shock. Thus depreciation of rupee causes cost-push inflation. For example, in the month of June 2013, there was sharp depreciation of the Indian rupee. The value of rupee fell by about 9.5 per cent in this single month from about Rs. 56 to a US dollar in the first week of June 2013 to around Rs. 61 to a dollar in the last week of June 2013.



#### 2.1.2.4 Wage Push Inflation:

The spread of inflation has been suggested to be caused by the growth of strong trade unions especially in the industrialised nations. Seldom, the trade union demand higher wages without any rise in productivity or cost of living to back their demands. Employers who are in a position of higher employment and demand tend to be amenable to trade union wage demands as they hope to compensate the rise in wages with a rise in prices to be paid for by consumers.

Cost push inflation pushes wages higher and the short run supply curve of output shifts to the left, with the aggregate demand curve constant the price levels of output increase.

#### Cost-Push Inflation Spiral:

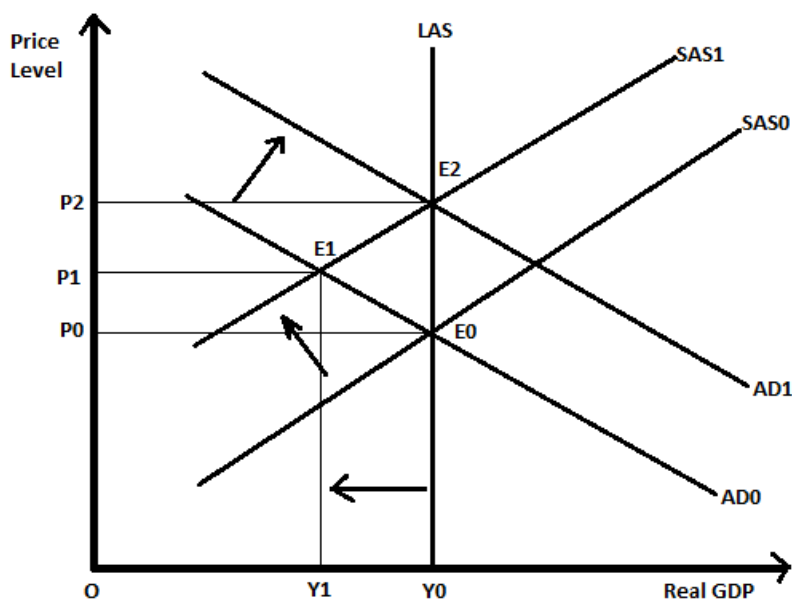


FIGURE 2-1: COST PUSH INFLATION SPIRAL

Source: Inflation in India: Causes, Effects and Curve. (2017)

In the above diagram the aggregate demand curve cuts the short run supply ( $SAS_0$ ) at the position  $E_0$  at the price level of  $P_0$  and output  $Y_0$ . Assuming that  $Y_0$  is the potential level of output and thus we have a vertical long run supply curve (LAS) at output level  $Y_0$ . Consider an increase in prices of oil which shifts the  $SAS_0$  to  $SAS_1$ . This shift of the  $SAS_0$  to the left

cause price levels to increase to  $P_1$  but results in a fall in the output accompanied by a decline in output and employment.

Cost push inflation is seen now to be result in not only an increase in price levels but also a fall in output or GDP levels. This phenomenon of rise in prices along with a fall in output is called stagflation which is a result of the cost push inflation.

Unemployment rises as the GDP falls as a result of cost push inflation. In response to the unemployment the central bank can respond by increasing the money supply to increase the aggregate demand or the government may increase its spending to provide a fiscal push to the aggregate demand. As a result of any of the two above action the AD curve will then shift to  $AD_1$ .

The economy then moves from equilibrium point  $E_1$  to the equilibrium point  $E_2$ . As seen in Fig. 2-1, as a result of this increase in aggregate demand while real GDP has returned to the potential GDP level  $Y_0$ , price level has further risen to  $P_2$  (there will be more).

Although the process of cost pushes inflation does not end at the equilibrium position of  $E_2$ . If the rise in the factors of cost push inflation like oil prices or farm output continues the short run supply curve will shift further to the left and cut the  $AD_1$  to the left of the LAS which results in further rise in the price levels or an inflation above the price level of  $P_2$  and a further drop in output and higher unemployment of labour.

To restore the output level to the potential level of output and restore the economy to full employment the central bank will supply more money or increase public expenditure, resulting in the left-ward shift of the AD curve to the right side of  $AD_1$ . This will bring back the output level to the potential level of output i.e.  $Y_0$  and the economy will have full employment. In such a way cost push inflation spiral causes sustained inflation.

Many economists are of the opinion that inflation is a result of demand pull and cost push factor, it may have originated from cost-push factors or demand-pull factors, but they will together be key in sustained inflation

### 2.1.3 Monetarist Theory of Inflation

The quantity theory of money is, at its core, a hypothesis about the main cause of changes in the value or purchasing power of money. The changes in the value of money are determined chiefly by changes in the quantity in circulation. When money is abundant its value or purchasing power will fall and thus there is a rise in the average commodity prices. Similarly, when quantity of money falls, the purchasing power of money falls and there is a fall in the general commodity prices. Or the theory simply states that the stock of money predominantly determines the general price levels.

It is among the oldest existing economic theory which was the looking glass through which various contemporary financial events were seen through in the 19<sup>th</sup> Century. Until 1752, when David Hume introduced the concept of causation into the relation of money supply (M) and price levels (P), it was considered there existed a proportional relation between M and P. Hume for the first time stated that changes in M would cause a proportionate change in P. He explained how the effects of the change in the monetary supply spreads across the economy through various sectors causing a change in both quantity and price.

David Ricardo first was noticed among economists over the “bullion controversy”. He blamed the Bank of England’s excessive issue of bank notes for the inflation in the early 19<sup>th</sup> century. He was an advocate of the quantity theory of money. Fisher (1911) introduced the equation of exchange that is the founding principle of the quantity theory of money and relates the increase in money supply to the increase in overall prices. Many economists believed that monetary control was possible with a regime of fractional reserve banking through the control of an exogenously determined stock of high powered money.

The monetarists argued that inflation exists in the economy when the money supply grows faster than the rate of growth of national income. If the supply of money increases proportionately to the inflation there shall be no inflation. According to Friedman inflation

everywhere is a monetary phenomenon arising from the increase in the quantity of money and not the total output.

Both the original quantity theorists and the modern monetarists (e.g. Milton Friedman, Henry Simons, Anna Schwartz, Lloyd Mints, Frank Knight and Jacob Viner), significant among who is Friedman (1956), explain inflation in terms of also excess demand for goods and services.

Although an important difference exists between the two views of demand pull inflation. According to Keynes inflation arises from real sector forces. There is excess demand due to autonomous rise in expenditure on investment or consumption or rise in public spending on goods and service that simply means that the increase in the total expenditure or the demand exists free of any increase in the money supply.

According to the monetarist idea, the increase in money supply is the cause of excess demand and the simultaneous rise in prices. Quoting Friedman (1956), “Inflation is always and everywhere a monetary phenomenon..... and can be produced only by a more rapid increase in the quantity of money than in output.” Friedman believed that if money supply increase in the economy, there is an excess supply of real money balances held by the public over the money demand. For equilibrium to be restored the public should reduce their balance of money by increasing their spending on goods and services ultimately leading to inflation.

The argument can be presented in the following scheme

$$M^s > kPY \rightarrow AD \uparrow \rightarrow P \uparrow$$

EQUATION 2.1

$M^s$  : Quantity of money and

$P$  : Price level

$Y$  : National income

$k$  : Ratio of income which people want to keep in cash balances

AD : Aggregate demand for or aggregate expenditure on goods and services which is composed of consumption demand (C) and investment demand (I).

Thus,  $M^s/P$  is the real cash balances and  $kPY$  represents demand for cash balances (i.e., demand for money).

As it can be seen above that when the supply of money ( $M^s$ ) increases, there emerges an excess supply of real cash balances. This is illustrated by the expression  $M^s > kPY$ . This extra supply of real money balances results in the increase in aggregate demand (AD). Then increase in aggregate demand (AD) results in the increase in prices (P).

To explain Friedman's monetarist theory of inflation we can use the quantity equation [ $P = MV/Y = M/Y * 1/k$ ] written in percentage form which is written as below taking k as constant:

$$\frac{\Delta P}{P} = \frac{\Delta M^s}{M^s} - \frac{\Delta Y}{Y}$$

EQUATION 2.2

In equation 1.2:

$\Delta P/P$  : is the rate of inflation

$\Delta M^s/M^s$  : is the rate of growth of money supply and

$\Delta Y/Y$  : is the rate of growth of output.

Equation (2) states, the rate of inflation ( $\Delta P/P$ ) is equal to the rate of growth of output ( $\Delta Y/Y$ ) subtracted from money supply ( $\Delta M^s/M$ ), with velocity of circulation (V) or k remaining constant. According to Friedman and monetarists the inflation is largely a monetary phenomenon which means that there are small changes in velocity and output. Following this one can say that an increase in supply of money cause a disruption in the equilibrium i.e.  $M^s > kPY$ . The result of this would be that the people would spend the extra money supply on consumer goods and services which brings the money supply in equilibrium with the money demand.

These results in the rise of aggregate demand or the spending on goods and services increases, with k held constant leading to a rise in the nominal national income (PY).

Friedman further argues that aggregate output or real national income stays stable in the long run at the full employment level as a result of flexible wage rates.

Thus Friedman and monetarist believe that a rise in PY or the nominal national income due to an increase in the supply of money cause an increase in the total demand or aggregate demand in the long run will cause a proportional rise in price levels.

According to them in the short run, very similar to the Keynesians, the economy may not work at full employment in the short run and there may exist excess capacity and unemployment of labour so that increase in money supply followed by an increase in nominal income partly brings about an expansion in the real income (Y) and partly leads to rise in the price level as seen in the Fig. 2-2.

The extent to which price level rises relies on the elasticity of the short run supply or aggregate output. In Fig. 2-2 we can see that an increase in supply of money to  $M_1$  and simultaneous rise in aggregate demand leads to partly a rise in price levels and an increase in the real income to  $Y_1$  from  $Y_0$ .

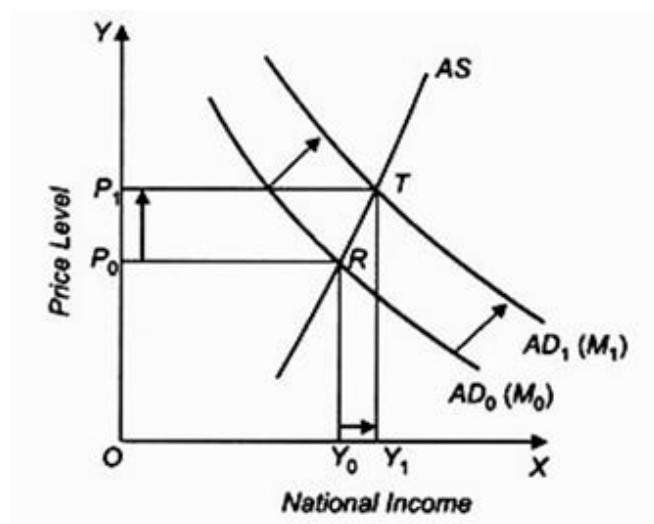


FIGURE 2-2: INFLATION UNDER MONETARISM

Source: ("Inflation in India: Causes, Effects and Curve", 2017)

Friedman and his followers believe that due to recessionary conditions there might exist full employment of labour and various other resources in the short run and thus there emerges a path for the output to increase. It should be emphasized that growth in money supply is

greater than growth in output in the short run which causes an excess of demand which results in demand pull inflation.

Keynesians and Friedman explain inflation as a cause of excess aggregate demand for goods and services. Keynesian say that emergence of this extra demand is caused by a rise in the autonomous expenditure independent of rise in the supply of money. While Friedman looks at inflation as cause by increase in money supply by a larger margin than total demand. Both views look at inflation as of the demand pull category.

### **Money and Sustained Inflation:**

An increase in the money supply causes aggregate demand curve to shift right and this causes the prices to rise in an economy operating at the natural rate of inflation. A major criticism of this theory of inflation is that supply of output fails to increase sufficiently so as to offset the effect of the increase in the supply of money on the total demand.

Both schools of thoughts believe that a sustained rise in price levels can only be accommodated by an increase in the money supply. Thus sustained inflation is a monetary phenomenon. If money supply remains constant it is impossible for the price level to keep rising. Thus, there is a need to differentiate between a single rise in the price level and sustained inflation which emerges when the general price level is seen to continuously rise over a long time period.

The rise in the supply of money shift the aggregate demand curve to the right; if aggregate supply does not increase proportionately to match the rise in aggregate demand, price level will keep rising.

When Government increases its expenditure without raising taxes, it is an example of sustained inflation. Resulting in a rise in the aggregate demand, aggregate supply being held constant, which in turn leads to an increase in the price levels. The rising price level increases the money demand to increase for transaction purposes.

Holding the money supply constant, higher demand for money results in the rate of interests to rise. The increase in interest rate crowds out private investment. To prevent the decline in the private investment, the country's Central Bank will increase the money supply which will keep the interest rates constant. Although the increase in money supply will, through its effect on aggregate demand, lead the price level to increase further if the supply of output cannot be increased.

This further ascent of the price level will again bring about more money demand leading to higher rates of interest. And if the Central Bank, wants to keep the interest rate constant to prevent the private investment from falling, will further increase the supply money which will further lead to inflation. This could ultimately result in hyperinflation which is categorized by continuous and quick increases in the price levels every consecutive period.

History shows us that hyperinflation emerged in a few of the countries when the Central Bank or Government of these countries kept expanding their supply of money to either fund their consistent budget deficit every year or to prevent the interest rate from rising. Although as mentioned earlier hyperinflation disturbs the payment system and there emerges a loss of credibility of the currency. This economy is a state of deep crisis. To avoid hyperinflation, the process of pumping more money into the economy must be stopped.

#### **2.1.4 Structuralist Theory of Inflation:**

Another important perspective is of the structuralist perspective of inflation which argues that in developing countries investment expenditure and increase in the supply of money is only an approximate measure of the causes of inflation but not the ultimate factors responsible. They believe in delving deeper into the reason aggregate output doesn't increase proportionately to the increase in demand as brought about by increasing investment expenditure. They question why the increase in investment is not funded by voluntary saving and instead by excessive deficit financing.



"Inflation in India: Causes, Effects and Curve" (2017) notes that this form of inflation has been used to explain the inflation seen occurring in most Latin American countries. The advocates of this theory argue that developing countries namely of those of Latin America and India are characterised by structurally underdeveloped and highly fragmented due to market imperfections and rigidities existing of various types. Due to these rigidities and imbalances there exist shortages in supply with respect to the demand. Myrdal (1968) and Streeten (1972), two well-known economists put forth this theory have analysed inflation in developing countries with respect to structural features of their economies. In recent times Kirkpatrick and Nixon (1976) have generalized this structural theory of inflation to explain the inflation existing in all developing countries.

Structuralists have listed many bottlenecks which exist in developing economies which cause such imbalances and lead to an inflationary rise in prices. These bottlenecks can be of various kinds namely they could be agricultural, which cause inelastic supply of agricultural goods. They can also be constraints in terms of resources or a foreign exchange bottleneck. Resource constraint simply means a lack of resources required for economic development it may be for industrialisation of the economy or infrastructural build up. The foreign exchange bottleneck is the lack of foreign exchange much needed for financing of imports by the developing countries. The process of industrialisation is accompanied by large imports of capital goods and essential raw materials. Another bottleneck which developing countries suffer is of the nature of physical infrastructure like the lack of transport, fuel and power. Thus, we see that structuralist view is greatly relevant for explaining inflation in the developing countries and for the adoption of measures to control it.

Myrdal (1968) and Streeten (1972) argue that applying the aggregative demand- supply model to explain for inflation in these developing countries would be incorrect. They believe that there exists a shortage of well balanced and integrated structures within these countries in which the possibility of substituting consumption for production or vice versa and that the

flow of resources between sectors are neither smooth nor fast due to which inflation in developing nations cannot be explained by aggregate demand and supply in isolation. The economies of the developing countries like those of Latin America and India are underdeveloped in their structural infrastructure and significantly fragmented because of existing market imperfections and a number of infrastructural rigidities.

Structural underdevelopment and rigidity leads to a situation where on one side we find that in a couple of sectors of these nations there exist a lack of supply relative to demand, while other sectors experience under-utilisation of resources because of the shortage of demand. Structuralists, due to these structural features of the developing countries they do not fit the aggregate demand-supply model of inflation.

Thus they call for analysing dis-aggregative and sectoral demand-supply gaps to understand the cause of inflation in these countries. They have identified various sectoral constraints or bottlenecks that cause or lead to the sectoral imbalances and ultimately result in the rise in prices.

Therefore, to explain the existence of inflation in the developing countries, the causes of the various bottlenecks or imbalances in path of economic development need to be analysed. An analysis of these imbalances is thus a must for explaining inflation in the developing countries.

**These bottlenecks are of three types:**

- i. Agricultural bottlenecks which make supply of agricultural products inelastic,
- ii. Resources constraint or Government budget constraint, and
- iii. Foreign exchange bottleneck.

**2.1.4.1 Agricultural Bottlenecks:**

The most immediate bottleneck that developing countries face is related to agriculture and restricts the supply of food grains to rise adequately. When talking of the structural factors, disparities in land ownership, defective land tenure system should be mentioned specifically,

they act as disincentives for increasing agricultural output in response to rising demand for them, resulting from the rise in people's incomes, urbanization and population growth .

The agricultural sector of developing countries is widely known to use out dated technology which limits the agricultural growth. Therefore, if the government wants to control inflation, these sectoral constraints have to be dealt with, so that agricultural production rises sufficiently so as meet the rising demand for them in the economic development process.

#### **2.1.4.2 Resources Gap or Government's Budget Constraint:**

According to structuralists lack of resources is another important bottleneck. It relates to the financing required for economic development. Governments of these countries are trying to move toward industrialisation which demands vast amounts of resources to fund public sector investment in various industries. For instance, in India, large amounts of resources were invested in the basic heavy industries initiated in the public sector.

Usual methods employed by governments to raise resources such as taxation, public borrowing, profit generation in the public sector ventures to finance the projects of economic development cannot be used in these countries due lack of stable social, economic and political structures. The developing countries only receive low amount of tax revenue due to a low tax base, widespread tax evasion, inefficient and corrupt tax administration.

The government is then forced to resort to excessive deficit financing (that is, creation of new currency) which results in further growth in money supply with respect to a rise in production every consecutive year and therefore results in inflation in the these countries. Though this quick growth of money supply is the apparent cause of inflation, it is not the correct and sufficient reason of inflation in developing economies.

For a better explanation of inflation we have to delve deeper and look in the running of structural forces which cause excessive expansion in the money supply in the developing countries. Also, there exists the problem of excessive bank credit, this is because of the gap in resources in the private sector because of the insufficient voluntary savings and lack of

development in the capital markets which leads to an increase in borrowings from the banks which ultimately lead to an a unhealthy increase in bank credit. This has been a factor in the increase in the money supply in developing economies resulting in an increase in price levels. In this context, Kirkpatrick and Nixon write, “The increase in the supply of money was a permissive factor which allowed the inflationary spiral to manifest itself and become cumulative—it was a system of the structural rigidities which give rise to the inflationary pressures rather than the cause of inflation itself.”

#### **2.1.4.3 Foreign Exchange Bottleneck:**

Another bottleneck which these developing economies have to face is the lack of foreign exchange to finance the imports required for developing economies. In these countries government have undertaken the process of industrialisation which requires large amounts of imports of capital goods, fundamental raw materials and in cases such as in India, even food grains have been part of the imports. Apart from which there are large imports of oil.

Due to imports on a large scale as mentioned above, the expenditure on imports of the developing countries has been on rising rapidly. On the other hand due to sluggish exports and rising imports, these developing economies face difficulties in their balance of payments and a lack in their supply of foreign exchange which a number of times have reached crisis proportions. This has had two influences on the price level:

Firstly, the shortage of foreign exchange curbs the availability of goods and services in these countries due to which their supply fails to be increased which leads to the rise in the price levels.

Secondly, countries of Latin American as well as those of Pakistan and India, try to fix the issue of foreign exchange shortage by encouraging exports and decreasing the devaluation of imports in the national currencies. This led to the rise in prices of imports which further led to a rise in the price levels of other goods which was also caused by the cascading effect. This led to the emergence of cost-push inflation in these countries.

#### **2.1.4.4 Physical Infrastructural Bottlenecks:**

According to the structuralists' point of view many bottlenecks like the shortage of infrastructural facilities such as power, transport and fuel curbs the sufficient growth in production. For instance, in India, there exists an acute lack of these fundamental infrastructural inputs which are curbing the adequate growth of output.

Slow growth of production accompanied by excessive expansion of money supply has led to stagflation, which is the inflation accompanied by stagnation or retarded economic growth.

Going by the structuralists' point of view, the bottlenecks mentioned earlier and other constraints are based in the structure of the social, political and economic institutions of the developing countries. Thus, from the perspective of broad-based strategy of development for growth to occur without inflation there need to be structural, social and institutional changes in these countries.

The structuralists give higher weightage to agricultural sector in the process of development if stable price levels are desired. Therefore, the structuralists' view is significant in the search for the cause of inflation in these developing economies and to bring forward measures to control it.

#### **2.1.5 Rational Expectations driven inflation**

The rational expectations theory states that there exists no lag in the change in nominal wages with respect to change in general price levels. Advocates of this theory believe that nominal wages adjust quickly to the expected rise in price levels and that there does not exist a Phillips curve showing the trade-off between rates of inflation and unemployment. The rate of inflation resulting from a rise in total demand is correctly predicted by the firms and employees and is incorporated in the new wage agreements inducing higher prices.

Rational expectations simply put states that when the public see a rise in money supply they will act in a way most beneficial to them. Labourers will demand higher wages expecting an increase in demand in consumption goods and firms will for see the increased demand will

increase wages but also raise the prices. When the perceived increase in money supply is realised its effect of higher productivity and employment is counteracted by higher wages and prices and the economy becomes increasingly inflationary.

Ultimately, narrowing down the sources of occurring inflation to either of them is not easy. Inflation usually tends to cause further inflation and leads to a spiral. Inflation is a dynamically occurring phenomenon which is caused by demand side and supply side shocks, monetary shocks and structural and political factors. It is brought about by not anyone but an interaction of all these factors. Inflation is at all points an institutional and macroeconomic factor.

The mixed results depicted by existing studies for India and otherwise, for causality of inflation through various variables are discussed next. This helps us identify the variables for the study and contributes to the construction of a model that is capable of covering the major sources of inflation. Some of the major studies highlighting the causal factors of inflation are now discussed first, followed by variable specific studies.

Darbha and Patel (2012) in their paper titled “Dynamics of Inflation ‘Herding’: Decoding India’s Inflationary Process”, show the evolution of empirical properties of the Indian inflationary dynamics (time series and cross-sectional) with disaggregated sector prices. The study finds widespread diffusion of inflation across sectors. An analysis of the common and specific factors revealed that the former has become more persistent. This study mainly triggers the motivation for the current study. The specific factors in the form of demand side pressures through output gap and money supply variables, and supply side cost push through international energy prices, domestic food prices and domestic energy prices along with their effects on core inflation are the concerns of the study.

Hudson (1992) found that inflation aversion (a result of expected inflation) Granger causes inflation. Also if the expectations actually prove to be true then inflation aversion will predate the rise in inflation.

Thornton (2006) validates Friedman's hypothesis about inflation causing uncertainty about future inflation with the help of a GARCH model on monthly inflation in India for the period 1957-2005. Uncertainty in inflation was found to have negative output effect subsequently.

According to Raghuram Rajan (2014) an important source of inflation in the recent times is expectations. People form their expectations simply based on extrapolation of recent or important experiences. Very interestingly, he notes that the consistent rise in food price is largely attributable to higher minimum support prices. The crops that are incorporated under minimum support price, constitute almost 33% of the primary products in WPI. Since market prices take a cue from the minimum support prices, this has weighed heavily on the overall price levels.

Rehman (2014) notes that monetary policy tools, for example, money supply and interest rate, are the most mainstream instruments to control inflation around the world. A tight monetary policy would either bring about diminished money supply or a surge in interest rate, which will decrease inflation by lessening aggregate demand in an economy. Nonetheless, monetary policy could be counterproductive if cost side effects of monetary tightening continue to exist. High energy prices may expand the cost of production by diminishing aggregate supply in the economy. In the event that tight monetary policy is utilized to lessen this cost push inflation, the cost reaction of energy prices will add to cost side effects of monetary tightening and will get to be distinctly predominant. For this situation, the monetary policy could be counterproductive. Moreover, synchronous decrease in aggregate supply and demand respectively will lead to a twofold decrease in output. These discoveries suggest that both monetary policy and oil prices have cost side effects on inflation

and monetary tightening could be counterproductive if used to decrease energy pushed inflationary trend.

Gul and Ekinici (2006) analyse the empirical relationship between nominal interest rate and inflation of Turkey. They find that there is a long-run relationship between the variables but causality effects run only from nominal interest rate to inflation.

Cheng, Taylor and Weng (2006) look into causal relationships between exchange rates and prices for the United States and its trading partners (Canada, Japan, Germany and the United Kingdom). Their study finds that exchange rate Granger caused wholesale price indices for all the four partners.

## **2.2 Evidence for output gap and inflation relation:**

Even though it has been rare to apply demand pull models of inflation in the Indian economy, Chand (1996) modeled GDP deflator as a function of output gap for the period of 1972-91. He found excess demand to be a significant factor in determining inflation. His study also found excess demand to have stronger (upward) effect on inflation excess supply (downward).

Coe and McDermott (1997) found that the output gap model functions in the Indian scenario only when money is considered in the equation.

Callen and Chang (1999) suggest that output gap does not explain inflation significantly. The study assesses the timely and reliable predictability of various potential indicators for future inflation through a model of inflation and by estimating a series of bivariate VARs. The results show that while developing an accurate model of inflation extreme difficulties are posed by swings (or volatility) in the prices of primary products and by changes in administered prices. Relying on a model with manufacturing prices instead of the overall WPI makes more sense under such an instance. The study also shows that modeling inflation



based on output gap does not predict the latter efficiently with Indian data. The study uses the manufacturing subcomponent of the WPI as a measure of core inflation. The authors suggest developing a measure of core inflation excluding the items that contribute to the volatility by the central bank as this entity is expected to provide better understanding of the underlying developments of inflation in the economy and would in turn help in conducting monetary policy more effectively. The results bring to light important linkages that exist between developments in the primary sector and other areas of the economy, and emphasizes the fact that the RBI needs to take this into account while framing policies.

Virmani (2004) estimates output gap for the Indian economy with the help of quarterly data from 1983 to 2001 on output series. He conducts regression of inflation on output gap and finds that inflation decreases with rise in output gap.

Manoj Kumar (2012) finds that the output gap ratio Granger causes inflation but inflation does not Granger cause output gap ratio in the Indian macro economy. Thus, there is only a unidirectional causation.

Tiwari (2013) used wavelet transform methods to understand the relationship between output gap and inflation for France. This approach measures the co-movement of the two series in the context of both time and frequencies. The study finds that the output gap is able to predict the inflation dynamics in the short and medium runs. The study further goes on to show that “in a discrete wavelet framework, the short and medium term fluctuations of both variables are more closely correlated, whereas the continuous wavelet analysis states that the output gap leads inflation in short and medium runs”.

## **2.3 Evidence for energy prices (domestic and international) and inflation relation:**

Various studies have tried to answer why increasing oil prices lead to slowing of economic activities more than the impetus provided by falling oil prices, while others have studied the channels for transmission mechanism for the same. Several studies have focussed on the decreasing significance of oil price volatility on economic activity.

The investigations of Pierce and Enzler (1974), Rasche and Tatom (1977), Mork and Hall (1980), and Darby (1982) reported on the inverse relationship between oil price increments and aggregate economic activity. Studies, for example, Gisser and Goodwin (1986) and the Energy Modeling Forum-7 study documented in Hickman et al. (1987) reaffirmed the inverse relationship between oil costs and aggregate economic activity for the United States. For nations other than the United States, comparable relationships between oil prices and the economy were detailed by Darby (1982), Burbidge and Harrison (1984), and Bruno and Sachs (1981, 1985)

One of the earliest comprehensive attempts to study the mechanism of this relationship was made by Hudson (1981). This study tried to investigate the impact of a deregulation in energy prices on the supply and demand for energy as well as the general economy with regards to the United States of America. As indicated by the investigation, such a deregulation of prices not only resulted in some expansion in the supply of energy products but also in a significant contraction in its demand. Such an alteration in the supply and demand for energy will definitely result in a readjustment in the overall economy by pitting against each other the competing forces of an increase in yield due to a growth in supply and on the other hand a decrease in yields due to dwindling demand. Hudson, with the help of quantitative tools, demonstrated that real economic growth would in fact increase due to such a deregulation

because of not only a supply side push to productivity but also due to the predominant influence of international trade.

Rahman (1982) develops a model of interdependence between energy and the macro-economy and estimates the same. The generalization of the model ensures that it can be applied to a wide range of developing countries that are majorly dependent on oil. The econometric estimation of the model for the Indian economy reveals that primary energy demand is price responsive.

Blinder (1982) finds energy prices to be an important driving factor for inflation in 1973 and 1974. His study in 1979 suggests a positive relation between energy prices and PCE deflator, where a per cent rise in the former led to 2.4 per cent rise in the latter. He also pointed out that this estimate was incomplete since it did not include energy cost that is embodied in consumer goods. According to Perry's (1975) study, this estimate is one per cent, which takes the final effect of a per cent rise in energy prices on inflation to 3.4 per cent. Blinder notes further that there exists indirect effect of wage-price spirals which eventually gets balanced by the negative effect of the recession on inflation, leaving the estimates close to the number quoted earlier.

Hamilton (1983) would then go on to demonstrate, by extending on this analysis, that a huge upsurge in oil prices foreshadowed all but one of the recessions to take place in the United States of America after World War II, usually with a lag of nine months between these two events. While this alone, in no way establishes shocks in oil prices as a reason for these recessions, the fact that other business cycle variables could not account for these recessions and Hamilton was able to establish a statistically significant and non-spurious correlation between oil shocks and recessions (for the period of 1948-72) points to the fact that fluctuations in oil prices influenced at least some of the recessions under consideration. The author was unable to find much evidence backing the proposition that perhaps some third set

of influences were responsible for both the oil price increases and the subsequent recessions. Further, no unusual behaviour was displayed by any of the six variables in Sim's (1980) macroeconomic system, either individually or collectively, in the year leading to the oil price increases which could have been used as statistical predictors of the oil price episodes. In fact, only import prices gave any statistically relevant information about future oil price movements based on 8 quarter lags, despite the fact that import prices would probably be expected to be the least indicative of endogenous business conditions of all the variables. Hamilton also noted that firstly, this latter correlation is by all accounts ascribable to that part of import price changes that could not have been anticipated based on any past changes in the yields, prices or growth rates of money; secondly, any statistically relevant information about future yield of oil would come from that part of oil price changes that would not have been anticipated based on past import price changes and thirdly, it would be futile to utilize import prices alone to speculate about any ensuing recessions. In addition, the previous conclusion that import prices gave statistically relevant information about future oil price movements fell apart completely when a different set of specification, relying on what may be considered more reasonable distributional suppositions, was introduced into the system. Hamilton also believed that on the off chance that some third macroeconomic variable was in reality the underlying influence on both the oil price increases and the recessions which followed this event, then its impact was unclear due to the small part of the macro economy under consideration.

Mallik (2009) studies the inter linkages between energy and growth for the Indian economy between 1970–71 and 2004–05. None of the components of energy is found to significantly influence the two components of economic growth viz. private consumption and investment. In contrast, the variance decomposition analysis of Vector Autoregression (VAR) depicts the possibility of a bidirectional influence between electricity consumption and economic

growth. Therefore, the study yields mixed and contradictory result compared to the previous studies in the Indian context.

The International Monetary Fund (IMF) had cited demand side explanation for the growing inflationary pressure in Emerging Market Economies (EMEs) in 2011. On the other hand, they attributed global inflationary pressure to supply-side factors like rising input prices – mainly oil and metals. Higher commodity prices can cause both a reduction in real output and a cost push inflation. The oil price shocks in the 1970s were a major source of inflationary pressure in the global economy.

Hatekar, Sharma & Kulkarni (2011) find that the IMF's argument of overheating is relevant only in the short run in the Indian context. However, the RBI's concern about rising international commodity prices seems to be more relevant in driving domestic inflation over the business cycle in the long run.

Nguyen, Cavoli and Wilson (2012) employ a simple macroeconomic model of inflation to empirically investigate the determinants of CPI inflation for Vietnam over the period 2001 to 2009. The study examined the role of supply side factors such as the prices of crude oil and rice on inflation, among other variables. Using a range of time series estimation techniques, they find that persistence in inflation and that the money supply, oil prices and rice prices had strongest effects on inflation.

Rehman (2014) notes that monetary policy tools such as money supply and interest rate, have been the most popular instruments to control inflation around the world. A tight monetary policy would either result in reduction in money supply or an increase in interest rate, which will reduce inflation by reducing aggregate demand in an economy. The authors argue that monetary policy could be counterproductive if cost side effects of monetary tightening prevail. High energy prices may lead to an increase in the cost of production by reducing

aggregate supply in the economy. If tight monetary policy is used to reduce this cost push inflation, the cost side effect of energy prices will add to cost side effects of monetary tightening and will become dominant. The monetary policy could then turn out to be futile. Furthermore, simultaneous reduction in aggregate supply and aggregate demand will bring twofold reduction in output. The findings suggest that both monetary policy and oil prices have cost side effects on inflation and monetary tightening could be counterproductive if used to reduce energy pushed inflationary trend.

## **2.4 Evidence for money supply and inflation relation**

Haberler (1948) in his study of post war price inflation notes that the most important factor that causes inflation is increase in the stock of money and other liquid resources within the economy. Consumer and investment demand closely follows the former in being an important determinant of inflation followed by large export surplus, aggressive wage policies of the strong trade unions and mis-anticipation of deflation (which led to erroneous prevention of anti-inflationary monetary policy).

Cagan (1956) studies the relation between quantity of money and price level during phases of hyperinflations, the typical characteristic of such periods being a rise in the ratio of price index to quantity of money. The study noted that substantial changes in the cash balances were in tandem with significant changes in prices with a lag.

Barro (1970) builds up a model of economic reactions to inflation. He considers the maximizing conduct of employers and workers with regards to a steady rate of inflation. Since the rate of price change can be explained as an effective cost of holding money, a higher rate gives expanded motivating force to conserving on cash balances. Two strategies for streamlining are viewed as: initially, diminishing the time interim between different sorts of payments (increments in "velocity") and, second, reduction in the division of "monetized" exchanges.

Harriss (1975) establishes the direct effect of increase in money demand (over and above increase in demand for goods and services) on inflation. He notes that the rise in money demand may be a result of rising quantity of money in circulation or rising velocity or a combination of the two. According to him, the economy creates inflation and suffers from it subsequently. The factors that initially act as passive responses go on to become causal factors for inflation. In his words, *“War, rapid increases in money (silver from the Americas to Spain in the sixteenth century or new check book money in most countries today), government budget deficits, crop failures, wage rates rising faster than productivity, monopolies exerting increases in power, freeing the currency from ties to gold or silver-these and other forces have been said to cause inflation. Spokesmen in many countries feel that at least part of their inflation has been imported.”*

Hoang (1981) uses quarterly data for modelling money wages and consumer prices in West Germany for the period 1964 to 1978. He uses Granger causality analysis for linear autoregressive model to establish an insignificant effect of money supply on money wages and consumer prices.

Callen and Chang (1999) looks at the factors that forecast inflationary trends most effectively in India. The study concludes that among other variables, monetary aggregates serve as an important factor in explaining and targeting future inflation despite the loss of emphasis that broad money target has faced.

Dave and Rami (2008) inspect the causality running from money supply to price level in India with monthly data for the time period of 1953-2005. Their study finds evidence of reverse granger causality from prices to money supply using pair-wise granger causality tests. The major findings of the study were as follows: Money is endogenous as it is partially determined by the price level; The direction of causality between WPI and money supply remains unaffected by the definition of money chosen for the analysis since the results are

similar for M1 and M3; Monetary policy especially regarding money supply has limited implication for controlling inflation in India; Money supply has increased in India mainly because of rise in the rate of inflation.

Sharma, Kumar and Hatekar (2010) found that in India money supply triggers output in the short run but at business cycle frequencies it causes inflation. Sharma (2008) found that both broad and narrow money lead to inflation at seasonal as well as zero frequency. He goes on to show that money is neutral in the long run but not in the short run.

## **2.5 Evidence for food prices and inflation relation**

Blinder (1979) estimated the effect of food price on inflation for the period of 1973 to 1975. He considered both direct and indirect effects arising from food being an important share in CPI and also the wage-price spiral. His estimates show that almost five percentage points of the rate of inflation was due to food prices.

Blinder(1982) notes that it is safe to believe that rise in food price leads to higher wage which eventually result in a wage-price spiral which subsequently leads to a rise in overall prices.

An IMF report in 2007 claims that in the emerging economies, the higher growth in inflation is partly due to the larger share of food in the consumption basket for countries with lower per capita income.

Cecchetti and Moessner (2008) takes a cue from the recent strong rises in commodity prices till mid 2008 that led to rising inflation across the worldwide. The authors study the effect of food price and energy price on headline inflation with CPI inflation and its food and energy components for developed and emerging economies. The results suggest that food price inflation helps explaining future inflation but energy prices do not.



## 2.6 Evidence for Granger Causality

Buiter (1984) studied policy effectiveness in the light of granger causality analysis. It is for the most part perceived that, if an arrangement of fiscal and monetary policy variables Granger-cause real economic variables, this does not suggest that alternate deterministic guidelines for determining the values of these policy instruments will change the joint density function of the real variables. The paper demonstrates that Granger-causality is not required for policy effectiveness, the deficiency for the same having been set already by Sargent. Similar pitfalls in Granger-causality tests are contained in various papers, prominently Jacobs, Leamer and Ward (1979), Sims (1977) and Zellner (1979). This paper goes past these prior contributions by depicting that no inferences about policy ineffectiveness can be drawn from the results of Granger-causality tests. It can be seen as an examination of the statement by Sims that "The fact that policy variables are always in one sense causally prior to the other variables in a model is sometimes assumed to make it likely that they are causally prior (i.e. exogenous) in data used for estimation" (Sims, 1979, pp. 105-106).

Michael P. Clements and Grayham E. Mizon (1991) shows that a differenced model loses out on information in case the variables are cointegrated.

Eichler (2007) notes that a major problem with applying Granger causality is the possibility of the presence of latent variables which affect the various measured components leading to spuriousness in the causality analysis. The study proposes a graphical representation to describe and analyse the causal relations in multivariate time series which may be influenced by latent variables. The author shows the use of such a structure in understanding causality from time series.

Hatekar and Patnaik (2016) study the causal relationship between consumer price index and wholesale price index. The authors focus on empirically testing causal effect of CPI on WPI in the frequency domain and check whether the observed CPI to WPI causation is demand-

driven or driven by supply shocks. They find that there exists a bidirectional causality between CPI-IW and WPI with WPI causing CPI-IW in the short run and the medium run and CPI causing WPI only in the short-run. The magnitude of causality from WPI to CPI is found to be higher than the magnitude of causality from CPI to WPI.

These studies generate various competing hypotheses that have strong policy focus:

1. The relation between food prices, rural incomes, shifts in dietary patterns and supply chain infrastructure
2. The relation between aggregate demand and inflation
3. The relationship between international prices of energy and other inputs and their inflationary impact.

Given the discussion above, it was evident that it is of utmost importance to check for causal effects of supply side instruments and demand side instruments that may affect domestic inflation in the frequency domain rather than just the time domain. Though some of the studies have looked into the effects of the said variables on inflation under various circumstances, none of them concentrate on the cyclical effects at all. The present study checks for evidence of causal effect of international energy prices, domestic food prices and domestic energy prices (representative for the cost push factor) and output gap and money supply (representative for the demand pull factor) on domestic core inflation in the frequency domain so that a better understanding can be provided about the business cycle nature of these two mechanisms.

### **3 Chapter 3. Data and Methods:**

This chapter spells out the data and methodology used for the study. Some of the variables had to be constructed manually from the reported data. The process of doing the same is the primary focus of the chapter followed by the econometric methods used to test causal relations among the variables. The chapter begins by citing the significance of using core inflation instead of headline inflation as the measure of inflation for the study and explains the methodology used to construct core inflation series from the wholesale price index available from the Office of the Economic Adviser. Next, the section discusses various literature on use of filters for calculating output gap and highlights in particular the four filters used for the study, namely, Hodrick-Prescott, Baxter-King, Butterworth and Cristiano-Fitzgerald filters. The methodology for constructing the filters and extracting the cyclical component and further constructing the output gap series are discussed thereafter. The sources of the variables chosen for the study are discussed. Next, the methodology for the econometric tests are discussed. The discussion begins with tests for stationarity and seasonality, in particular the HEGY test, followed by ARIMA model used to filter the data to extract the residuals to be used for causality analysis. A discussion on Granger causality in the frequency domain follows next ending with explanation of the method for innovation analysis – impulse response function and forecast error variance decomposition methods.

#### **3.1 Data**

Bhattacharya, Patnaik and Shah (2008) note that most of the Indian studies have been reliant on annual changes in price indices for measuring inflation. In effect, each data point of yearly inflation is the sum of twelve monthly changes. They suggest that better information regarding inflationary pressure is likely to be revealed by the monthly changes rather than its annual counterpart. In their study, the authors adjust the data for seasonality and obtain seasonally adjusted monthly inflation in India and show that the monthly version of the data provides faster and better understanding of inflation.

The data for the current study is monthly WPI from January 2000 to April 2014. The data was obtained from the Office of Economic Adviser (2014) Wholesale Price Index (WPI) Data (1993-94 base) and Wholesale Price Index (WPI) Data (2004-05 base). The weights assigned to various components of WPI are as follows:

Weights of various components of WPI			
Base Year →	1993-94	2004-05	Average
Components ↓			
Primary	22.02525	20.11815	21.07170
Food articles	15.40246	14.33709	14.86978
Non-food articles	6.13812	4.25756	5.19784
Minerals	0.48468	1.52350	1.00409
Fuel and Power	14.22624	14.91021	14.56823
Manufactured products	63.74851	64.97164	64.36008

TABLE 3.1: WEIGHTS OF WPI COMPONENTS

Source: Office of Economic Advisor (2014) and Author's calculations

Data till 2004 was reported with respect to 1993-94 as the base year and that from 2004-2014 is available with 2004-05 as the base year. The data was linked, using the linking factor as obtained from the Office of Economic Adviser (2014) (Linking Factor for WPI Series 1993-94). The core inflation was calculated from non-food and non-energy WPI. The weights of the two base years being different, average of the same was considered for computation of the core inflation. The core inflation for every month was constructed using the following –

$$\text{Core Inflation}_t =$$

$$\frac{(\text{Non Food Articles}_t * 5.19784) + (\text{Minerals}_t * 1.00409) + (\text{Manufactured Products}_t * 64.36008)}{70.56201}$$

EQUATION 3.1

Core WPI components and weights				
Base Year →	1993-94	2004-05	Average	Weight of core inflation
Components ↓				
Non-food articles	6.13812	4.25756	5.19784	70.56201
Minerals	0.48468	1.52350	1.00409	
Manufactured products	63.74851	64.97164	64.36008	

TABLE 3.2: CORE WPI COMPONENTS & WEIGHTS

Source: Office of Economic Adviser (2014) and Author's calculations

Data for monthly international energy prices for the same period was obtained from Federal Reserve Economic Data (FRED) with a base year of 2004-05.

The monthly IIP data was collected from Ministry of Statistics and Planning of India (MOSPI) and linked to the base year of 2004-05 for further calculations of the various output gaps. The variable output gap was calculated by applying the Hodrick-Prescott filter (Hodrick and Prescott 1997), Baxter King filter (Baxter and King 1999), Butterworth filter (Pollock 2000) and Christiano and Fitzgerald filter (Christiano and Fitzgerald 2003) using the actual output data (monthly index of industrial production IIP) to decompose the data into its trend and shock components. The difference between the actual output from the trend is then calculated, which serves as a measure of the output gap. The Hodrick-Prescott  $\lambda$  was set equal to 1,29,600 as per the suggestions of Ravn and Uhlig (2002) for monthly data.

Data for money supply was collected from the Reserve Bank of India. All the four measures of money supply – M1, M2, M3 and M4 have been considered for the study to see whether broadness of the monetary base has any specific effect on inflation.

Logarithmic transformations of the variables were used for the analysis other than output gap.

## **3.2 Methodology**

### **3.2.1 Core Inflation**

The usual index of inflation measures the headline inflation which comprises of the trend as well as the cyclical components of the variable – the trend being the permanent consistent factor of the price and the cycle being the temporary price fluctuations. In the act to target explicit inflation (which is the scenario that most economies are moving towards), it seems meaningless to use headline inflation as the measure of price change since it will be strongly influenced by the slightest fluctuations in the cyclical components.

Also, it may be the case that the items whose prices are included to construct the index face some kind of price control which makes adjustment of their prices comparatively much slower. This may misguide any understanding about the variable as the slow adjustments will not necessarily reflect the market forces. The headline inflation, under such circumstances, will not be a true representative of the underlying inflationary trend.

In order to avoid the above mentioned circumstances, the measure of core inflation is relied upon. “Core inflation is generally associated with the demand pressure component of measured inflation and is often viewed as being important for the determination of inflation expectations” (Callen and Chang, 1999). With the impact of supply shocks on prices of primary goods coupled with price control playing rampantly against the true reflection of the inflationary (or deflationary) pressures, an alternative measure in the form of underlying inflation is imperative for framing monetary policy. Core or underlying inflation is constructed by considering only the permanent trend component of the price after removing the temporary fluctuations.

The properties of the various measures of core inflation have been studied by OECD (2005), Rich and Steindel (2005), Blinder and Reis (2005), Marques et al (2003) and Bryan and Cecchetti (1994) for various countries. The studies conclude that there is no objective way of

commenting on the superiority of one particular measure over another based on the criteria considered.

Core inflation is not measured or reported by any agency (government or otherwise) in the Indian economy and hence there is no index that is computed and available publicly. The most obvious proxy for core inflation is the sub-component of the WPI for manufactured prices. According to Callen and Chang (1999) “This eliminates primary products (whose prices are most likely to be subject to temporary supply shocks) and fuel and energy (whose prices are often administered), from the WPI.”

### **3.2.2 Calculating Output Gap**

In the long run, any economy is expected to grow and develop in a balanced way maintaining a constant rate of inflation and full employment condition. The output produced by the economy in such a stage is referred to as the potential output. The deviation of the output level (from this equilibrium level) experienced in the short runs is of utmost importance to propel the economy towards long term growth. The phenomenon of business cycle may be explained in terms of the short run deviations of the output from its long run level. The difference between the potential output and the actual output is called the output gap which may be considered as a reflection of the business cycle and also excess demand or excess supply.

Due to the unobservable nature of the equilibrium, the potential output too remains unobservable and hence requires estimation. There are two schools of thought that exist in the literature that attempt to achieve the same – a Neoclassical one and a Keynesian. The former bases its method on the statistical de-trending tools to extract the level of potential output from past output values (due to the belief that the dynamics of the economy tend to move towards the equilibrium eventually). The latter school believes that the deviations from the

equilibrium can be long-lived making reliance on past data essentially futile. Instead, they prefer to rely on a structural model like a production function to estimate the potential output.

Virmani (2004) stressed on the significance of a possible output series for examining macroeconomic phenomena. It allows policy evaluation studies (e.g. analysis of Taylor-type rules for monetary policy) and supports the inquiry of the possibilities of analysing the ‘what if’ situations in both structural and reduced form models (e.g. in VARs for monetary policy analysis, modelling inflation using structural models). Also many macroeconomic phenomena are better comprehended and explained with the output taken as deviation from a long-run trend (e.g. Phillips curve trade off studies).

Grech (2014) notes that it is practically extremely subjective and difficult to rely on the Neoclassical framework as it is very difficult to estimate the factors of production accurately. This may end up giving different levels of potential output even for the same economy. Hence, researchers often prefer to use the filter method for estimating potential output since these methods are objective in nature and may be applied uniformly.

Whittaker (1923) designed a technique of progressive or graduating data (data smoothing) that could eliminate the effects of the measurement errors and expose the fundamental trend in the data. However, this technique was preceded by various actuarial studies, of which, many were by Deforest (1873, 1874, and 1876) on “interpolative methods based on probabilistic principles”. The Whittaker Method usually takes the least squares best fitted to the data, subject to a penalty involving the squared higher order differences of the data. This technique has many variations, contingent upon the nature of the penalties employed. Whittaker and Robinson (1924) discusses these penalty methods in detail that were later studied by various experts (e.g. Greville, 1957). Whittaker and Robinson (1924) have also provided a proper explanation for their smoothing procedure using Bayesian principles, as a rationale to motivate the penalised least-squares method – this has influenced various bodies



of work later. For example, the use of smoothness priors in econometrics by Shiller (1973, 1984) and the spline smoothing methods suggested by Wahba (1978) are a direct outcome the Whittaker Method. Currently, the available literature based on the discussed method is fairly wide-spread. In his doctoral thesis, Aitken (1925) based his work on the systematic investigation of general numerical procedures. Numerical algorithms for graduating data by these techniques have been used in actuarial work dating back at least to Henderson (1924, 1925, 1938). Camp (1950) presented a synopsis of the Whittaker-Henderson graduation processes. Schoenberg (1964), Reinsch (1967), and Boneva et.al (1970) developed algorithms previous to the formal Bayesian approach to spline smoothing that was used in Wahba (1978), which in turn, diligently resonated with the original justification given by Whittaker and Robinson (1924). Recently, Kim et al (2009) argued some related trend capture methods using modern penalized estimation where sums of absolute values replace sums of squares in penalizing variations from trend. Diewert and Wales (2006) considered smoothing algorithms based on previous ideas, going back to Sprague (1887), that the second differences of smooth series do not change sign too frequently.

For Economics related applications, this approach was systematically used by Hodrick and Prescott (1980, 1997), where second order differences were used in the penalty. This variant of the method, endorsed by Leser (1961) for the purpose of trend construction in economic data, has later become known as the HP filter in Economics. In the last few decades, the HP filter has been employed comprehensively in applied econometric work to de-trend data, mainly to assist in the measurement of business cycles. Like other trend removal techniques such as trend regression, moving average de-trending, and band-pass filtering, the HP filter is often used to yield new time series such as potential GDP and the output gap that are useful in macroeconomic modelling and monetary policy research.

The literature offers a variety of filters of which the study relies on four of them – HP filter, BW filter, BK filter and CF filter.

Pedregal and Yound (2001) and Jong and Sakarya (2016) note the following about the HP filter – the filter acts as a smoothing filter which helps highlight the long term trend in the cycle and if used with discretion, it yields extremely fast results and can prove very useful for the initial exploratory analysis of time series. The weak dependence of the unit root process has been initially absorbed into the trend component. This can be used to imply that the HP filter is capable of removing unit roots from a data generating process. The HP filter for every value of  $t$  weighs  $(t-1)$  earlier observations and  $(T-t)$  later observations, making it impossible for the cyclic component of the HP filter to be strictly or weakly stationary. The HP filter has weak dependence properties and these properties ensure that laws of large numbers and central limit theorems can hold for functions of the cyclical component. This provides one of the main justifications for using the HP filter.

However, Hamilton (2017) argues that HP filter should not be used for removing cyclical component from time series as the main formula used for the HP filter is an inaccurate representation of the data generating process (DGP). The HP filter generates an artificial set of relations from a clean and simple understanding of true properties of the series. In a way they have an artificial ability to ‘predict’ the future. The HP filter imposes patterns that are not a feature of the data generating process and could not be realised in real time ( Eg: The stock market crash of 2009 was interpreted as a temporary phenomenon but in reality it was a permanent one). The HP filter is a one sided filter and it violates several principles of filter design, generating misleading output.

The Baxter-King (BK) Filter passes through components of time series with fluctuations between 6 and 32 quarters while removing lower and higher frequencies. Due to its symmetric property, it does not present phase shift. As it has a constant and finite length, the

filter is stationary. It can render stationarity to time series integrated up to 2 orders, minimizing error between filter coefficients and ideal band pass filter coefficients. The BK filter is smoother than Hodrick-Prescott filter.

The setbacks of the filter are that if the series are dominated by lower frequencies, it provides distorted cyclical components. It can filter mainly components of higher frequencies. It induces spurious dynamic properties and extracts cyclical component that fails to capture a significant fraction of variance. Conditions required to obtain good approximation with BK filter are rarely met in practice. In case of integrated input series, BK produces a distorted output series. It induces a peak at business cycle frequencies even if it is absent in original series.

The most suited conditions for applying the BK filter are when the data is dominated by higher rather than lower frequencies. It is suitable for rendering stationarity in a time series with 2 unit roots. BK filter is more powerful at zero frequency.

The Butterworth Filter (BF) has the flattest pass band. It does not change the amplitude of the time series too much. Average gain for desired frequencies is greater when BW filter is used. It retains the properties of symmetry and phase neutrality.

The BW filter has an inefficient stop-band because it gradually goes to zero so some parts of the stop-band are still passed. It leaves components of higher frequencies in the time series.

Cristiano-Fitzgerald (CF) Filter solves an optimization problem quite similar to the one that leads to the BK filter, with a few notable differences. The objective function for the CF filter is also a mean squared error, but it differs from the one used by Baxter and King (1999) in that it relies on squared deviations between the approximate filter and the ideal filter.

The CF filter, however, is derived under the assumption that the time series follows a random walk. As in the BK filter, the CF time domain coefficients are constrained to sum to zero, so the filter can deal with the single unit root implicit in the random walk assumption. In

contrast to the BK filter, the symmetry restriction is not imposed on the coefficients ( all of which may be nonzero). This extension is motivated by the predictive properties of the random walk assumption. The CF filter puts different weights to each observation and hence the filter is not symmetric (Haug & Dewald 2004). Contrast to the BK is that the BK assumes the weights are fixed regardless of the number of observations. Besides, the CF is consistent compared to the BK as it converges to an ideal band pass filter as the sample size increases. The reason is that the approximation error of the weights diminishes as the sample size increases. CF is able to decompose the series to trend and cycles and it is also able to decompose the signal in specific time frames.

The CF filter obtains its optimality properties at the cost of an additional parameter that must be estimated and a loss of robustness. The CF filter is optimal for a random-walk process and also works well for processes that are close to being random walks or random walks plus drift. The CF filter has better performance than the BK filter of passing through only the business-cycle components. The CF filter is closer to the gain of the ideal filter than the BK filter. The gain of the CF filter oscillates above and below 1 for desired frequencies.

To sum up, the HP filter is probably the most rudimentary, even though it is still widely used during the policy making process and determining future trends most economists swear against the usage of the HP filter as it lacks some basic features. BK probable encompasses more of the variables in question but the CF provides a better picture compared to BK as in CF , the BK formula is modified.

Okun (1962) made an influential contribution in Economics that helped define the concept of potential GDP – that is, the value of output when the economy is under full employment conditions. This exposition helped understand a vital aspect in the macro economy: that potential output is not the level of output that is achievable, in a mechanical sense, with the maximum utilisation of the factors of production. Since marginal costs increase greatly and

surpass marginal revenue at high levels of factor utilisation, the complete use of all the factors of production becomes economically infeasible. Hence, potential output indicates that optimising resources in a constrained factor markets, such as the prevailing natural rate of unemployment. In sum, De Masi (1997) states the potential GDP is the maximum output an economy can withstand without causing a rise in inflation; while, the output gap is an aggregate measure of resource strain in the economy, and can serve as a means for policymakers to represent how “hot” or “cold” an economy is at any particular time, and to forecast inflationary pressures. It also helps to gauge the economic volatility, indicating if resources alternate between significantly high levels of employment and slack, or if the economy is stabilized.

Generally, potential output in neoclassical macroeconomic thought is identical with the trend growth rate of actual output. Fundamental to this concept of potential output is the belief that under laissez faire conditions, the economy is at equilibrium while it allocates resources optimally. Hence, the business cycle principally possesses a temporary nature.

The output series can be decomposed into a permanent and a cyclical components that exhibit stationary behaviour, such that it always returns to the permanent level. However, what confounds the situation is that the permanent or equilibrium level of output is not stable and instead, exhibits an upward trend in most economies, reflecting mainly productivity shocks. Hence, techniques that try to extract the cyclical element must be able to recognise movements in the time series that are due to the cycle, and those that reflect changes in potential output.

Baxter & King (1999) have found out from their study that the processes to measure the business cycle entail that the investigators begin by specifying characteristics of the cyclical component of the series and isolate them by simply applying moving averages and then develop adequate filters constrained to extract a specified range of periods, and otherwise

leave the properties of the extracted component unaffected; not modify the timing relationships between series at any frequency; result in a stationary time series even when applied to trending data; yield business cycle components that are unrelated to sample length; be operational, in that it does not result in too-long moving averages, with few data.

The simplest technique is linear de-trending. The key drawback of this method is that it indicates that potential GDP growth is constant, a postulation that has little economic foundation, especially given that many economies pass through a period of quick growth rates which then slow down as the country becomes richer. Based on this, phase average de-trending was developed, involving the estimation of a segmented linear trend, with shifts allowing for structural breaks (found by means of dummy variables). Another method, known as peak-to-peak de-trending, recommends that maximum observed production in the past be calculated as the output that is possible with full capital utilisation. The noticeable shortcoming of this method is that it is not possible to conclude when GDP expands rapidly and if this is a positive trend deviation or a higher trend growth. Moreover, this method, by definition, ignores most data points of a series. Robust trend estimation, or using nonparametric regression to approximate the trend function, has also been recommended in order to overcome the difficulties that arise with these simple linear de-trending methods.

The most popular filtering method is the HP filter. It takes the form:

$$\text{Min} \left( \sum_{t=1}^T (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2 \right)$$

This first term minimises the distance between the actual and the potential ( ) value, while the second minimises the change in the trend value. Given that these two intents are in opposition, the weight  $\lambda$  is used to control for the smoothness of the trend. It is typically set at 1600 for quarterly data. Its widespread use derives mainly from its simplicity, though it has

other useful properties, for example it produces an output gap that is stationary even when the original series is integrated.

Despite its popularity, its use has been controversial. It is totally mechanistic and results depend crucially on the choice of  $\lambda$ . If  $\lambda$  is set at zero, the trend will be the same as the actual series, while if it is set at infinity the trend reduces to the linear form. The arbitrary choice of the smoothing parameter influences the size of potential output estimates and some studies have argued that the commonly used  $\lambda$ s are only applicable for the normal business cycle of the United States. Long run deviations from equilibrium are ruled out, and the filter assumes the business cycle lasts between two and thirty two quarters. The method also suffers from a distinct end-of-sample problem. Baxter and King (1999) find that it takes data for three additional years to make sure the actual output gap makes sense. Cotis et al (2005) maintain that the sample end point flaws typifying HP filtering are beyond practical remedy, given that predictors tend to adopt a “back to average growth” forecasting approach. Another criticised aspect of the HP filter is that it accepts the cycle to be symmetric. In addition, Scacciavillani (1999) records that if there are structural breaks, the use of the HP filter could be unsuitable since the filtering procedure may remove from the data shifts that in fact represent a change in the trend level or growth rate of potential output. Baxter & King (1999), instead propose a band-pass filter, which treats fluctuations longer than six quarters and shorter than thirty two as being cyclical.

The time series observed over the period  $t$  is decomposed into trend (growth, signal) and cyclical (noise) component. It is usually assumed that they are independent. It is also assumed that the seasonality has been removed from the time series under consideration.

$$y_t = g_t + c_t$$

EQUATION 3.2

$$E(g_t, c_t) = 0$$

EQUATION 3.3

Applying the filter to the time series produces a new time series. As a simplest example we can see moving average filter

$$y_t^* = \sum_{h=-K}^K a_h y_{t-h} = a(L)y_t$$

EQUATION 3.4

where  $L$  is the lag operator and  $h = 1, \dots, K$ , such that  $a(L) = \sum_{h=-K}^K a_h L^h$ . In the case if the MA process is symmetric, then  $a_h = a_{-h}$ : If the weights sum to 0 then it is shown that the symmetric MA has trend reduction properties. Thus one can write

$$a(L) = (1 - L)(1 - L^{-1})\psi(L)$$

EQUATION 3.5

Where  $\psi(L)$  is a symmetric moving average with lags and leads  $K - 1$ :

The Cramer representation of the stationary time series is:

$$y_t = \int_{-\pi}^{\pi} \xi(\omega) d\omega$$

EQUATION 3.6

That is one can represent the time series as the integral of random periodic components,  $\xi(\omega)$ , which are mutually orthogonal,  $E(\xi(\omega_1)\xi(\omega_2)) = 0$ . Thus the filtered series can be expressed as:

$$y_t^* = \int_{-\pi}^{\pi} a(\omega)\xi(\omega)d\omega$$

EQUATION 3.7

Where  $a(\omega)$  is frequency response function of the linear filter, and



$$a(\omega) = \sum_{h=-K}^K a_h e^{-i\omega h}$$

EQUATION 3.8

Thus, the variance of the filtered series is given by

$$var(y_t^*) = \int_{-\pi}^{\pi} |a(\omega)|^2 f_y(\omega) d\omega$$

EQUATION 3.9

Where  $|a(\omega)|^2$  is squared gain function of the linear filter and  $f_y(\omega) = var(\xi(\omega))$ . The squared gain indicates the extent to which a moving average raises or lowers the contribution to variance in the filtered series from the level in the original series.

One of the issues of de-trending the time series is designing filters to isolate specific frequencies from the data. A basic building block in filter designing is low pass filter, a filter which retains only slow-moving components of the data. An ideal low pass filter passes through the frequencies  $-\underline{\omega} \leq \omega \leq \underline{\omega}$ . High pass and band pass filters are constructed from the low pass filter. High pass filter passes components of the data with frequency equal or less than  $p$  while low pass filter passes the components of the data with frequency bigger than  $p$ : The ideal band pass filter is constructed using two low pass filters with cut-off frequencies  $\underline{\omega}$  and  $\bar{\omega}$ , since it passes only frequencies in the range  $\underline{\omega} \leq \omega \leq \bar{\omega}$ .

Approximate filter,  $a_K(\omega)$  is constructed using the strategy of choosing the approximating filters weights  $a_h$  to minimize:

$$Q = \int_{-\pi}^{\pi} |\delta(\omega)|^2 d\omega$$

EQUATION 3.10

Where  $\delta(\omega) = \beta(\omega) - \alpha_K(\omega)$  is the discrepancy arising from approximation at frequency  $\omega$ .  $\beta(\omega)$  is specific filter which is to be approximated. The result of this

maximization problem is general: the optimal approximating filter for a given maximum length  $K$ , is constructed by simply truncating the ideal filters weights  $a_h$  at lag  $K$ .

The Hodrick-Prescott (1980) filter is an ad hoc fixed, 2- sided MA filter which is constructed using penalty-function method. This filter optimally extracts the stochastic trend (unit root), moving smoothly over time. The filter is constructed as the solution to the problem of minimizing the variability in the cyclical component subject to a penalty for the variation in the second difference or the smoothness of the trend or growth component. The smoothness of cyclical component is calculated taking the sum of squares of its second difference.

$$y_t = g_t + c_t$$

EQUATION 3.11

$$M = \text{Min} \left( \sum_{t=1}^T (y_t - g_t)^2 + \lambda \sum_{t=1}^T [(g_{t+1} - g_t) - (g_{t-1} - g_{t-2})]^2 \right)$$

EQUATION 3.12

Where  $y_t$  is the natural logarithm of the given series,  $g_t$  is the growth component,  $c_t$  are the deviations from the growth and  $\lambda$  is the smoothness parameter which penalizes the variability in the growth function. The  $r^{\text{st}}$  term in the right hand side is goodness of the measure and the second term is sum of squares of the growth components second difference, i.e. smoothness of  $g_t$ .

Taking the derivatives of the minimization problem with respect to growth component the first order condition is:

$$\frac{\partial M}{\partial g_t} = 0$$

EQUATION 3.13

$$H(L) = \frac{\lambda L^{-2}(1-L)^4}{\lambda L^{-2}(1-L)^4 + 1}$$

EQUATION 3.14

where the  $H(L)$  is the representation of the trend elimination Hodrick-Prescott filter.

The Fourier transformation or the spectral representation (frequency response function) of the filter by King and Rebelo (1993) has the following form:

$$H(l) = \frac{4\lambda(1 - \cos \omega)^2}{4\lambda(1 - \cos \omega)^2 + 1}$$

EQUATION 3.15

Where  $\omega$  represents the frequency.

An alternative representation of the H-P filter is the Wiener- Kolmogorov derivation of the filter which provides an efficient and simple computational algorithm (Kaiser and Marvall, 1999). This representation is equivalent with Kalman and Danthine and Girardin filter. The estimator of the cyclical component is given as:

$$\hat{c}_t = \xi(B, F)y_t = \left[ k_{c(HP)} \frac{\nabla^2 \bar{\nabla}^2}{\theta_{H-P}(B)\theta_{H-P}(F)} \right] y_t$$

EQUATION 3.16

Where  $\xi(B, F)$  is symmetric, two-sided and convergent linear filter.

The Hodrick-Prsecott filter shares some important properties with ideal high pass filter. An ideal high pass filter removes the low frequencies or the long cycle component, passing through the data with frequency lower than  $p$ . Therefore the Fourier transformation of ideal high pass filter is zero. We can see that the spectral H-P filter is zero at zero frequency, since  $\cos(0) = 1$ . It implies that the H-P filter generates stationary time series.

In the case of H-P filter the Fourier transformation is also treated as the gain function of the filter since the filter is symmetric by construction. Symmetricity in its turn eliminates the phase shift from the time series which is another desired property of H-P filter. Another important property is that the filter has a near unit gain at frequency equal to  $\pi$ , since  $\cos(\pi) = -1$

The H-P filter depends on one variable: smoothness parameter,  $\lambda$ . The optimal value of this variable is calculated as:

$$\lambda = \frac{\sigma_g^2}{\sigma_c^2}$$

EQUATION 3.17

Where  $\sigma_g^2$  and  $\sigma_c^2$  are the standard deviations of the innovations in the growth and cyclical components respectively. Variations in  $\lambda$  alters the trade-off between goodness of fit and smoothness degree which needs to be minimized. As penalty gets bigger,  $\lambda \rightarrow \infty$  the smoothness of the growth component increases, thus making it linear trend. With quarterly data Hodrick and Prescott (1997) set the value of  $\lambda$  priori equal to 1600 in order to approximate it to the high pass filter. This choice is interpreted as setting the cyclical component as fluctuations with a period less than 8 years. For this value of  $\lambda$  the filter is close to an approximate high pass filter with cut-off frequency =  $\pi/16$ . It means that if the quarterly data used then this choice makes the filter look like the ideal high pass filter which passes components of the data with periodicity  $p = 32$ .

As it was indicated above H-P filter is also usually applied to the seasonally adjusted time series. In this framework it is essential that the seasonality does not contaminate the time series.

### 3.2.3 Stationarity and seasonality

If the following regression model is considered:

$$Y_t = a_1 + b_1X_t + e_t$$

EQUATION 3.18

The assumption of the classical regression model requires  $Y_t$  and  $X_t$  to be stationary sequences and the disturbance term to have zero mean and some constant finite variance. In the presence of non-stationarity, there may exist spurious regression (Granger and Newbold,

1974). Under such a circumstance, the estimates are inconsistent and the usual tests of inference don't hold true. Granger and Newbold (1974) tested the repercussions of non-stationarity with the help of two independent random walks generating  $Y_t$  and  $X_t$ . Since the sequences are independent of each other, equation (3.18) is necessarily meaningless, in other words, the relationship between the two variables is spurious. If the residual sequence  $e_t$  is non-stationary, then the relationship is non-sensical. If the sequence has a stochastic trend then the errors don't decay and hence the deviation of the model from its equilibrium condition is permanent. A simple way to examine the properties of  $e_t$  is to abstract from the intercept and rewrite (3.18) as follows:

$$e_t = Y_t - b_1 X_t$$

EQUATION 3.19

Given that  $X_t$  and  $Y_t$  are generated through random walk processes, the initial condition of  $Y_0=X_0=0$  may be imposed such that,

$$e_t = \sum_{i=1}^t \varepsilon_{yi} - b_1 \sum_{i=1}^t \varepsilon_{xi}$$

EQUATION 3.20

Where 'ε' s are the error terms of the random walk processes. The variance of the error approaches infinity as t increases. Also, the error has a permanent component –

$$E_t e_{t+1} = e_t, \quad \forall i \geq 0$$

EQUATION 3.21

Hence, all the tests (t, F) or  $R^2$  values are unreliable. The essence of the issue at hand is that if  $b_1=0$ , the data generating process in (3.18) is  $Y_t = a_1 + e_t$ .  $Y_t$  being integrated of order 1, i.e. I(1), it follows that  $e_t$  is also I(1) under the null hypothesis. The error term being a unit root process, the distributional theory underlying the OLS method is hence challenged. Essentially, all that needs to be checked is whether  $b_1 = 0$  or not. In order to do so, the Dickey-Fuller test suggests subtracting  $Y_{t-1}$  from both sides of the random walk process  $Y_t =$

$c_1 Y_{t-1} + \varepsilon_t$  to write it in the form of  $\Delta Y_t = \gamma Y_{t-1} + \varepsilon_t$  where  $\gamma = c_1 - 1$ . Testing  $c_1 = 0$  is then equivalent to testing the hypothesis that  $\gamma = 0$ . Dickey and Fuller (1979) considered three different regression equations that can be tested for existence of unit roots:

$$\Delta Y_t = \gamma Y_{t-1} + \varepsilon_t$$

EQUATION 3.22

$$\Delta Y_t = c_0 + \gamma Y_{t-1} + \varepsilon_t$$

EQUATION 3.23

$$\Delta Y_t = c_0 + \gamma Y_{t-1} + c_2 t + \varepsilon_t$$

EQUATION 3.24

The first being a pure random walk model, second with a drift and the third with a drift and a linear time trend. In all the equations (3.22 – 3.25) the parameter of interest is  $\gamma$ ; if  $\gamma = 0$  the sequence  $Y_t$  contains a unit root. The equation is estimated using OLS method and the t-statistic is compared with the values reported by the Dickey-Fuller tables to ascertain whether the null hypothesis  $\gamma = 0$  can be accepted or rejected.

### Seasonality

Seasonality is the systematic (not necessarily regular) intra-year movement caused by the changes of the weather, the calendar, and timing of decisions, directly or indirectly through the production and consumption decisions made by the agents of the economy. These decisions are influenced by endowments, the expectations and preferences of the agents and the production techniques available in the economy (Modelling Seasonality, Hylleberg 1992).

Many economic variables display some kind of seasonality. Forecasts made by ignoring such patterns usually lead to high variances. The combination of a strong seasonality is often found in economic data alongside non-stationarity. Hence, it is important to identify whether a seasonal pattern exists in the process and then remove it before progressing with further analysis. The Autocorrelation Function (ACF) for a process with strong seasonality will show

spikes at lags  $s, 2s, 3s, \dots$  that do not decay rapidly. If the autocorrelations at the seasonal lags do not decay, it is necessary to take seasonal differences. This prevents the other autocorrelations from getting dwarfed due to the seasonal effects. After stationarising the data, in order to remove the persistent seasonality, the seasonal difference, i.e.  $(Y_t - Y_{t-4})$  for quarterly data or  $(Y_t - Y_{t-12})$  for monthly data needs to be taken.

To test for the presence of seasonal unit roots the authors have applied the Hylleberg, Engle, Granger and Yoo (henceforth, HEGY) test (1990). Considering the quarterly case (same methodology can be extended for monthly data case), let  $x_t$  be a univariate stochastic process as follows:

$$x_t = \alpha x_{t-4} + u_t \quad t = 1, 2, \dots, T$$

EQUATION 3.25

The  $x_t$  process has four roots on the unit circle when  $\alpha = 1$ ; one at frequency  $\theta = 0$ , one at frequency  $\theta = \pi$ , and a pair of complex roots at frequencies  $\theta = \pi/2, 3\pi/2$ .

HEGY (1990) introduced a factorization of the seasonal differencing polynomial  $\Delta_4 = (1 - B^4)$  and developed a testing procedure for seasonal unit roots, which consists in estimating via OLS the following regression:

$$\Delta_4 x_t = \pi_1 y_{1,t-1} + \pi_2 y_{2,t-1} + \pi_3 y_{3,t-2} + \pi_4 y_{3,t-1} + \varepsilon_t$$

EQUATION 3.26

where  $y_{1,t} = (1 + B + B^2 + B^3)x_t$ ,  $y_{2,t} = -(1 - B + B^2 - B^3)x_t$  and  $y_{3,t} = -(1 - B^2)x_t$ .

Notice that when  $\alpha = 1$  in (3.25),  $y_{1,t}$ ,  $y_{2,t}$ , and  $y_{3,t}$  have unit roots only at  $\theta = 0, \pi$ , and  $\pi/2$ , respectively. Hence, the unit root found at  $\theta = 0$  in  $x_t$ , implies accepting the null that  $\pi_1$  is zero. Similarly, when  $\pi_2$  is zero, it indicates the existence of a unit root at  $\theta = \pi$ . When both  $\pi_3$  and  $\pi_4$  are zero, then we have a pair of complex unit roots at  $\theta = \pi/2$ . HEGY proposed t-statistics for  $\pi_1, \pi_2$  and  $\pi_3$  if  $(\pi_4 = 0)$ , which will be denoted  $t_1$  through  $t_4$ , as well as F-tests for  $\pi_3$  and  $\pi_4$  jointly denoted  $F_{34}$ . Each test may be considered for regression

models with and without a constant, trend, or seasonal dummies. Likewise, the regression model can be extended via an AR polynomial augmentation.

### 3.2.4 ARIMA

Autoregressive Integrated Moving Average (ARIMA) process is a non-stationary process generated through a combination of Autoregressive (AR) and Moving Average (MA) processes. The data generation process (DGP) looks like the following:

$$Y_t = a_0 + \sum_{i=1}^p a_i Y_{t-i} + \sum_{i=0}^q \beta_i \varepsilon_{t-i}$$

EQUATION 3.27

Where  $\beta_0=0$  always. When the characteristic roots of the above process are all within the unit circle,  $Y_t$  is an ARMA (Autoregressive Moving Average) process; if one or more characteristic roots is greater than or equal to unity, then it is an ARIMA process. The residuals from ARIMA model are used to estimate the spectra and the cross spectra for the frequency domain analysis.

### 3.2.5 Causality

With the residual data, spectra for core inflation and international energy prices were calculated followed by co-spectrum and quadrature. Cross-spectrum was calculated with the help of co-spectrum and quadrature. Finally the coherence was calculated for various cycles.

The bivariate Granger Causality (GC) test over the spectrum as proposed by Lemmens et al (2008) is followed here. They reconsidered the framework that was originally proposed by Pierce (1979), and proposed a testing procedure for Pierce's spectral GC measure. Let  $X_t$  and  $Y_t$  be two stationary time series of length T. The goal is to test whether  $X_t$  Granger causes  $Y_t$  at a given frequency  $\lambda$ . Pierce's measure for GC (Pierce 1979) in the frequency-domain is performed on the univariate innovations series,  $u_t$  and  $v_t$ , derived from filtering the  $X_t$  and  $Y_t$  as univariate ARMA processes, i.e.,



$$\Theta_x(L)X_t = C_x + \Phi_x(L)u_t$$

EQUATION 3.28

$$\Theta_y(L)Y_t = C_y + \Phi_y(L)v_t$$

EQUATION 3.29

where,  $\Theta_x(L)$  and  $\Theta_y(L)$  are autoregressive polynomials,  $\Theta_x(L)$  and  $\Theta_y(L)$  are moving average polynomials and  $C_x$  and  $C_y$  potential deterministic components. The obtained innovation (error/disturbance) series  $u_t$  and  $v_t$ , are the series of importance in the GC test proposed by Lemmens et al (2008). Let  $S_u(\lambda)$  and  $S_v(\lambda)$  be the spectral density functions, or spectra, of  $u_t$  and  $v_t$  at frequency  $\lambda \in ]0, \pi [$ , defined by

$$S_u(\lambda) = \frac{1}{2\pi} \sum \gamma_u(k) e^{-i\lambda k}$$

EQUATION 3.30

$$S_v(\lambda) = \frac{1}{2\pi} \sum \gamma_v(k) e^{-i\lambda k}$$

EQUATION 3.31

Where,  $\gamma_u(k) = \text{Cov}(u_t, u_{t-k})$  and  $\gamma_v(k) = \text{Cov}(v_t, v_{t-k})$  represent the autocovariances of  $u_t$  and  $v_t$  at lag  $k$ . The idea of the spectral representation is that each time series may be decomposed into a sum of uncorrelated components, each related to a particular frequency  $\lambda$ . The spectrum can be interpreted as a decomposition of the series variance by frequency. The portion of variance of the series occurring between any two frequencies is given by area under the spectrum between those two frequencies. In other words, the area under  $S_u(\lambda)$  and  $S_v(\lambda)$  between any two frequencies  $\lambda$  and  $\lambda + d\lambda$ , gives the portion of variance of  $u_t$  and  $v_t$  respectively, due to cyclical components in the frequency band  $(\lambda, \lambda + d\lambda)$ .

The cross spectrum represents the cross covariogram of two series in frequency-domain. It allows determining the relationship between two time series as a function of frequency. Let  $S_{uv}(\lambda)$  be the cross spectrum between  $u_t$  and  $v_t$  series. The cross spectrum is a complex number, defined as,

$$\begin{aligned}
S_{uv}(\lambda) &= C_{uv}(\lambda) + iQ_{uv}(\lambda) \\
&= \frac{1}{2\pi} \sum \gamma_{uv}(k) e^{-i\lambda k}
\end{aligned}$$

EQUATION 3.32

where,  $C_{uv}(\lambda)$  called cospectrum and  $Q_{uv}(\lambda)$  called quadrature spectrum are respectively, the real and imaginary parts of the cross-spectrum. Here  $\gamma_{vu}(k) = \text{Cov}(u_t, v_{t-k})$  represents the cross-covariance of  $u_t$  and  $v_t$  at lag  $k$ . The cospectrum  $Q_{uv}(\lambda)$  between two series  $u_t$  and  $v_t$  at frequency  $\lambda$  can be interpreted as the covariance between two series  $u_t$  and  $v_t$  that is attributable to cycles with frequency  $\lambda$ . The quadrature spectrum looks for evidence of out-of-phase cycles (Hamilton 1994: 274). The cross-spectrum can be estimated non-parametrically by,

$$\hat{S}_{uv}(\lambda) = \frac{1}{2\pi} \sum w_k \hat{\gamma}_{uv}(k) e^{-i\lambda k}$$

EQUATION 3.33

With  $\hat{\gamma}_{uv}(k)$  as the empirical cross-covariances, and with window weights  $w_k$ , for  $k = -M, \dots, M$ . Eq (6) is called the weighted covariance estimator, and the weights  $w_k$  are selected as the Bartlett weighting scheme, i.e.,  $1 - \frac{|k|}{M}$ . The constant  $M$  determines the maximum lag order considered. The spectra of Eq (3) and (4) are estimated in a similar way. This cross-spectrum allows us to compute the coefficient of coherence  $h_{uv}(\lambda)$  defined as,

$$h_{uv}(\lambda) = \frac{|S_{uv}(\lambda)|}{\sqrt{S_u(\lambda)S_v(\lambda)}}$$

EQUATION 3.34

Coherence can be interpreted as the absolute value of a frequency specific correlation coefficient. The squared coefficient of coherence has an interpretation similar to the R-square in a regression context. Coherence thus takes values between 0 and 1. Lemmens et al (2008) have shown that, under the null hypothesis that  $h_{uv}(\lambda) = 0$ , the estimated squared coefficient

of coherence at frequency  $\lambda$ , with  $0 < \lambda < \pi$  when appropriately rescaled, converges to a chi squared distribution with 2 degrees of freedom, denoted by  $\chi^2_2$ .

$$2(n-1)\hat{h}_{uv}^2(\lambda) \xrightarrow{d} \chi^2_2$$

EQUATION 3.35

where  $\xrightarrow{d}$  stands for convergence in distribution, with  $n = \frac{T}{\sum w_k^2}$ . The null hypothesis  $h_{uv}(\lambda) = 0$  versus  $h_{uv}(\lambda) > 0$  is then rejected if

$$\hat{h}_{uv}(\lambda) > \sqrt{\frac{\chi^2_{2,1-\alpha}}{2(n-1)}}$$

EQUATION 3.36

with  $\chi^2_{2,1-\alpha}$  being the  $1 - \alpha$  quantile of the chi squared distribution with 2 degrees of freedom. The coefficient of coherence in Eq 3.34 gives a measure of the strength of the linear association between two time series, frequency by frequency, but does not provide any information on the direction of the relationship between two processes. Lemmens et al (2008) have decomposed the cross-spectrum into three parts: (i) the instantaneous relationship between  $u_t$  and  $v_t$ ; (ii) the directional relationship between  $v_t$  and lagged values of  $u_t$ ; and (iii) the directional relationship between  $u_t$  and lagged values of  $v_t$ , i e,

$$S_{uv}(\lambda) = \frac{1}{2\pi} [\gamma_{uv}(0) + \sum_{k=-\infty}^{-1} \gamma_{uv}(k)e^{-i\lambda k} + \sum_{k=1}^{\infty} \gamma_{uv}(k)e^{-i\lambda k}]$$

EQUATION 3.37

The proposed spectral measure of GC is based on the key property that  $u_t$  does not Granger cause  $v_t$  if and only if  $\gamma_{uv}(k) = 0$  for all  $k < 0$ . The goal is to test the predictive content of  $u_t$  relative to  $v_t$  which is given by the second part of Eq (10), i e,

$$S_{u \Rightarrow v}(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{-1} \gamma_{uv}(k)e^{-i\lambda k}$$

EQUATION 3.38

The Granger coefficient of coherence is then given by,

$$h_{u \Rightarrow v}(\lambda) = \frac{S_{u \Rightarrow v}(\lambda)}{\sqrt{S_u(\lambda)S_v(\lambda)}}$$

EQUATION 3.39

Therefore, in the absence of GC,  $h_{u \Rightarrow v}(\lambda) = 0$  for every  $\lambda$  in  $] 0, \pi [$ . The Granger coefficient of coherence takes values between zero and one, Pierce (1979). The distribution of the estimator of the Granger coefficient of coherence is derived from the distribution of the coefficient of coherence.

Under the null hypothesis  $h_{u \Rightarrow v}(\lambda) = 0$ , the distribution of the squared estimated Granger coefficient of coherence at frequency  $\lambda$ , with  $0 < \lambda < \pi$  is given by,

$$2(n' - 1)h_{uv}^2(\lambda) = \chi_2^2$$

EQUATION 3.40

where  $n$  is now replaced by  $n' = \frac{T}{\sum w_k^2}$ . The null hypothesis  $h_{u \Rightarrow v}(\lambda) = 0$  is then rejected if

$$h_{u \Rightarrow v}(\lambda) > \sqrt{\frac{\chi_{2,1-\alpha}^2}{2(n' - 1)}}$$

EQUATION 3.41

We then compute the Granger coefficient of coherence given by Eq (3.39) and test the significance of causality by making use of Eq (3.41) (Hamilton, 1994)

### 3.2.6 Structural VAR

Structural Vector Autoregressions (SVARs), introduced by Sims (1980), have been in the use for recovering economic shock components from observable data with the help of few assumptions that have been compatible with many classes of models in the literature. They are linear, multivariate representations of vector of observable variables on their own lagged values and/or other variables. SVARs are constructed based on ‘explicit identifying assumptions’ that isolate estimates of policy or private agent behaviours and their effect on

the economy, freeing the model of other restrictive assumptions that may have been required to provide every parameter an interpretation. SVARs have been used extensively to ascertain a variety of macroeconomic behaviours. Sims and Zha (2006) use the method to understand effect of money on output, Blanchard and Quah (1989) used it to understand significance of supply and demand shocks on business cycles, Blanchard and Perotti (2002) studied the implications of fiscal policies with SVAR models. The model has been instrumental in explaining aggregate fluctuations.

Sims' (1980) VAR approach has the desirable property that all variables are treated symmetrically, so that the econometrician does not rely on any "incredible identification restrictions." A VAR can be quite helpful in examining the relationships among a set of economic variables. Moreover, the resulting estimates can be used for forecasting purposes.

Consider a first-order VAR system of the type represented by

$$x_t = A_0 + A_1 x_{t-1} + e_t$$

**EQUATION 3.42**

Although the VAR approach yields only estimated values of  $A_0$  and  $A_1$ , for exposition purposes, it is useful to treat each as being known. The  $n$ -step ahead forecast error is

$$x_{t+n} - E_t x_{t+n} = e_{t+n} + A_1 e_{t+n-1} + A_1^2 e_{t+n-2} + \dots + A_1^{n-1} e_{t+1}$$

**EQUATION 3.43**

Even though the model is under-identified, an appropriately specified model will have forecasts that are unbiased and have minimum variance. Of course, if we had a priori information concerning any of the coefficients, it would be possible to improve the precision of the estimates and reduce the forecast-error variance. A researcher interested only in forecasting might want to trim down the over-parameterized VAR model. Nonetheless, it should be clear that forecasting with a VAR is a multivariate extension of forecasting using a simple auto-regression. The VAR approach has been criticized as being devoid of any

economic content. The sole role of the economist is to suggest the appropriate variables to include in the VAR. From that point on, the procedure is almost mechanical. Since there is so little economic input in a VAR, it should not be surprising that there is little economic content in the results. Of course, innovation accounting does require an ordering of the variables, but the selection of the ordering is generally ad hoc. Unless the underlying structural model can be identified from the reduced-form VAR model, the innovations in a Choleski decomposition do not have a direct economic interpretation. Consider the two-variable VAR model

$$y_t + b_{12}z_t = b_{10} + \gamma_{11}y_{t-1} + \gamma_{12}z_{t-1} + \epsilon_{yt}$$

EQUATION 3.44

$$b_{21}y_t + z_t = b_{20} + \gamma_{21}y_{t-1} + \gamma_{22}z_{t-1} + \epsilon_{zt}$$

EQUATION 3.45

So that it is possible to write the model in the form

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t}$$

EQUATION 3.46

$$z_t = a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{2t}$$

EQUATION 3.47

The important point to note is that the two error terms  $e_{1t}$  and  $e_{2t}$  are actually composites of the underlying shocks  $\epsilon_{yt}$  and  $\epsilon_{zt}$

$$\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = \frac{1}{(1 - b_{12}b_{21})} \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{zt} \end{bmatrix}$$

EQUATION 3.48

Although these composite shocks are the one-step ahead forecast errors in  $y_t$  and  $z_t$ , they do not have a structural interpretation. Hence, there is an important difference between using VARS for forecasting and using them for economic analysis. In (3.46 & 3.47)  $e_{1t}$  and  $e_{2t}$  are forecast errors. If we are interested only in forecasting, the components of the forecast errors

are unimportant.  $\epsilon_{yt}$  and  $\epsilon_{zt}$  are the autonomous changes in  $y_t$  and  $z_t$  in period  $t$ , respectively. If the intention is to obtain an impulse response function or a variance decomposition to trace out the effects of an innovation in  $y_t$  or  $z_t$  it is necessary to use the structural shocks (i.e.,  $\epsilon_{yt}$  and  $\epsilon_{zt}$ ) and not the forecast errors. The aim of a structural VAR is to use economic theory (rather than the Choleski decomposition) to recover the structural innovations from the residuals  $\{e_{1t}\}$  and  $\{e_{2t}\}$ .

The Choleski decomposition actually makes a strong assumption about the underlying structural errors. Suppose we select an ordering such that  $b_{21} = 0$ . With this assumption, the two pure innovations can be recovered as

$$\epsilon_{zt} = e_{2t}$$

EQUATION 3.49

And

$$\epsilon_{yt} = e_{1t} - b_{12}e_{2t}$$

EQUATION 3.50

Forcing  $b_{21} = 0$  is equivalent to assuming that an innovation in  $y$ , does not have a contemporaneous effect on  $z_t$ . Unless there is a theoretical foundation for this assumption, the underlying shocks are improperly identified. As such, the impulse responses and variance decompositions resulting from this improper identification can be quite misleading.

If the correlation coefficient between  $e_{1t}$  and  $e_{2t}$  is low, the ordering is not likely to be important. However, in a VAR with several variables it is improbable that all correlations will be small. In selecting the variables to include in a model, you are likely to choose variables that exhibit strong co-movements. When the residuals of a VAR are correlated, it is not practical to try all alternative orderings. With a four-variable model, there are 24 (i.e., 4!) possible orderings.

Sims (1986) and Bemanke (1986) propose modelling the innovations using economic analysis. To understand the procedure, it is useful to examine the relationship between the forecast errors and structural innovations in an n-variable VAR. Since this relationship is invariant to lag length, the first-order model with n variables should suffice at this point

$$\begin{bmatrix} 1 & b_{12} & b_{13} & \cdots & b_{1n} \\ b_{21} & 1 & b_{23} & \cdots & b_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ b_{n1} & b_{n2} & b_{n3} & \cdots & 1 \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \\ \cdots \\ x_{nt} \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \\ \cdots \\ b_{n0} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \cdots & \gamma_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \gamma_{n1} & \gamma_{n2} & \gamma_{n3} & \cdots & \gamma_{nn} \end{bmatrix} \begin{bmatrix} x_{1(t-1)} \\ x_{2(t-1)} \\ \cdots \\ x_{n(t-1)} \end{bmatrix} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ \cdots \\ \epsilon_{nt} \end{bmatrix}$$

EQUATION 3.51

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \epsilon_t$$

EQUATION 3.52

Pre-multiplying by  $B^{-1}$  then gives

$$x_t = B^{-1}\Gamma_0 + B^{-1}\Gamma_1 x_{t-1} + B^{-1}\epsilon_t$$

EQUATION 3.53

Defining  $A_0 = B^{-1}\Gamma_0$ ,  $A_1 = B^{-1}\Gamma_1$  and  $e_t = B^{-1}\epsilon_t$ , yields the multivariate generalization of (3.41). The problem, then is to take the observed values of  $e_t$  and restrict the system so as to recover  $\epsilon_t$  as  $\epsilon_t = Be_t$ . The selection of the various  $b_{ij}$  cannot be completely arbitrary. The issue is to restrict the system so as to (1) recover the various  $\{\epsilon_{it}\}$  and (2) preserve the assumed error structure concerning the independence of the various  $\{\epsilon_{it}\}$  shocks. To solve this identification problem - simply needs a count of equations and unknowns. Using OLS, the variance/covariance matrix  $\Sigma.$  can be obtained as follows -

$$\Sigma. = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \cdots & \sigma_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_n^2 \end{bmatrix}$$

EQUATION 3.54

Where each element of  $\Sigma.$  is constructed as the sum



$$\sigma_{ij} = \frac{1}{T} \sum_{t=1}^T e_{it} e_{jt}$$

EQUATION 3.55

Since  $\Sigma$  is symmetric, it contains only  $(n^2+n)/2$  distinct elements. There are  $n$  elements along the principal diagonal  $(n-1)$  along the first off-diagonal,  $(n-2)$  along the next off-diagonal, ... , and one corner element for a total of  $(n^2+n)/2$  free elements.

Given that the diagonal elements of  $B$  are all unity,  $B$  contains  $(n^2 - n)$  unknown values. In addition, there are the  $n$  unknown values  $Var(\epsilon_{it})$  for a total of  $n^2$  unknown values in the structural model (i.e., the  $(n^2 - n)$  values of  $B$  plus the  $n$  values of  $Var(\epsilon_{it})$ ). Now, the answer to the identification problem is simple; in order to identify the  $n^2$  unknowns from the known  $(n^2 + n)/2$  independent elements of  $\Sigma$ , it is necessary to impose an additional  $n^2 - (n^2 + n)/2 = (n^2 - n)/2$  restrictions on the system. This result generalizes to a model with  $p$  lags: To identify the structural model from an estimated VAR, it is necessary to impose  $(n^2 - n)/2$  restrictions on the structural model.

The Choleski decomposition requires all elements above the principal diagonal to be zero:

$$b_{12} = b_{13} = b_{14} = \dots = b_{1n} = 0$$

$$b_{23} = b_{24} = \dots = b_{2n} = 0$$

$$b_{34} = \dots = b_{3n} = 0$$

...

$$b_{(n-1)n} = 0$$

EQUATION 3.56

Hence, there are total  $(n^2 - n)/2$  restrictions; the system is exactly identified.

### 3.2.7 Impulse Response Function:

Hamilton (1994) and Enders (1995) note that the vector moving average (VMA) representation expresses the variables  $y_t$  and  $z_t$  in terms of the current and past values of the two types of shocks, i.e.,  $e_{1t}$  and  $e_{2t}$ . The VMA representation is an essential feature of Sims' (1980) methodology in that it allows tracing out the time path of the various shocks on the variables contained in the VAR system. The VMA representation for a two variable model can be written as follows

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$$

EQUATION 3.57

Or

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^i \begin{bmatrix} e_{1(t-i)} \\ e_{2(t-i)} \end{bmatrix}$$

EQUATION 3.58

It is furthermore useful to rewrite the above equation in terms of  $\{\epsilon_{yt}\}$  and  $\{\epsilon_{zt}\}$  sequences. From the vector of errors the following representation in terms of the structural shocks can be obtained -

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \frac{1}{(1 - b_{12}b_{21})} \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^i \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{zt} \end{bmatrix}$$

EQUATION 3.59

For the sake of simplicity, the above representation may also be expressed as

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \epsilon_{y(t-i)} \\ \epsilon_{z(t-i)} \end{bmatrix}$$

EQUATION 3.60

Where  $\phi_i = \left[ \frac{A_1^i}{(1 - b_{12}b_{21})} \right] \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix}$

EQUATION 3.61

Alternatively, it may be written as

$$x_t = \mu + \sum_{i=0}^{\infty} \phi_i \epsilon_{t-i}$$

EQUATION 3.62

This expression is a particularly important one in the sense that it helps examine interactions between  $\{y_t\}$  and  $\{z_t\}$  sequences. The coefficients of  $\phi_i$  can be used to generate the effects of  $\{\epsilon_{y_t}\}$  and  $\{\epsilon_{z_t}\}$  shocks on  $\{y_t\}$  and  $\{z_t\}$  sequences. The four elements of  $\phi_{jk}(0)$  are nothing but the impact multipliers. The coefficient  $\phi_{12}(0)$  is the instantaneous impact of a one-unit change in  $\{\epsilon_{z_t}\}$  on  $\{y_t\}$ ;  $\phi_{12}(1)$  is the response of unit change in  $\{\epsilon_{z_{(t-1)}}\}$  on  $\{y_t\}$ ;

The accumulated effects of unit impulses in  $\{\epsilon_{y_t}\}$  and/or  $\{\epsilon_{z_t}\}$  can be obtained by the appropriate summation of the coefficients of the impulse response functions. Thus, after  $n$  periods, the cumulated sum of the effects of  $\{\epsilon_{z_t}\}$  on  $\{y_t\}$  is given by

$$\sum_{i=0}^n \phi_{12}(i)$$

EQUATION 3.63

As  $n$  approaches infinity, the long-run multiplier becomes evident. Given that  $\{y_t\}$  and  $\{z_t\}$  sequences are stationary in nature, it must hold true that

$$\sum_{i=0}^{\infty} \phi_{jk}^2(i) \text{ is finite } \forall j \text{ and } k$$

EQUATION 3.64

The four sets of coefficients given by  $\phi_{11}(i)$ ,  $\phi_{12}(i)$ ,  $\phi_{21}(i)$  and  $\phi_{22}(i)$  are the impulse response functions. Plotting these functions against  $i$  provides a practical way to visually represent the behaviour of the sequences  $\{y_t\}$  and  $\{z_t\}$  in response to the various shocks.

### 3.2.8 Variance Decomposition:

Since unrestricted VARs are over-parameterized, they are not particularly useful for short-term forecasts. However, understanding the properties of the forecast errors is exceedingly

helpful in uncovering inter-relationships among variables in the system. If the coefficients  $A_0$  and  $A_1$  in equation (3.41) are known, then forecasting  $x_t$  becomes apparent.

$$E_t x_{t+1} = A_0 + A_1 x_t$$

EQUATION 3.65

One-step ahead forecast error is then given by  $x_{t+1} - E_t x_{t+1} = e_{t+1}$ . Thus the  $n$ -step-ahead forecast will be given by

$$E_t x_{t+n} = (I + A_1 + A_1^2 + \dots + A_1^{n-1})A_0 + A_1^n x_t$$

EQUATION 3.66

With the forecast error being

$$e_{t+n} + A_1 e_{t+n-1} + A_1^2 e_{t+n-2} + \dots + A_1^{n-1} e_{t+1}$$

EQUATION 3.67

The same can also be expressed in terms of the structural errors.

$$x_{t+n} = \mu + \sum_{i=0}^{\infty} \phi_i \epsilon_{t+n-i}$$

EQUATION 3.68

Such that the  $n$ -period forecast error is given by

$$x_{t+n} - E_t x_{t+n} = \sum_{i=0}^{n-1} \phi_i \epsilon_{t+n-i}$$

EQUATION 3.69

Focusing only on the sequence  $\{y_t\}$ , the  $n$ -step ahead forecast error can be written as

$$\begin{aligned} y_{t+n} - E_t y_{t+n} &= \phi_{11}(0)\epsilon_{y(t+n)} + \phi_{11}(1)\epsilon_{y(t+n-1)} + \dots + \phi_{11}(n-1)\epsilon_{y(t+1)} \\ &+ \phi_{12}(0)\epsilon_{z(t+n)} + \phi_{12}(1)\epsilon_{z(t+n-1)} + \dots + \phi_{12}(n-1)\epsilon_{z(t+1)} \end{aligned}$$

EQUATION 3.70

Representing variance of  $n$ -step-ahead forecast error variance of  $y_{t+n}$  as  $\sigma_y(n)^2$  the above equation can be re-written as follows

$$\begin{aligned}\sigma_y(n)^2 &= \sigma_y^2[\phi_{11}(0)^2 + \phi_{11}(1)^2 + \dots + \phi_{11}(n-1)^2] \\ &\quad + \sigma_z^2[\phi_{12}(0)^2 + \phi_{12}(1)^2 + \dots + \phi_{12}(n-1)^2]\end{aligned}$$

EQUATION 3.71

Since all values of  $\phi_{jk}(i)^2$  are positive, the variance of the forecast error increases as the forecast horizon  $n$  increases. Note that it is possible to decompose the  $n$ -step-ahead forecast error variance due to each one of the shocks. Respectively, the proportions of  $\sigma_y(n)^2$  due to  $\{\epsilon_{yt}\}$  and  $\{\epsilon_{zt}\}$  sequences are as follows

$$\frac{\sigma_y^2[\phi_{11}(0)^2 + \phi_{11}(1)^2 + \dots + \phi_{11}(n-1)^2]}{\sigma_y(n)^2}$$

EQUATION 3.72

And

$$\frac{\sigma_z^2[\phi_{12}(0)^2 + \phi_{12}(1)^2 + \dots + \phi_{12}(n-1)^2]}{\sigma_y(n)^2}$$

EQUATION 3.73

The forecast error variance decomposition tells us the proportion of the movements in a sequence due to its "own" shocks versus shocks to the other variable. If  $\{\epsilon_{zt}\}$  shocks explain none of the forecast error variance of  $\{y_t\}$  at all forecast horizons, then it can be said that the sequence is exogenous. Under such a circumstance, the  $\{y_t\}$  sequence would evolve independently of the  $\{\epsilon_{zt}\}$  shocks and the sequence  $\{z_t\}$ . At the other extreme,  $\{\epsilon_{zt}\}$  shocks could explain all the forecast error variance in the  $\{y_t\}$  sequence at all forecast horizons, so that  $\{y_t\}$  would be entirely endogenous. In applied research, it is typical for a variable to explain almost all its forecast error variance at short horizons and smaller proportions at longer horizons. We would expect this pattern if  $\{\epsilon_{zt}\}$  shocks had little contemporaneous effect on  $\{y_t\}$  but acted to affect the  $\{y_t\}$  sequence with a lag.

In order to identify the  $\{\epsilon_{yt}\}$  and  $\{\epsilon_{zt}\}$  sequences, it is necessary to restrict the B matrix. The Choleski decomposition necessitates that all the one-period forecast error variance of  $\{z_t\}$  is due to  $\{\epsilon_{zt}\}$ .

Thus, impulse response analysis and variance decompositions (together called innovation accounting) can be useful tools to examine the relationships among economic variables.

## 4 Chapter 4. The Model

The chapter reports the model constructed to check for causality effects of the chosen variables on core WPI. The section begins by highlighting all the variables used in the study followed by the structural VAR models constructed to test dependence of core WPI on each of the other five variables. The chapter includes the sixteen models being considered for the analysis – each model has one variant of output gap measure and one variant of money supply measure.

The variables under consideration for the study are as follows:

1. Core inflation
2. Food inflation
3. Energy inflation
4. International Energy Price
5. Output Gap HP
6. Output Gap BW
7. Output Gap BK
8. Output Gap CF
9. M1
10. M2
11. M3
12. M4

In order to construct the SVAR models with the above variables, the number of restrictions required to be imposed are  $(n^2-n)/2 = (6^2-6)/2 = 15$ . The restrictions are laid down as follows:

1. Core inflation doesn't affect any of the variables contemporaneously  $b_{21} = b_{31} = b_{41} = b_{51} = b_{61} = 0$  - 5 restrictions
2. IntEnergyP is exogenous  $b_{42} = b_{43} = b_{45} = b_{46} = 0$  - 4 restrictions
3. Food prices don't affect core (based on the results from the spectral coherence)  $b_{12} = 0$  - 1 restriction
4. Money supply is not affected by the variables contemporaneously  $b_{62} = b_{63} = b_{64} = b_{65} = 0$  - 4 restrictions

5. Energy doesn't affect output gap contemporaneously  $b_{53} = 0$  - 1 restriction

The following SVAR models are constructed and tested for each with core inflation, domestic food prices, domestic energy prices, international energy prices, one of the four measures of output gap and one of the measures of money supply. The study is particularly interested in the equation with core inflation as the dependent variable and all the other variables as independent variables. The sixteen possible models<sup>2</sup> are presented below–

<b>Structural Vector Autoregression Models</b>						
Variables → Model Name ↓	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap Variant	Money Supply Variant
Model 1	Yes	Yes	Yes	Yes	HP	M1
Model 2	Yes	Yes	Yes	Yes	BW	M1
Model 3	Yes	Yes	Yes	Yes	BK	M1
Model 4	Yes	Yes	Yes	Yes	CF	M1
Model 5	Yes	Yes	Yes	Yes	HP	M2
Model 6	Yes	Yes	Yes	Yes	BW	M2
Model 7	Yes	Yes	Yes	Yes	BK	M2
Model 8	Yes	Yes	Yes	Yes	CF	M2
Model 9	Yes	Yes	Yes	Yes	HP	M3
Model 10	Yes	Yes	Yes	Yes	BW	M3
Model 11	Yes	Yes	Yes	Yes	BK	M3
Model 12	Yes	Yes	Yes	Yes	CF	M3
Model 13	Yes	Yes	Yes	Yes	HP	M4
Model 14	Yes	Yes	Yes	Yes	BW	M4
Model 15	Yes	Yes	Yes	Yes	BK	M4
Model 16	Yes	Yes	Yes	Yes	CF	M4

TABLE 4.1: SVAR MODELS FOR THE STUDY

<sup>2</sup> the detailed equations for each SVAR model is available in the Appendix section



## 5 Chapter 5. Results and Discussions

This chapter of the study reports and explains the results for spectral causality and SVAR modelling with innovation analysis. The results show that only international energy prices have a long run causal effect on core inflation, food prices do not cause core inflation at any of the frequencies and domestic energy prices, output gap and money supply cause core inflation in the short run. The SVAR and innovation analysis shows that an unprecedented change in each of the variables (a shock) has significant effect on core inflation for subsequent periods of time and the variability of core inflation is explained significantly by each of the variables (except food inflation).

### 5.1 Stationarity and Seasonality

The HEGY test for seasonal unit roots was conducted where the null is  $H_0$ : There exists unit root. A statistically significant result would require rejection of the null hypothesis, meaning that there are no unit roots at the particular frequency. The results (test statistic and corresponding p-values) have been reported in the table below. The results show that food inflation has unit roots at two of the frequencies and output gap (except BW) and money supply (all four measures) have unit roots at almost all the various frequencies. The rest of the variables in the study are found not to suffer from seasonality.

Seasonal Unit Root Test Result								
Frequency→		0	$\pi$	$\pi/2$	$2\pi/3$	$\pi/3$	$5\pi/6$	$\pi/6$
Variable ↓								
lnFood	Statistic	-2.42	-3.12	9.28	3.34	7.59	1.19	0.53
	p-value	0.1	0.01**	0.01**	0.03**	0.01**	0.1	0.1
lnEnergy	Statistic	-1.86	-2.73	15.92	14.23	13.05	15.22	3.25
	p-value	0.1	0.01**	0.01**	0.01**	0.01**	0.01**	0.03**

<b>lnCore</b>	<b>Statistic</b>	-2.44	-2.79	7.31	6.27	8.6	4.46	4.74
	<b>p-value</b>	0.1	0.01**	0.01**	0.01**	0.01**	0.01**	0.01**
<b>lnIntEnergyP</b>	<b>Statistic</b>	-2.11	-3.88	15.55	25.79	17.04	10.16	4.79
	<b>p-value</b>	0.1	0.01**	0.01**	0.01**	0.01**	0.01**	0.01**
<b>lnWPIAll</b>	<b>Statistic</b>	-1.97	-4.09	9.34	4.57	3.95	3.94	2.28
	<b>p-value</b>	0.1	0.01**	0.01**	0.01**	0.02**	0.02**	0.1
<b>GapHP</b>	<b>Statistic</b>	-2.68	-0.58	0.32	0.62	0.04	0.38	0.35
	<b>p-value</b>	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<b>GapBK</b>	<b>Statistic</b>	-3.01	-0.29	2.46	0.005	0.63	0.58	16.33
	<b>p-value</b>	0.1	0.1	0.088*	0.1	0.1	0.1	0.01**
<b>GapBW</b>	<b>Statistic</b>	-3.89	-2.75	8.55	6.21	11.71	2.42	12.77
	<b>p-value</b>	0.01**	0.01**	0.01**	0.01**	0.01**	0.09*	0.01**
<b>GapCF</b>	<b>Statistic</b>	-13.34	-1.05	2.29	0.16	2.22	0.74	173.31
	<b>p-value</b>	0.01**	0.1	0.1	0.1	0.1	0.1	0.01**
<b>lnM1</b>	<b>Statistic</b>	2.61	-0.44	1.46	1.37	0.21	0.30	1.21
	<b>p-value</b>	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<b>lnM2</b>	<b>Statistic</b>	2.65	-0.42	0.64	0.80	0.30	0.45	1.42
	<b>p-value</b>	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<b>lnM3</b>	<b>Statistic</b>	1.09	-0.84	0.60	0.38	0.47	0.10	1.51
	<b>p-value</b>	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<b>lnM4</b>	<b>Statistic</b>	1.40	-0.83	0.62	0.39	0.55	0.11	1.38
	<b>p-value</b>	0.1	0.1	0.1	0.1	0.1	0.1	0.1
*, ** & *** denote statistically significant result for 10%, 5% & 1% levels of significance respectively.								

**TABLE 5.1: HEGY RESULTS**

Source: Author's calculations

The variables exhibiting seasonality are seasonally differenced and the de-seasonalised data is used for further analysis.

## 5.2 ARIMA

The stationarised and deseasonalised data was filtered with ARIMA models and the residuals were collected for conducting the analysis for frequency wise causality.

## 5.3 Spectral causality

The coherence for the two pairs of variables were calculated for all the frequencies/cycles. The smaller the frequencies, the larger the cycles; a smaller frequency value corresponds to a longer run or a business cycle while a larger value of the frequency corresponds to a shorter run. After all the adjustments, there were 169 observations that were left with us. Out of these observations the newest 12 months' observations were left out to be used for forecasting and checking the precision of the results. Thus, the number of observations used for the analysis was 157. The results have been reported through the graphs below.

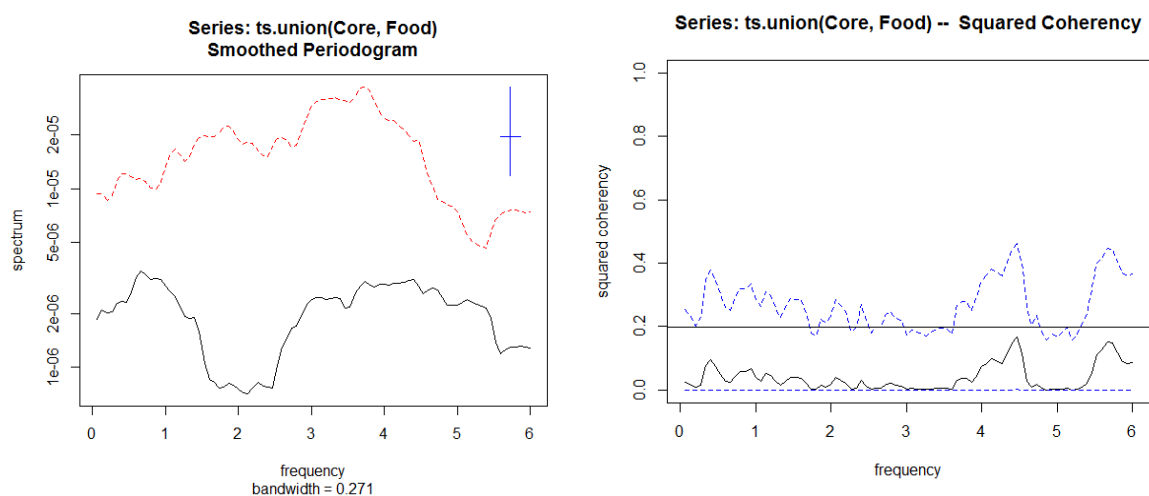
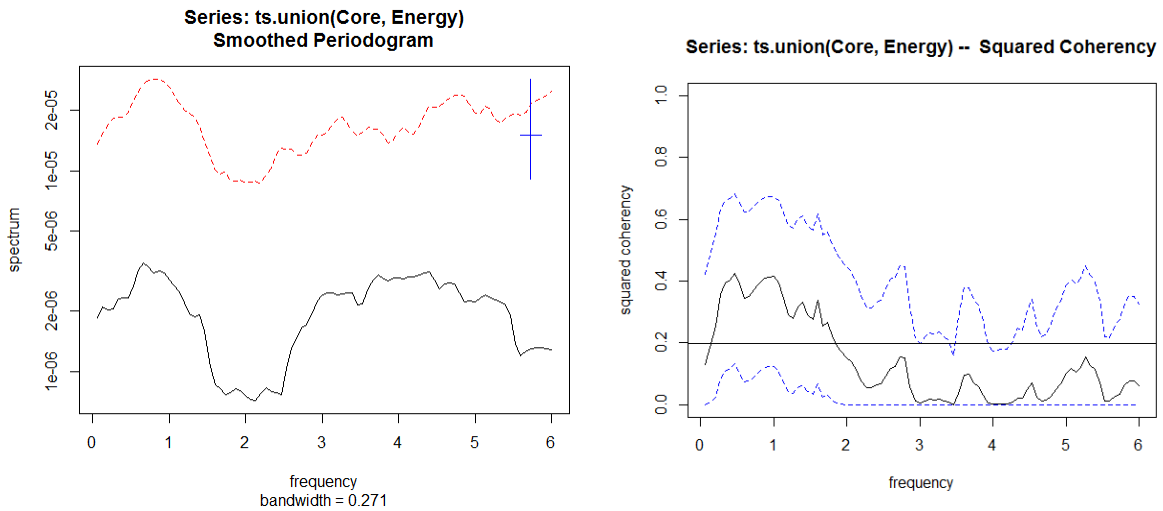


FIGURE 5-1: PERIODOGRAM & COHERENCY - CORE & FOOD INFLATION

Source: Author's calculations

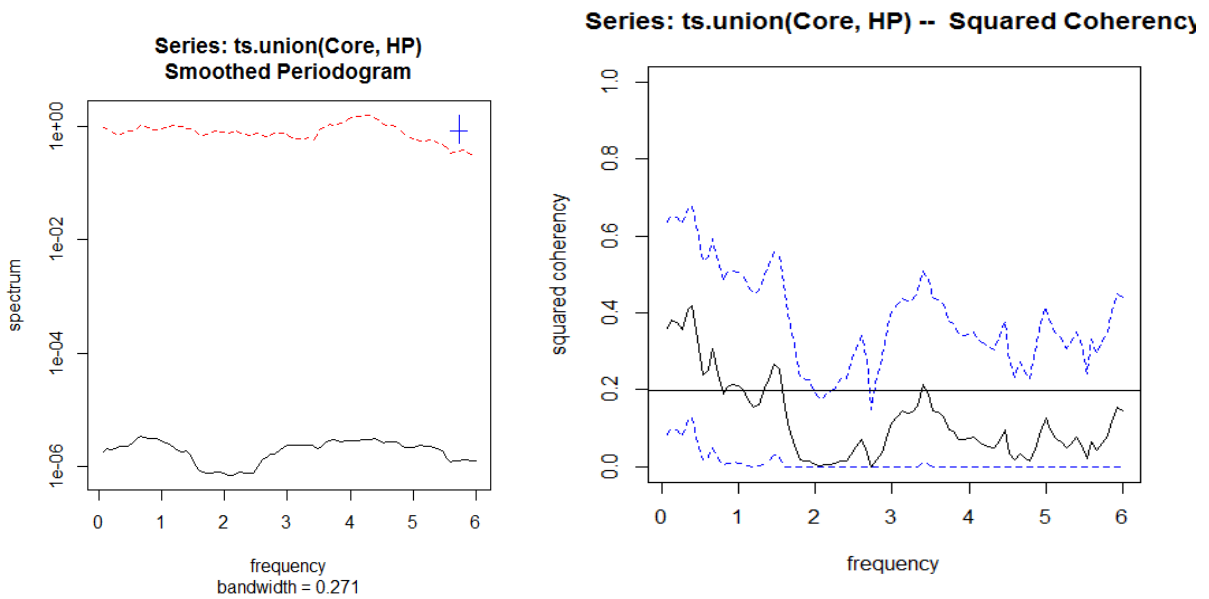
The graphs above indicate that core inflation and food inflation are not statistically significantly correlated at any of the frequencies.



**FIGURE 5-2: PERIODOGRAM & COHERENCY - CORE & ENERGY INFLATION**

Source: Author's calculations

Domestic energy prices and core inflation are significantly correlated in the long run but not in the short run.



**FIGURE 5-2: PERIODOGRAM & COHERENCY - CORE INFLATION & OUTPUT GAP (HP)**

Source: Author's calculations

Output gap HP and core inflation show significant correlation in the medium and long run but no statistically significant correlation in the short run.

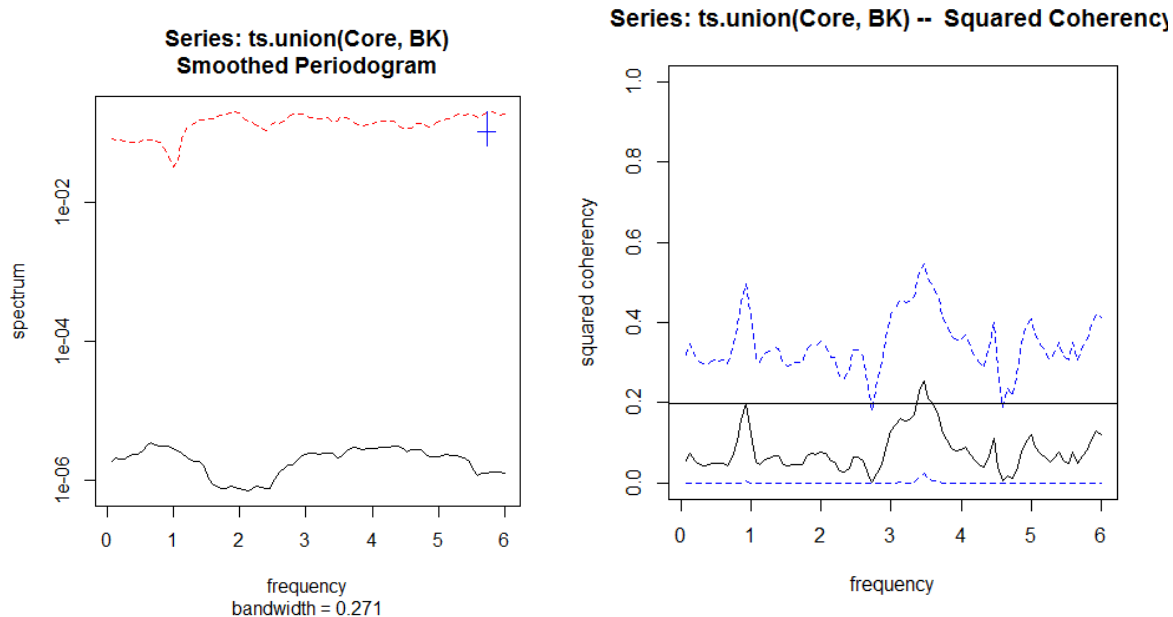


FIGURE 5-3: PERIODOGRAM & COHERENCY - CORE INFLATION & OUTPUT GAP (BK)

Source: Author's calculations

Output gap BK and core inflation show significant correlation in the medium run (for a small phase), at a single frequency in the long run but no statistically significant correlation in the short run.

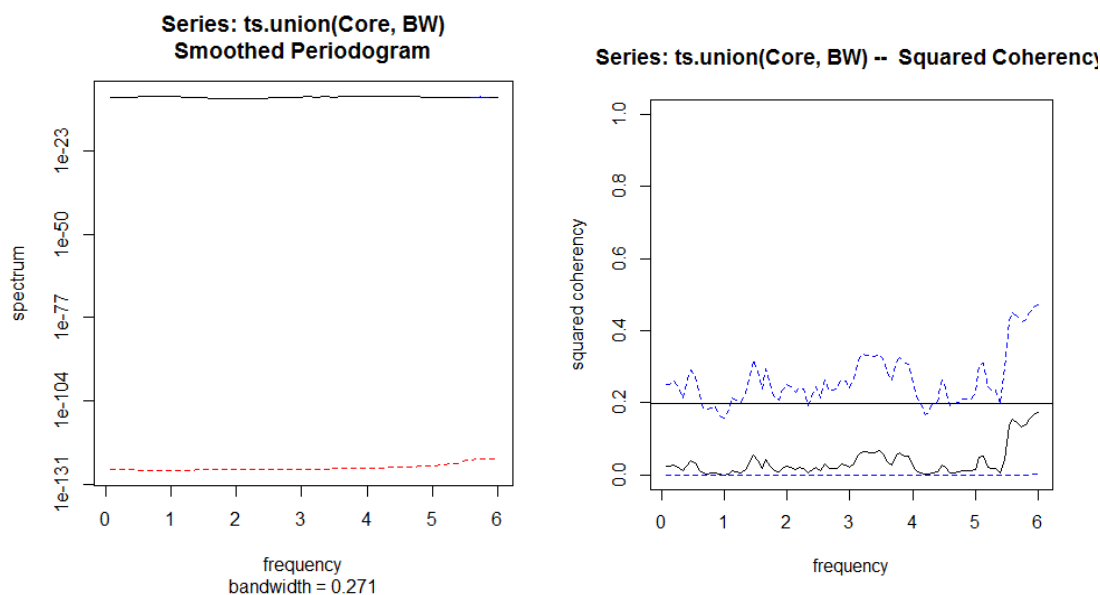


FIGURE 5-4: PERIODOGRAM & COHERENCY - CORE INFLATION & OUTPUT GAP (BW)

Source: Author's calculations

Output gap BW and core inflation show no correlation at any of the frequencies.

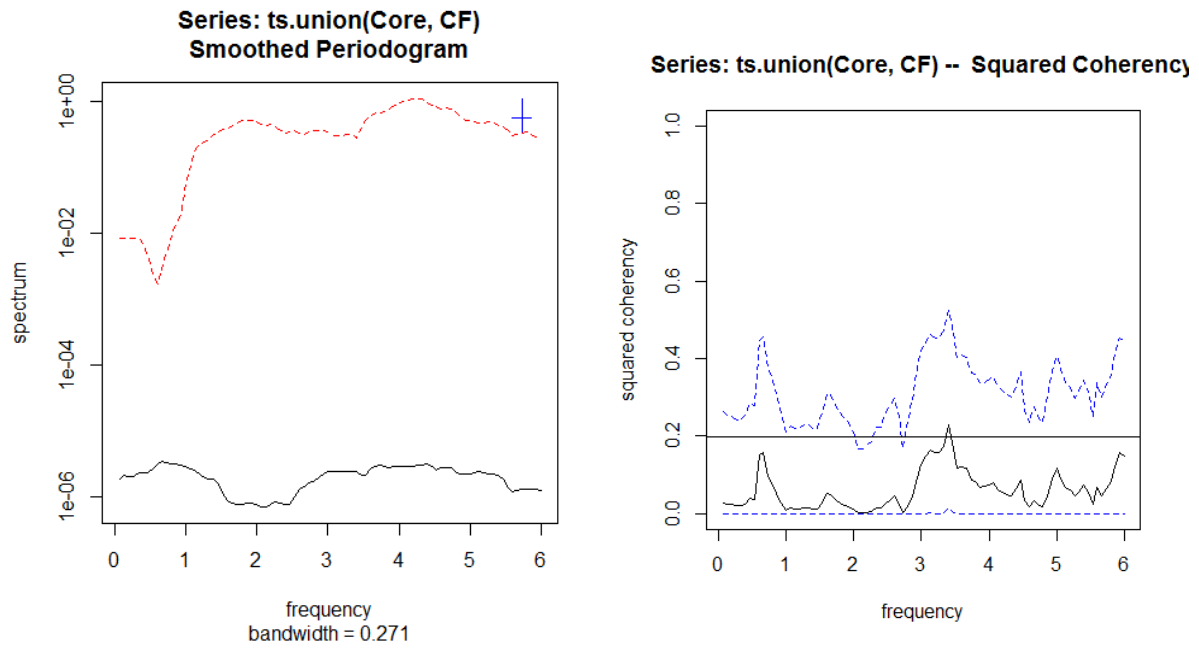


FIGURE 5-5: PERIODOGRAM & COHERENCY - CORE INFLATION & OUTPUT GAP (CF)

Source: Author's calculations

Output gap CF and core inflation have significant correlation only in the medium run.

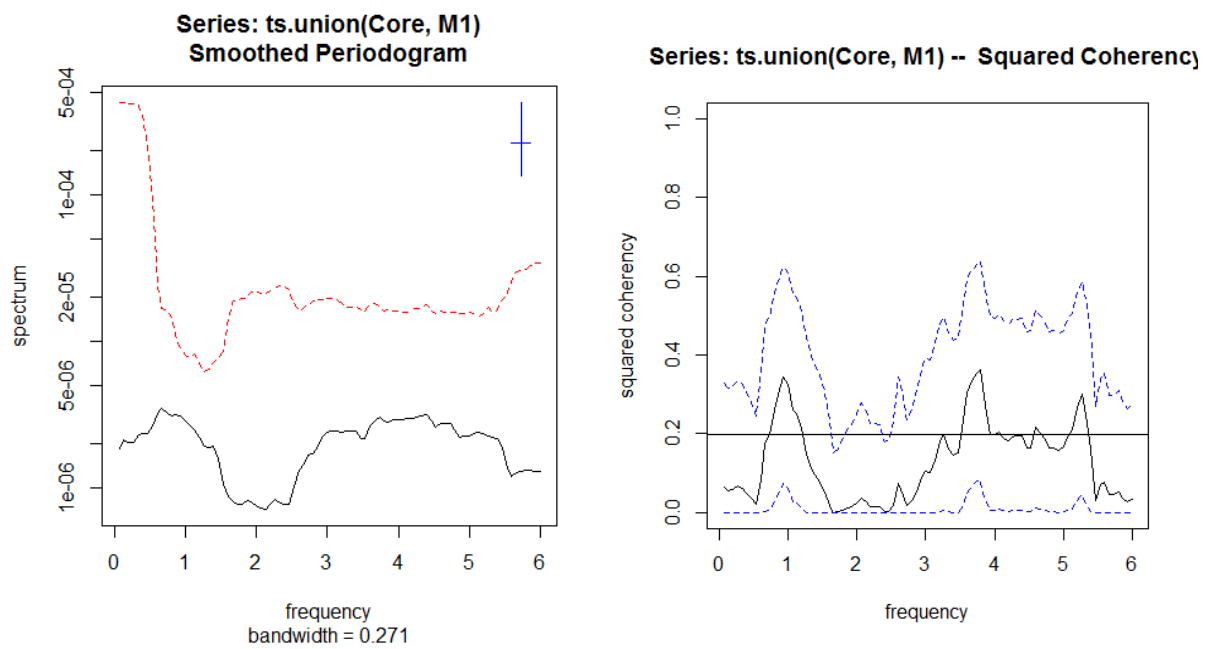
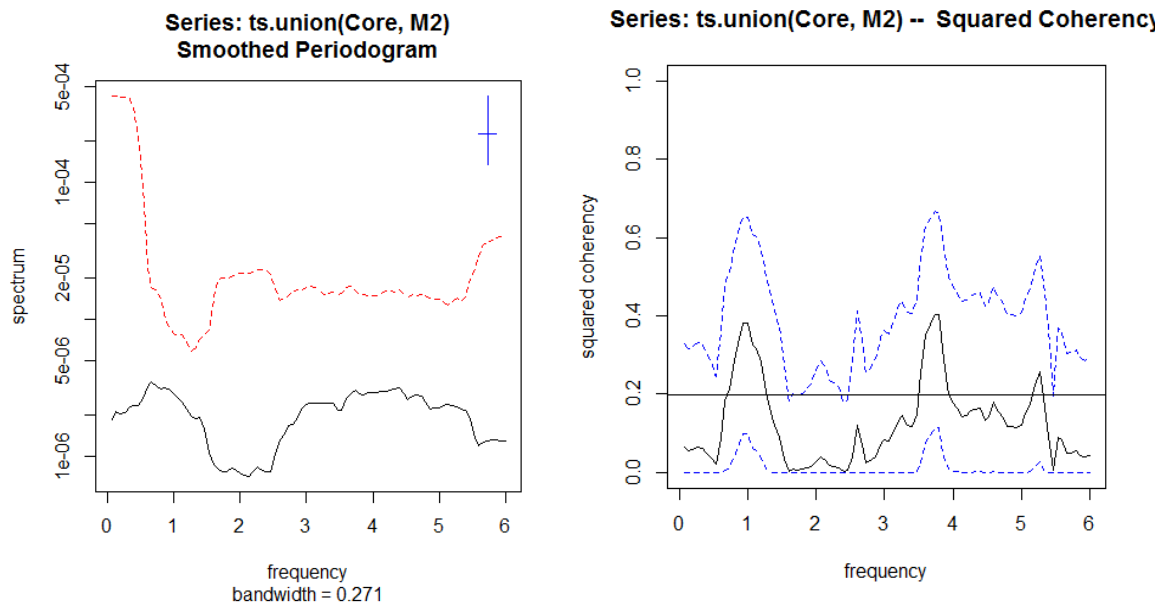


FIGURE 5-6: PERIODOGRAM & COHERENCY - CORE INFLATION & MONEY SUPPLY (M1)

Source: Author's calculations

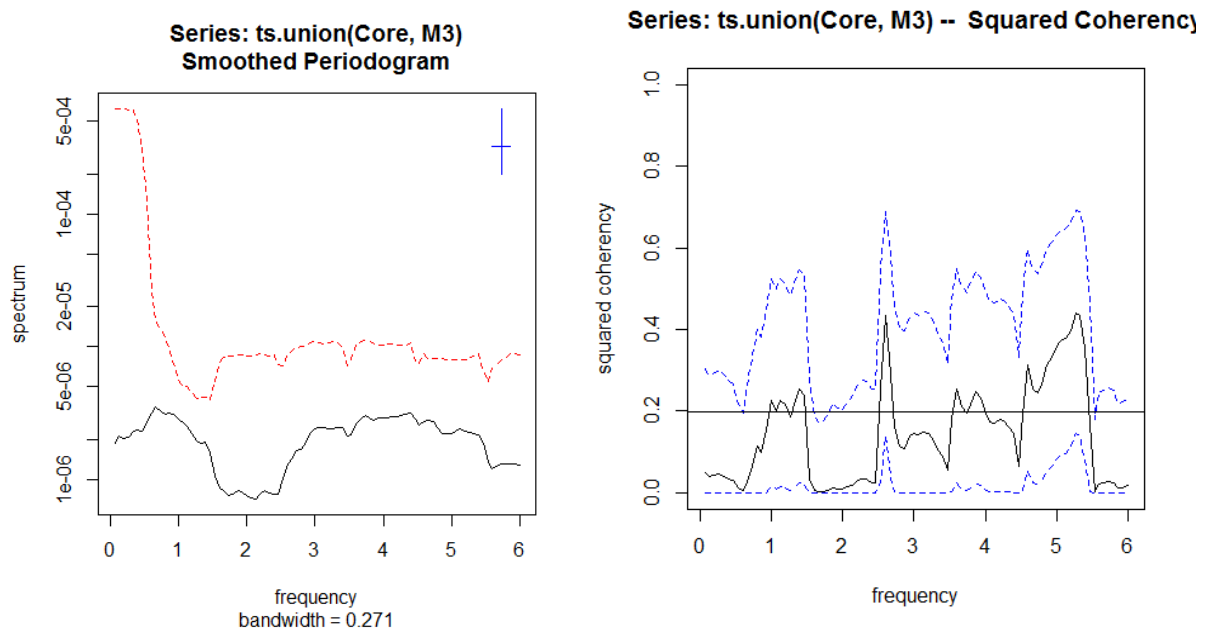
Money supply M1 and core inflation show significant correlation in the long, medium and short run.



**FIGURE 5-7: PERIODOGRAM & COHERENCY - CORE INFLATION & MONEY SUPPLY (M2)**

Source: Author's calculations

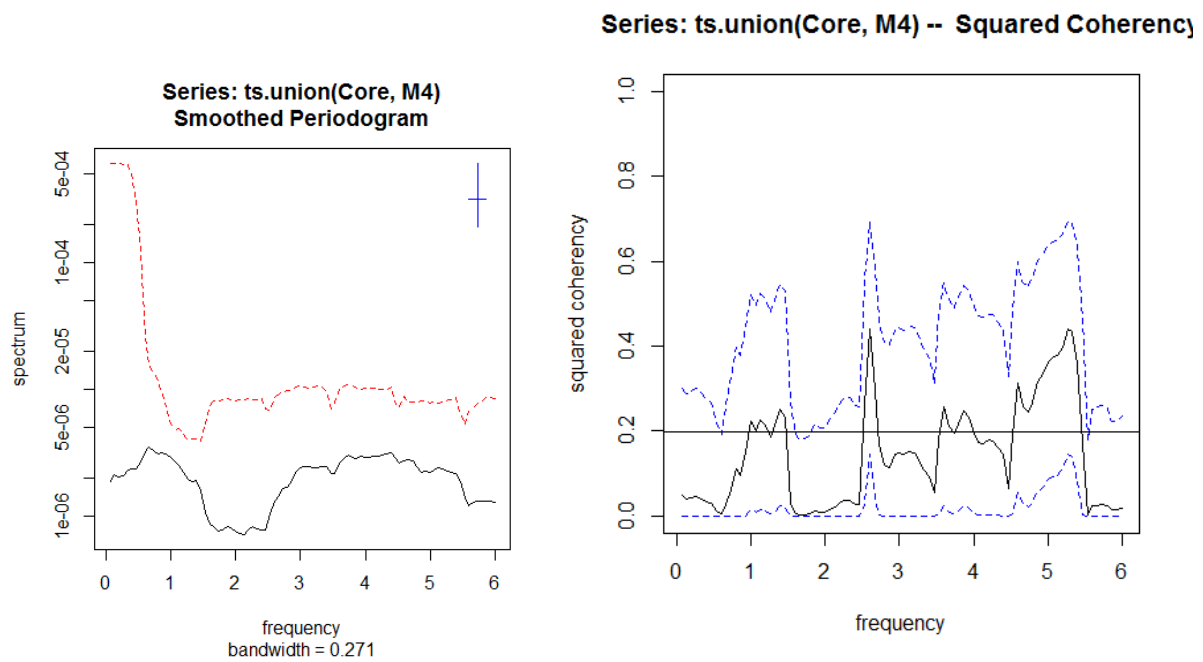
Money supply M2 and core inflation show significant correlation in the long, medium and short run.



**FIGURE 5-8: PERIODOGRAM & COHERENCY - CORE INFLATION & MONEY SUPPLY (M3)**

Source: Author's calculations

Money supply M3 and core inflation show significant correlation in the long, medium and short run.



**FIGURE 5-9: PERIODOGRAM & COHERENCY - CORE INFLATION & MONEY SUPPLY (M4)**

Source: Author's calculations

Money supply M4 and core inflation show significant correlation in the long, medium and short run.

### 5.3.1 Causality from International Energy Prices to Core Inflation

The causality running from international energy prices to domestic core inflation is statistically significant if the h-statistic is greater than the critical value at a particular frequency. The results show that core inflation is caused by international energy prices only in the long run and not in the short run. Only for cycles of approximately 22 months and above does the causality turn out to be statistically significant. For any cycle lesser than that, international energy prices do not cause core inflation.



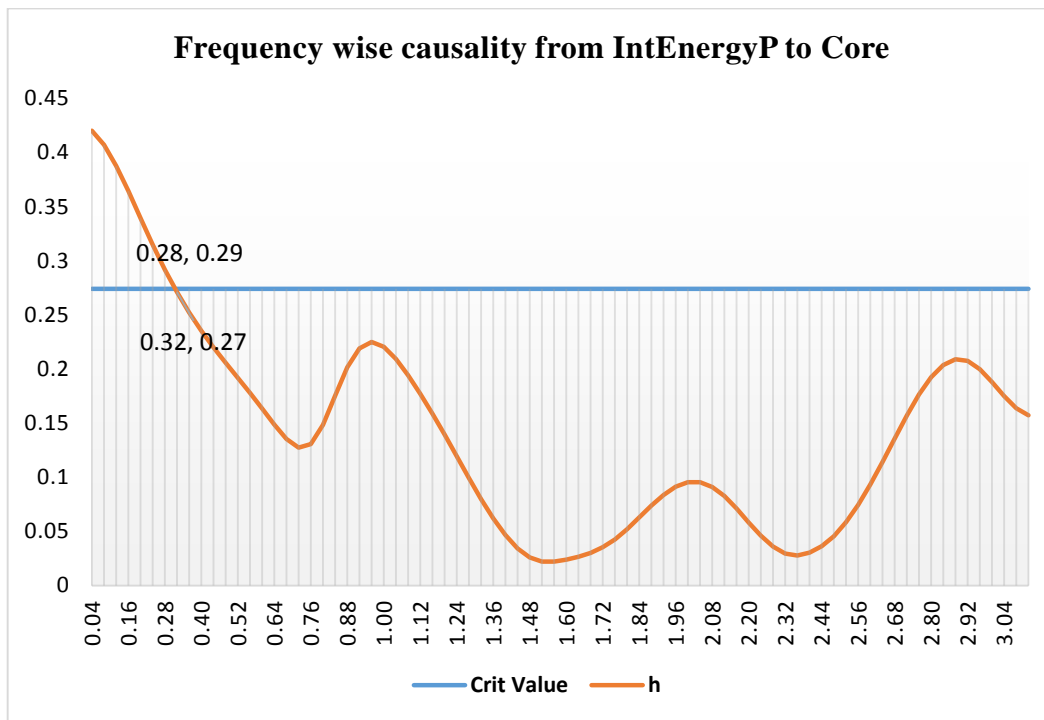


FIGURE 5-10: FREQUENCY WISE CAUSALITY INTENERGYP TO CORE

Source: Author’s calculations

### 5.3.2 Causality from Output Gap HP to Core Inflation

Output gap from HP filter is seen to cause core inflation only in the short run and not in the long run. Only for frequencies greater than 2.88 (which corresponds to 2 months’ cycle) are the h-statistics greater than the critical value, i.e. the causality is statistically significant for cycles lesser than or equal to two months.

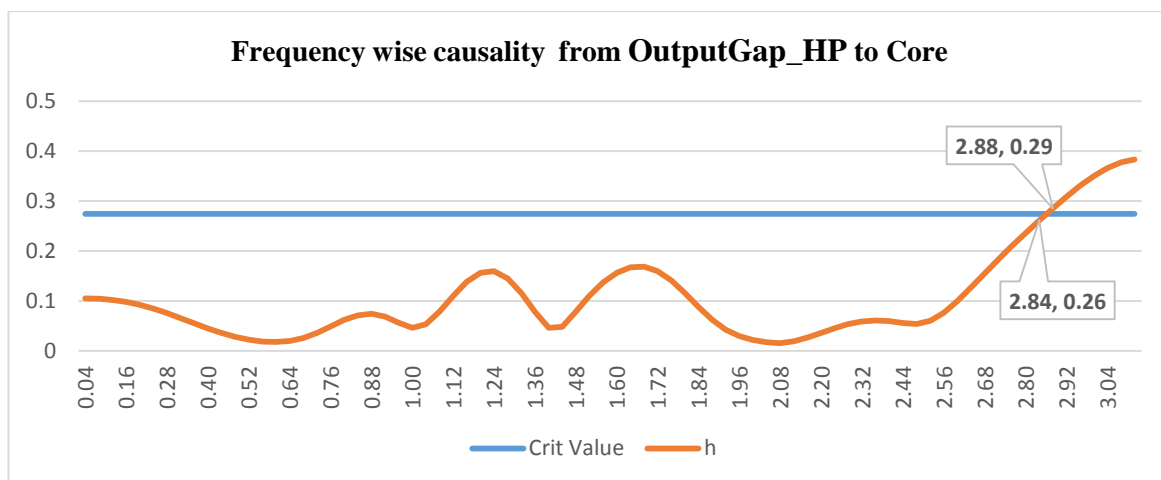


FIGURE 5-11: FREQUENCY WISE CAUSALITY FROM OUTPUTGAP\_HP TO CORE

Source: Author’s calculations

### 5.3.3 Causality from Output Gap BW to Core Inflation

Output gap received through BW filter is found to cause core inflation in the lower and medium frequencies. Thus the causality effect is witnessed in the long run and in the medium run cycles. To be precise, significant causality is found to exist in the following range of cycles – five to six months, seven and a half to nine and a half months and twenty-two to forty months.

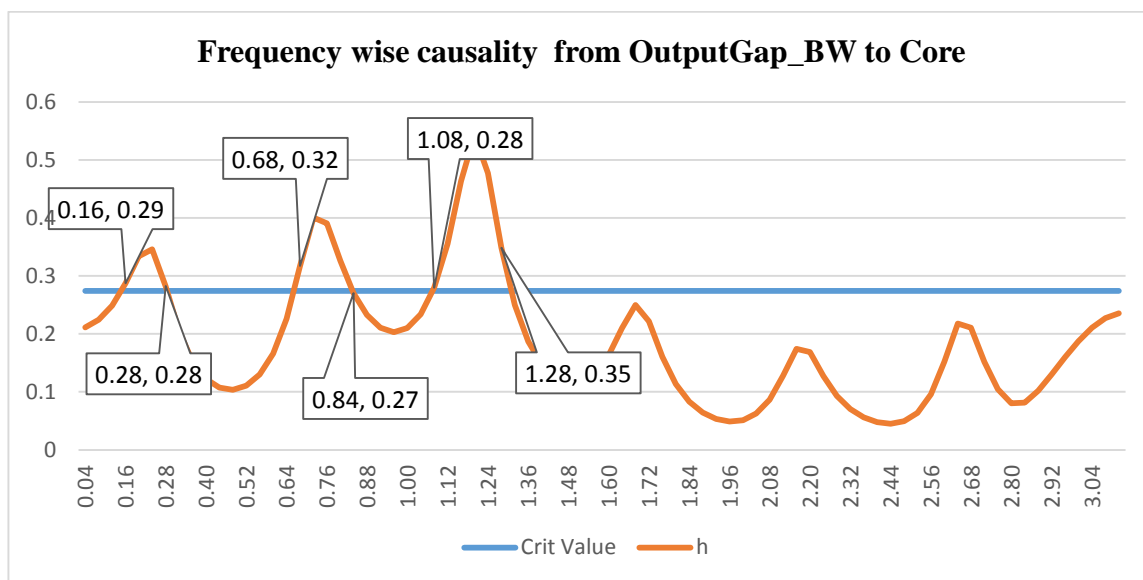


FIGURE 5-12: FREQUENCY WISE CAUSALITY FROM GAP\_BW TO CORE

Source: Author's calculations

### 5.3.4 Causality from Output Gap BK to Core Inflation

The output gap computed through the BK filter is found not to cause core inflation at any of the frequencies.

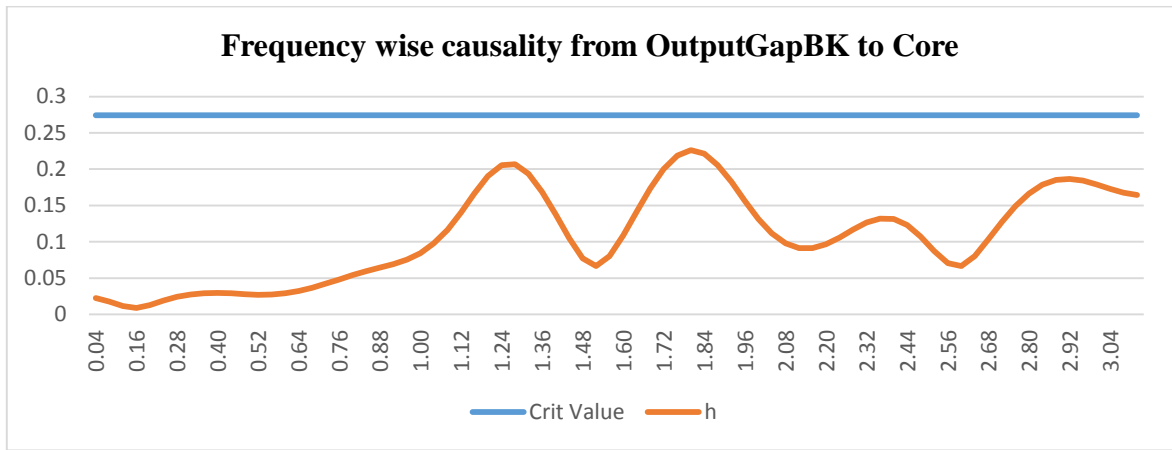


FIGURE 5-13: FREQUENCY WISE CAUSALITY FROM GAPBK TO CORE

Source: Author's calculations

### 5.3.5 Causality from Output Gap CF to Core Inflation

Output gap computed through the CF filter is found to cause core inflation only for cycles of two months. No medium or long run causality is displayed.

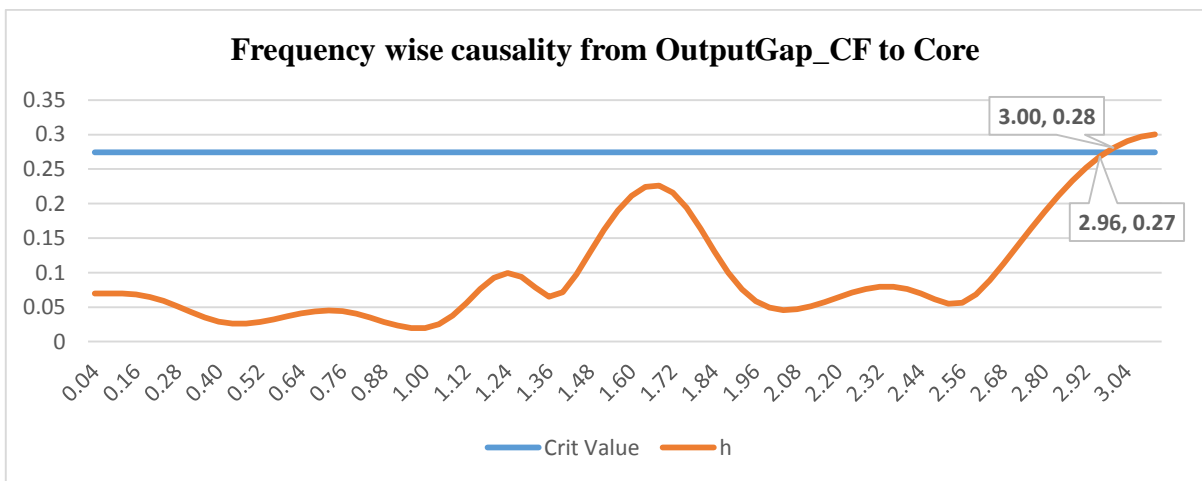


FIGURE 5-14: FREQUENCY WISE CAUSALITY FROM GAP\_CF TO CORE

Source: Author's calculations

### 5.3.6 Causality from Domestic Energy to Core Inflation

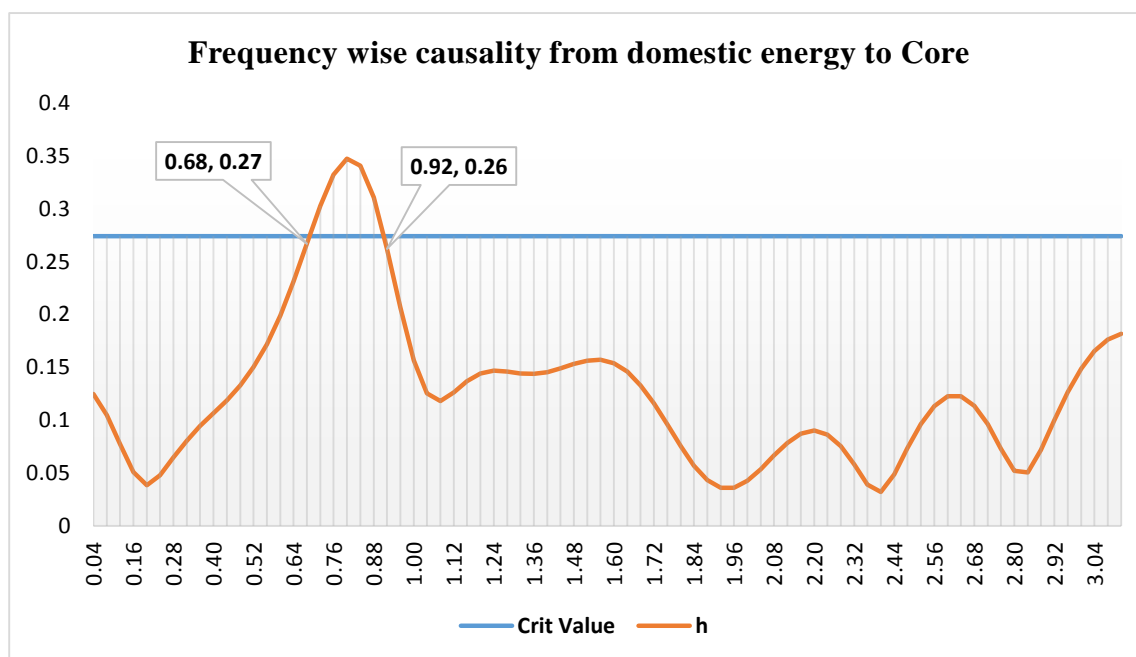


FIGURE 5-15: FREQUENCY WISE CAUSALITY FROM ENERGY TO CORE

Source: Author's calculations

Domestic energy price is seen to cause core inflation only in between frequencies 0.72 and 0.88 which is analogous to an interval of 8.7 months and 7.1 months. The causality is statistically insignificant for cycles greater than 9 months and less than 7 months.

### 5.3.7 Causality from Domestic Food Prices to Core Inflation

It is found that food prices do not cause core inflation at any frequency at all. The h statistic is statistically insignificant for all the frequencies.

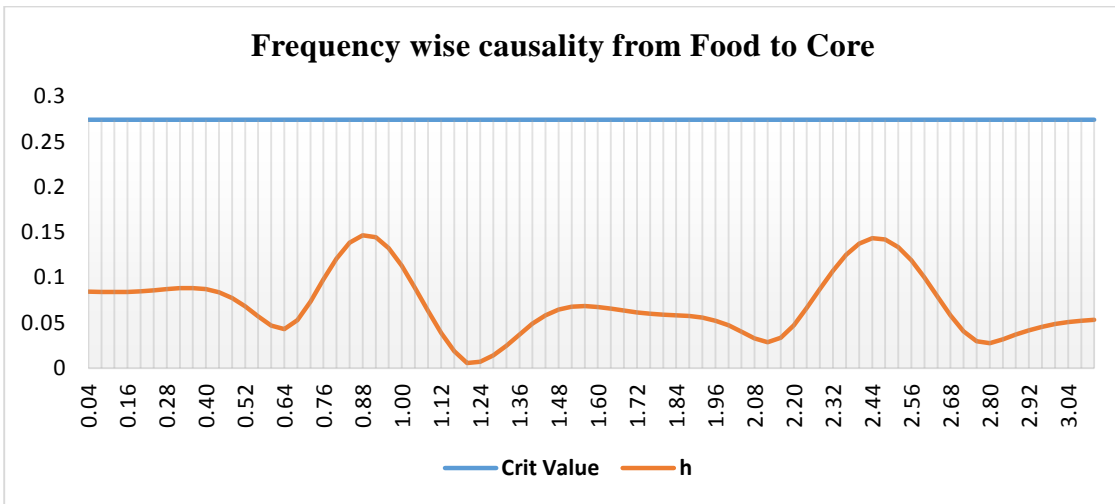


FIGURE 5-16: FREQUENCY WISE CAUSALITY FOOD TO CORE

Source: Author's calculations

### 5.3.8 Causality from Money Supply (M1) to Core Inflation

The M1 measure of money supply is seen to cause core inflation at a cycle of 8 months and approximately 2 months.

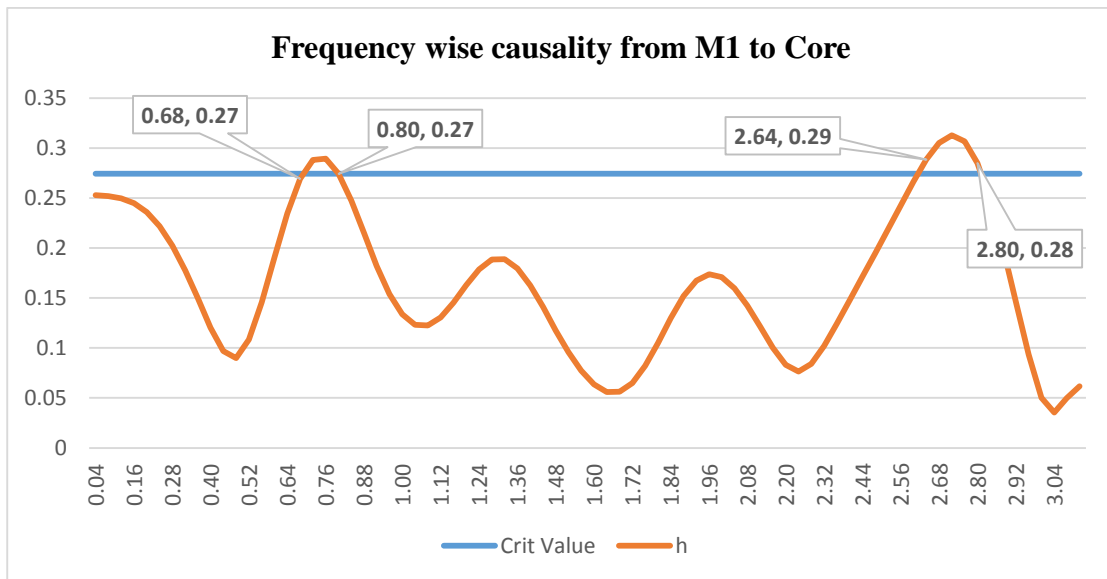


FIGURE 5-17: CAUSALITY FROM M1 TO CORE

Source: Author's calculations

### 5.3.9 Causality from Money Supply (M2) to Core Inflation

The M2 measure of money supply is found to cause core inflation for cycles equal to and greater than 52 months.

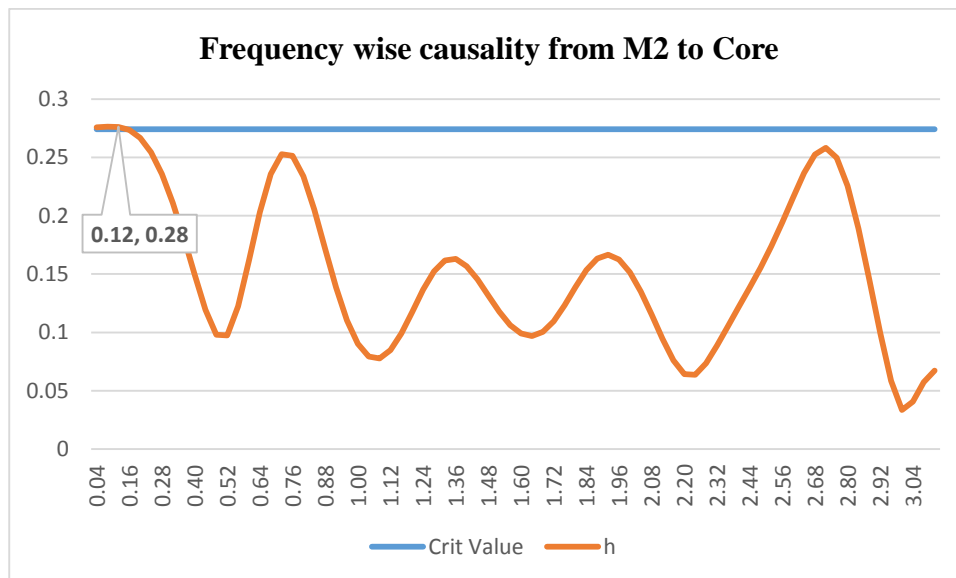


FIGURE 5-18: CAUSALITY FROM M2 TO CORE

Source: Author's calculations

### 5.3.10 Causality from Money Supply (M3) to Core Inflation

The M3 measure of money supply is seen to cause core inflation at cycle of 3 months.

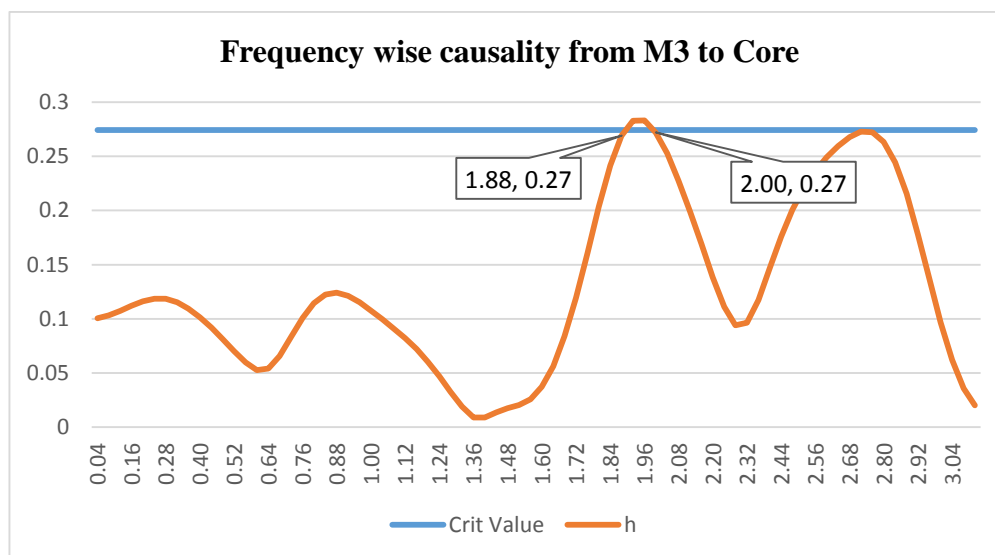


FIGURE 5-19: CAUSALITY FROM M3 TO CORE

Source: Author's calculations

### 5.3.11 Causality from Money Supply (M4) to Core Inflation

The M4 measure of money supply is seen to cause core inflation at a cycle of 3 months and 2 months.

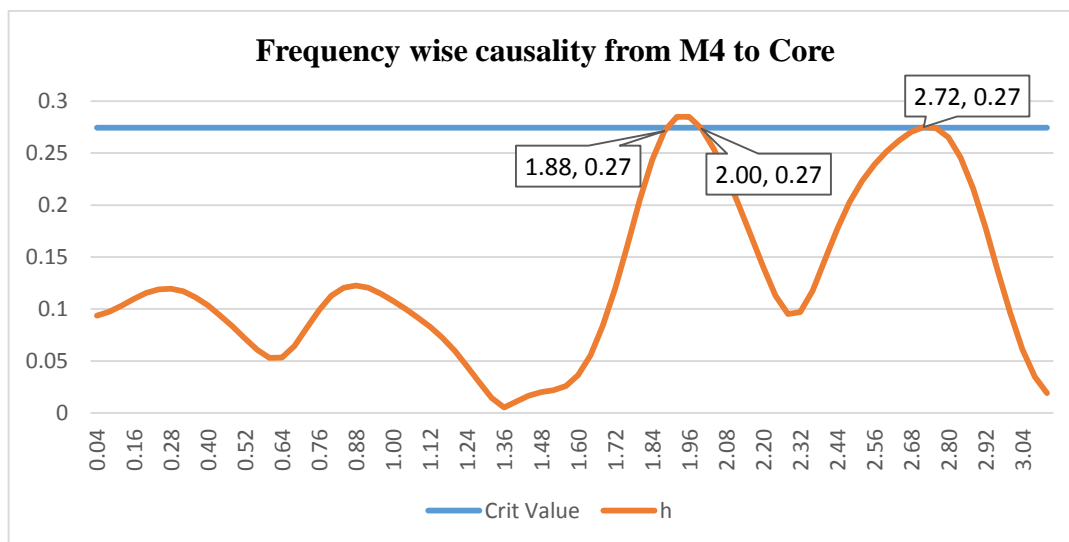


FIGURE 5-20: CAUSALITY FROM M4 TO CORE

Source: Author's calculations

## 5.4 Structural Vector Autoregression and Innovation Analysis

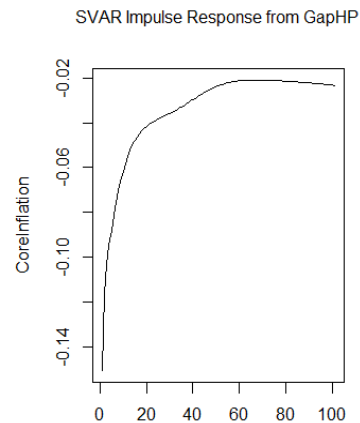
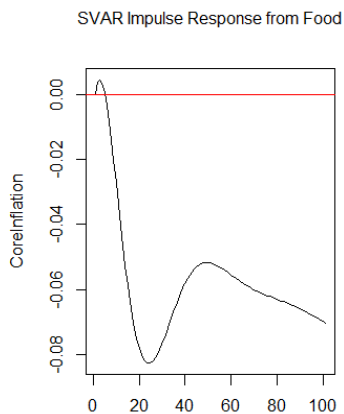
The sixteen models constructed in the previous section are estimated to check for impacts of shocks of food inflation, energy inflation, international energy prices, four measures of output gap and four measures of money supply on domestic core inflation. The intention here is to understand the effects of the disaggregated components of WPI inflation along with output gap and international energy prices on domestic core inflation, not the other way around.

### 5.4.1 Model 1

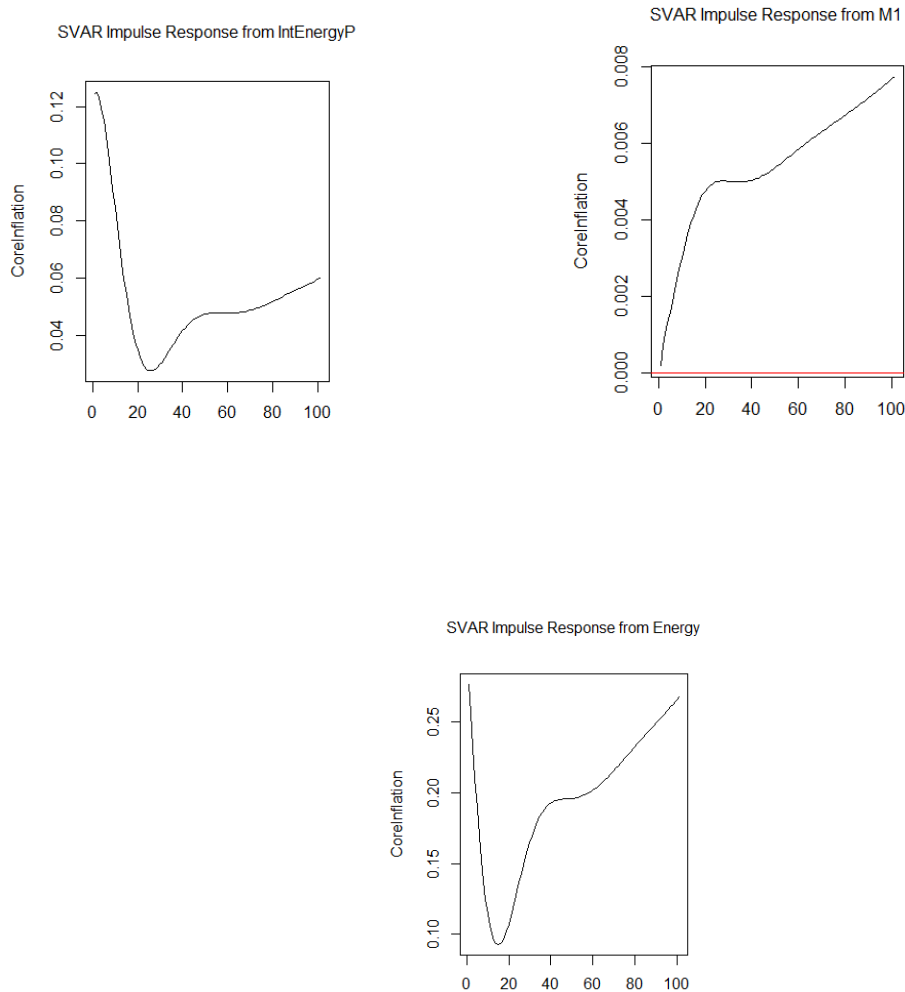
Model 1 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap HP	M1
Core Inflation	1.00	0.00	0.28	0.12	-0.15	1.93E-04
Domestic Food Prices	0.00	1.00	0.27	0.12	0.16	-3.49E-03
Domestic Energy Prices	0.00	0.14	1.00	0.14	0.02	1.14E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap HP	0.00	0.08	0.00	0.12	1.00	1.28E-02
M1	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.2: SVAR MODEL 1

The SVAR estimate of the model shows that domestic energy prices, international energy prices and money supply have positive effect on core inflation (domestic energy has the strongest influence and money supply M1, the weakest), however, output gap computed through the HP filter has a negative effect on core inflation.







**FIGURE 5-21: IRF MODEL 1**

The five impulse response functions from the variables domestic food inflation, domestic energy inflation, international energy prices, output gap (HP filter) and money supply (M1) have been reported above. The graphs show that the impulse from food inflation has a positive effect on the response variable, core inflation till the tenth month but beyond that, the effect is negative. The effect of impulse from domestic energy prices, international energy prices and money supply have positive effect and the impulse from output gap has negative effect on core inflation up to hundred months (number of runs considered for the response functions is 100). A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation

significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

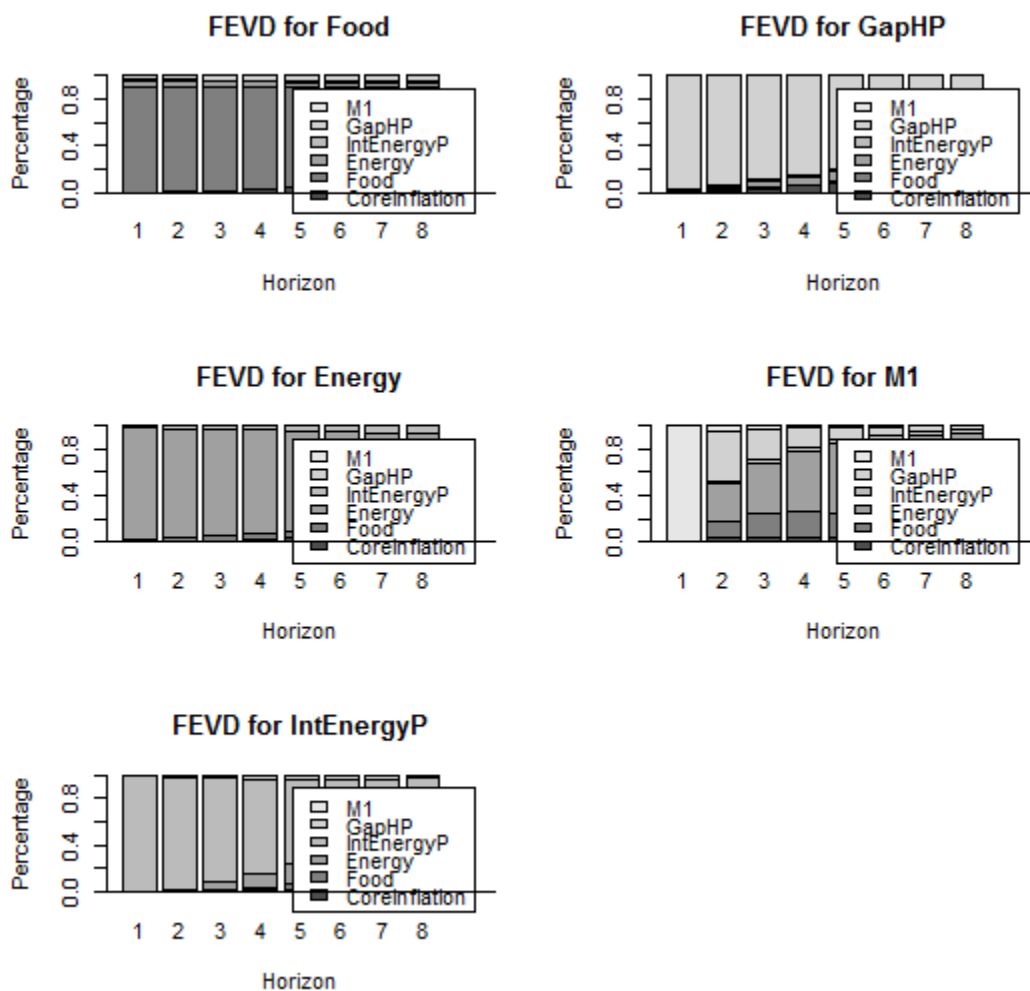


FIGURE 5-22: FEVD MODEL 1

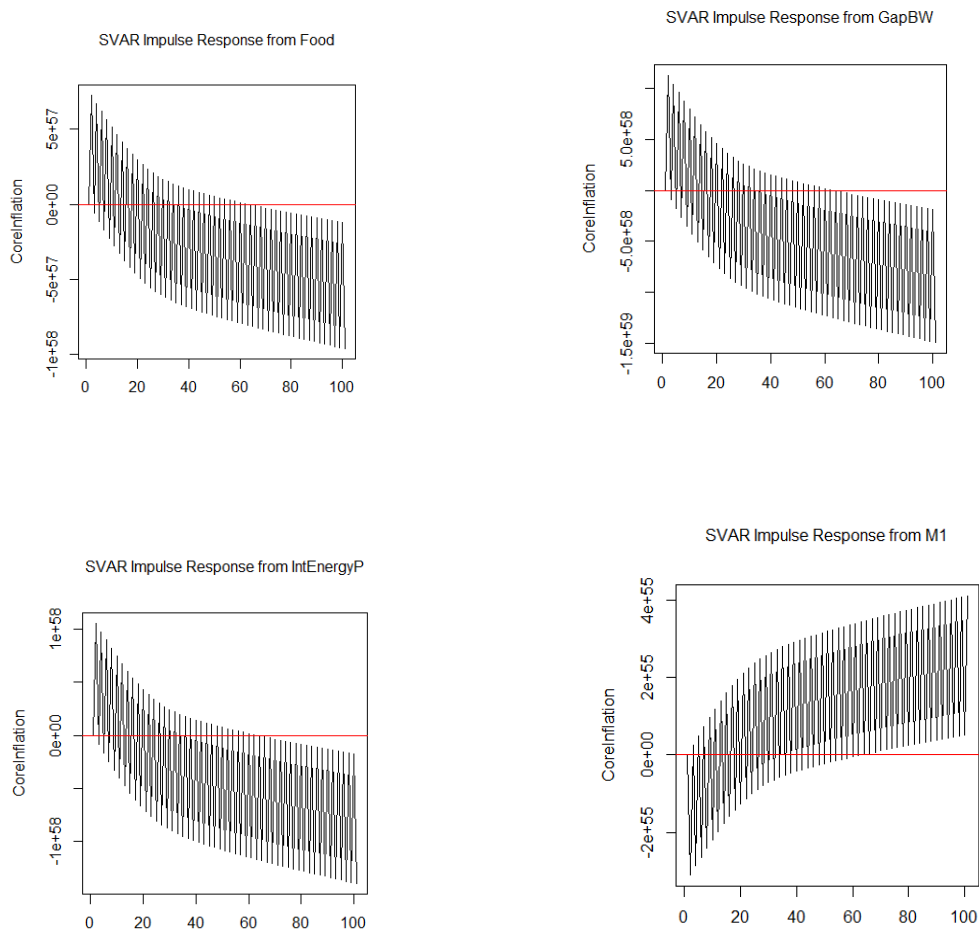
The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression and determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time.

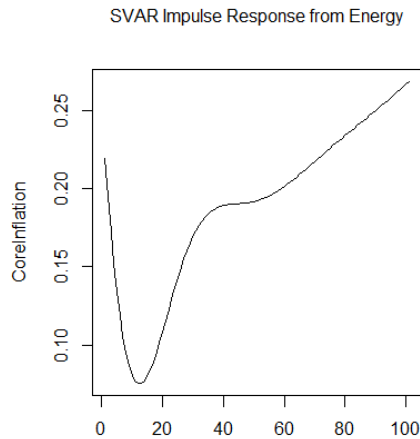
## 5.4.2 Model 2

Model 2 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BW	M1
Core Inflation	1.00	0.00	0.22	0.08	0.23	3.52E-04
Domestic Food Prices	0.00	1.00	0.20	0.04	0.08	-3.89E-03
Domestic Energy Prices	0.00	0.12	1.00	0.16	0.20	-1.47E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BW	0.00	0.06	0.00	0.09	1.00	-2.74E-04
M1	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.3: SVAR MODEL 2

All the variables have positive effect on core inflation – the effect of output gap computed through the BW filter is the strongest and the effect of money supply (M1) is the weakest.





**FIGURE 5-23: IRF MODEL 2**

The IRFs from food inflation, output gap BW, M1 and international energy prices show oscillatory behavior – every alternate period the effect rises and falls. For food inflation, output gap BW and international energy prices, the effect is positive for the first few periods; the effect oscillates between positive and negative in alternate periods for the new few periods and finally becomes negative. M1, on the other hand, has negative effect in the first few periods, oscillates between positive and negative effects for the next few periods moving on to positive oscillatory effect after that. Domestic energy prices have positive effect on core inflation throughout, though the effect weakens around the tenth period but catches up by eighteenth period. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (be it positive or negative, the values move away from zero) showing that the effects keep on building up month after month.

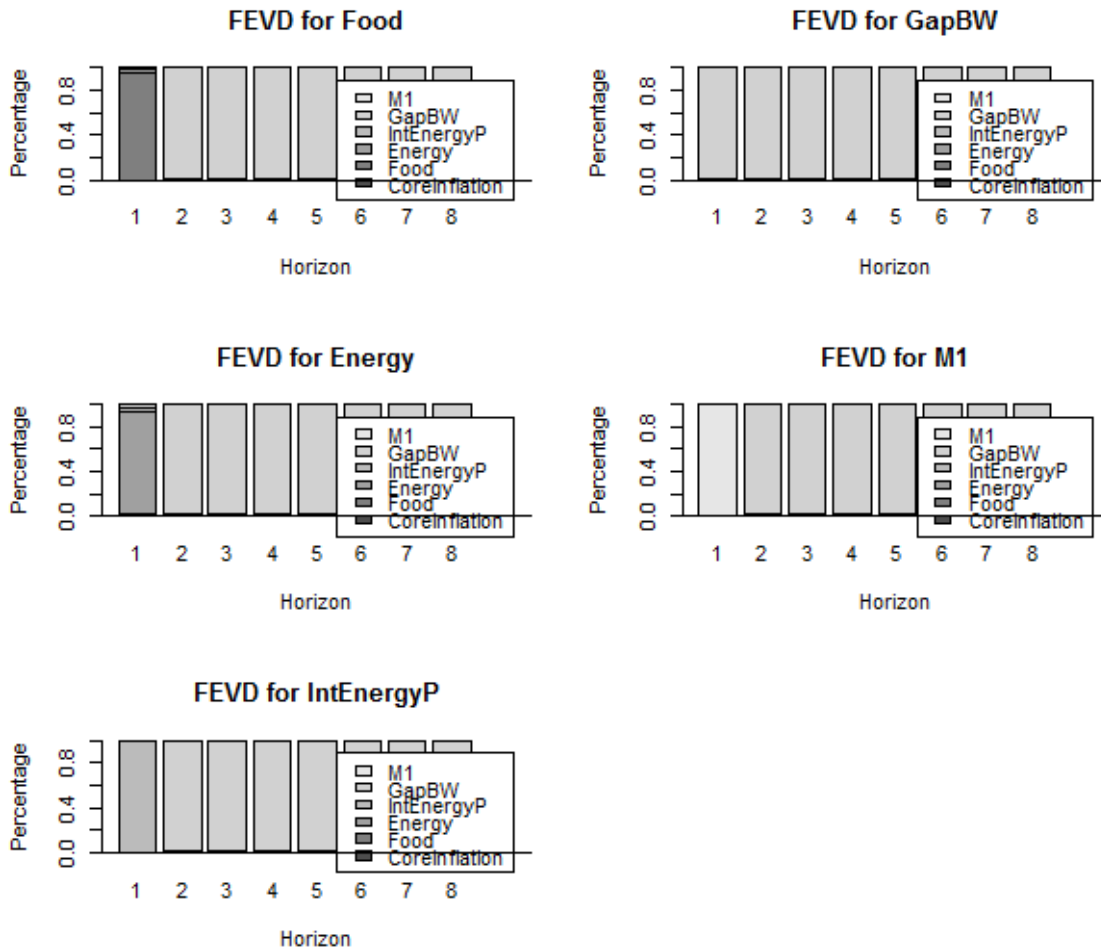


FIGURE 5-24: FEVD MODEL 2

The FEVD results show that a unit rise in the shock of each of the five variables lead to a more or less constant contribution of the variable in the variance share for core inflation over time.

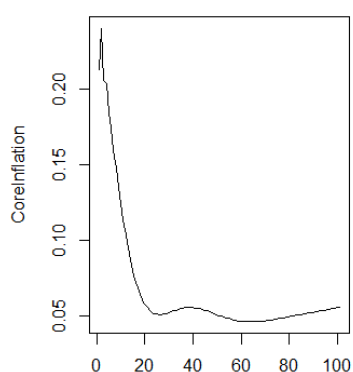
### 5.4.3 Model 3

Model 3 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BK	M1
Core Inflation	1.00	0.00	0.17	0.11	0.21	-1.03E-04
Domestic Food Prices	0.00	1.00	0.17	0.11	0.05	-4.08E-03
Domestic Energy Prices	0.00	0.05	1.00	0.18	0.16	-2.15E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BK	0.00	0.13	0.00	0.12	1.00	3.00E-03
M1	0.00	0.00	0.00	0.00	0.00	1.00

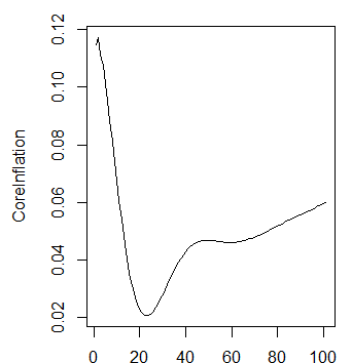
TABLE 5.4: SVAR MODEL 3

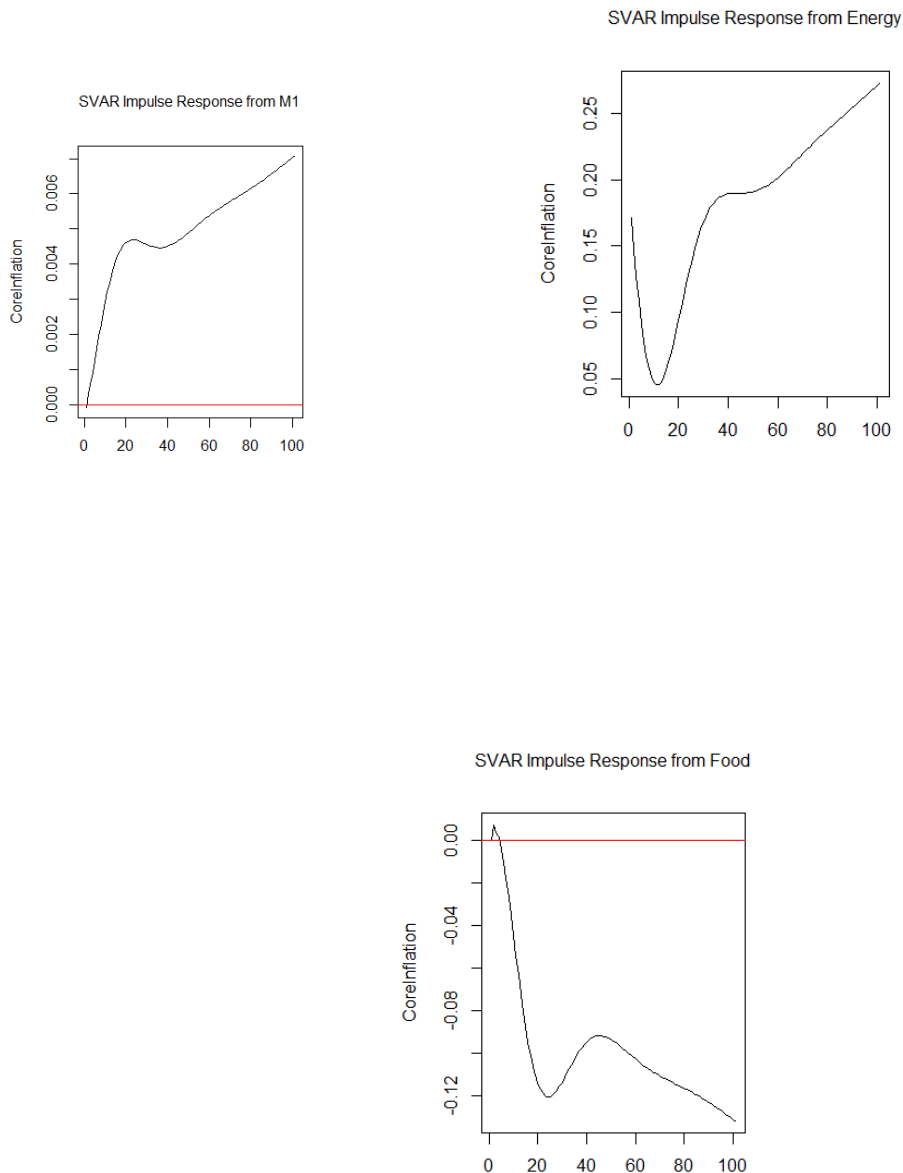
Domestic energy inflation, international energy prices and output gap computed through BK filter have positive effects on core inflation – the effect of output gap being the strongest and that of international energy prices being the weakest. Money supply is found to have a negative effect on core inflation.

SVAR Impulse Response from GapBK



SVAR Impulse Response from IntEnergyP





**FIGURE 5-25: IRF MODEL 3**

The graphs show that the impulse from domestic energy prices, international energy prices and output gap computed through BK filter have positive effect on core inflation up to hundred months (number of runs considered for the response functions is 100). Money supply impulse has negative effect in the first period and thereafter has increasingly positive effect. The effect of impulse from food inflation has a positive effect on the response variable, core inflation till the tenth month but beyond that, the effect is negative. A one unit rise in the

shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect does not die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

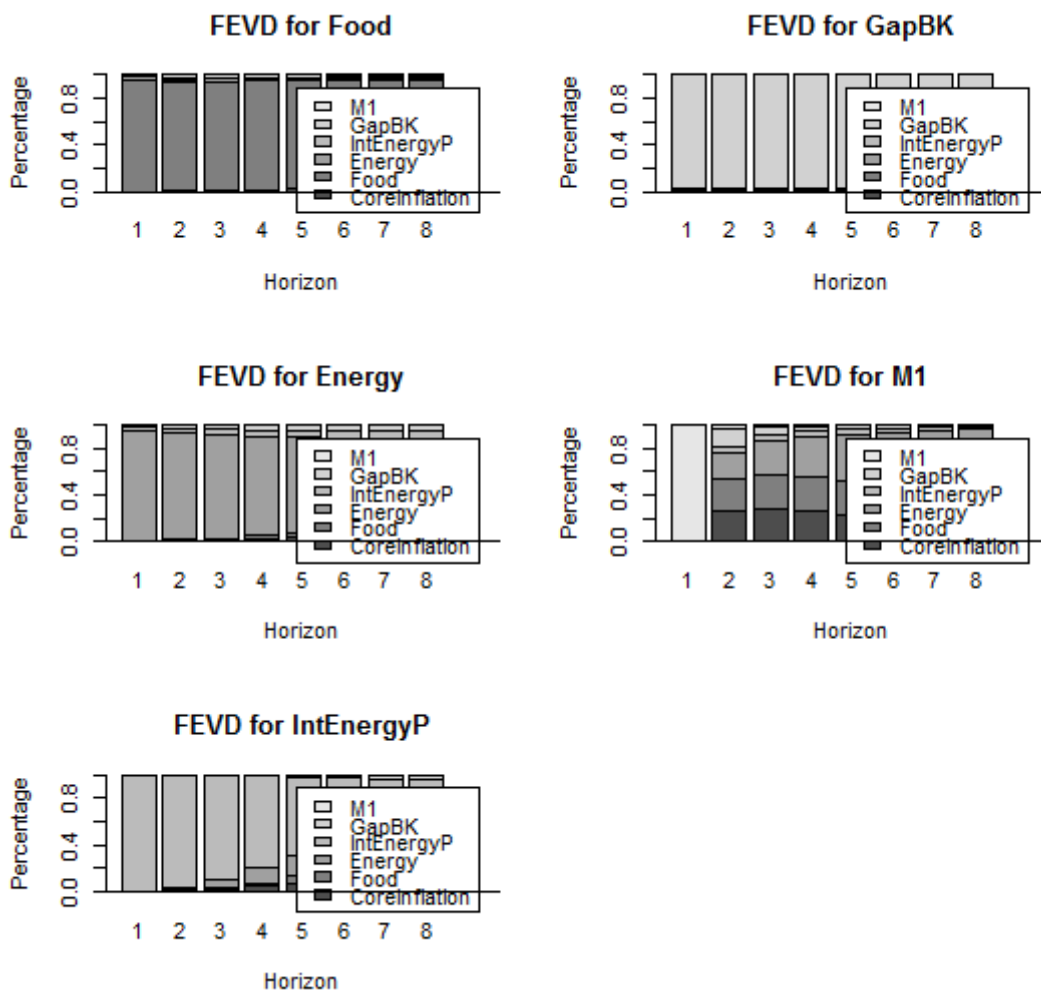


FIGURE 5-26: FEVD MODEL 3

The FEVD results show that a unit rise in the shock of each of the five variables lead to an increasing contribution of the variable in the variance share for core inflation over time.

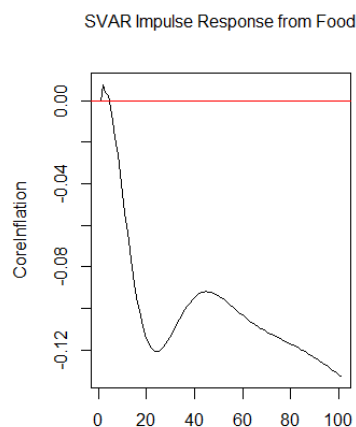
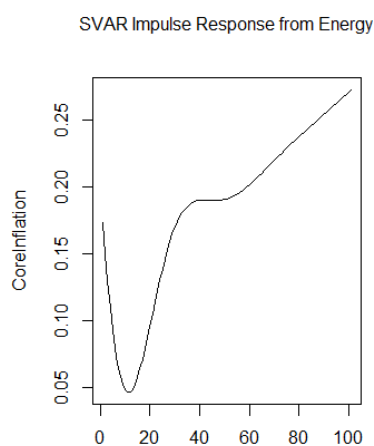


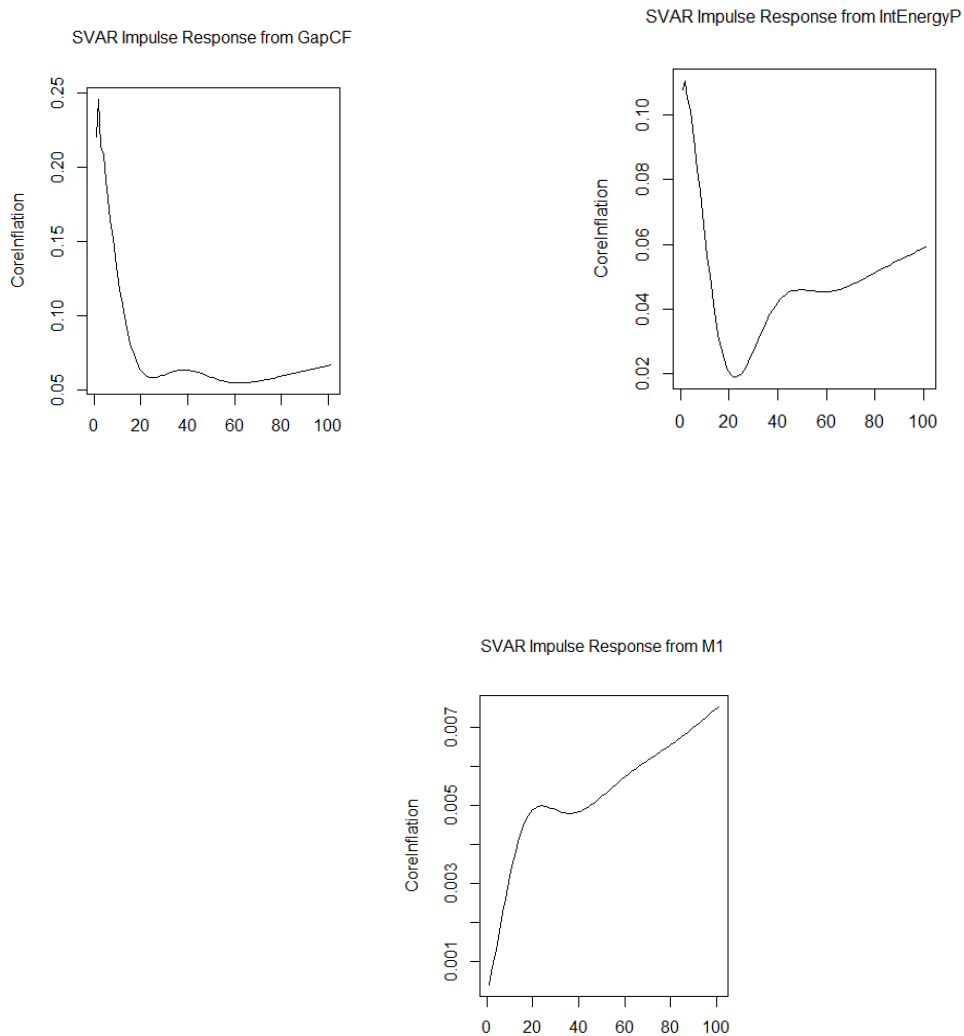
## 5.4.4 Mode 14

Model 4 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap CF	M1
Core Inflation	1.00	0.00	0.17	0.11	0.22	3.93E-04
Domestic Food Prices	0.00	1.00	0.17	0.10	0.02	-4.52E-03
Domestic Energy Prices	0.00	0.05	1.00	0.18	0.17	-9.70E-04
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap CF	0.00	0.13	0.00	0.12	1.00	3.01E-03
M1	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.5: SVAR MODEL 4

All the four variables have positive effect on core inflation, the greatest effect is seen to come from output gap computed through CF filter and the least effect from money supply M1.





**FIGURE 5-27: IRF MODEL 4**

The effect of impulse from domestic energy prices, output gap CF, international energy prices and money supply have positive effect. Food price has positive effect for the first ten periods and thereafter has negative effect. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation remains significant in value.

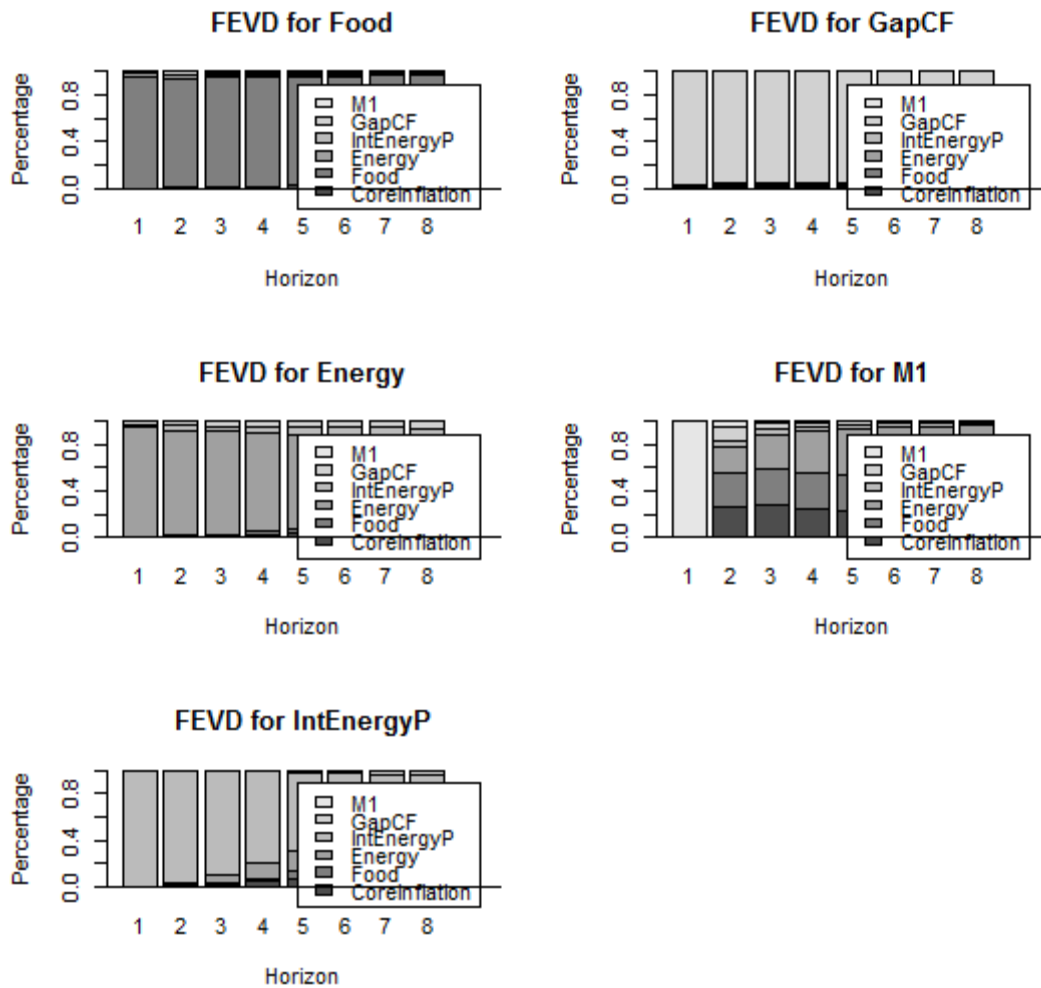


FIGURE 5-28: FEVD MODEL 4

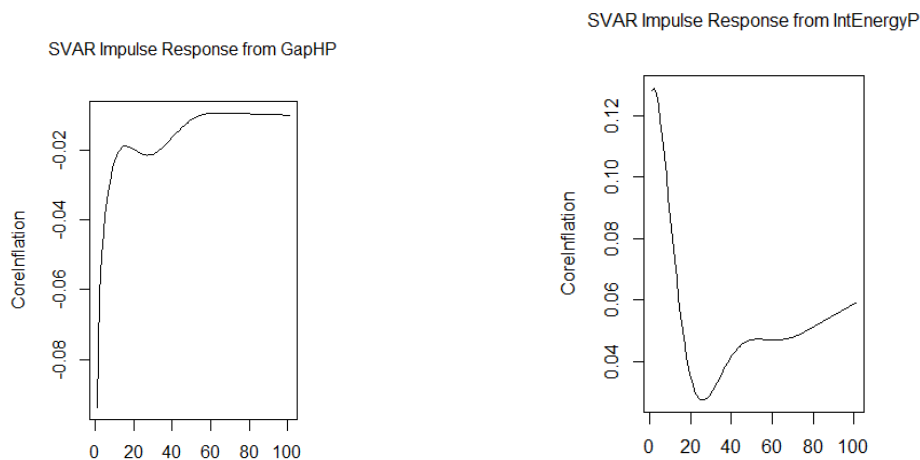
The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time. The variance share is seen to be substantially high from money supply.

### 5.4.5 Model 5

Model 5 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap HP	M2
Core Inflation	1.00	0.00	0.26	0.13	-0.09	5.45E-04
Domestic Food Prices	0.00	1.00	0.26	0.12	0.16	-2.83E-03
Domestic Energy Prices	0.00	0.14	1.00	0.14	-0.01	3.28E-04
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap HP	0.00	0.08	0.00	0.14	1.00	1.33E-02
M2	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.6: SVAR MODEL 5

The SVAR estimate of the model shows that domestic energy prices, international energy prices and money supply have positive effect on core inflation (domestic energy has the strongest influence and money supply M2, the weakest), however, output gap computed through the HP filter has a negative effect on core inflation.



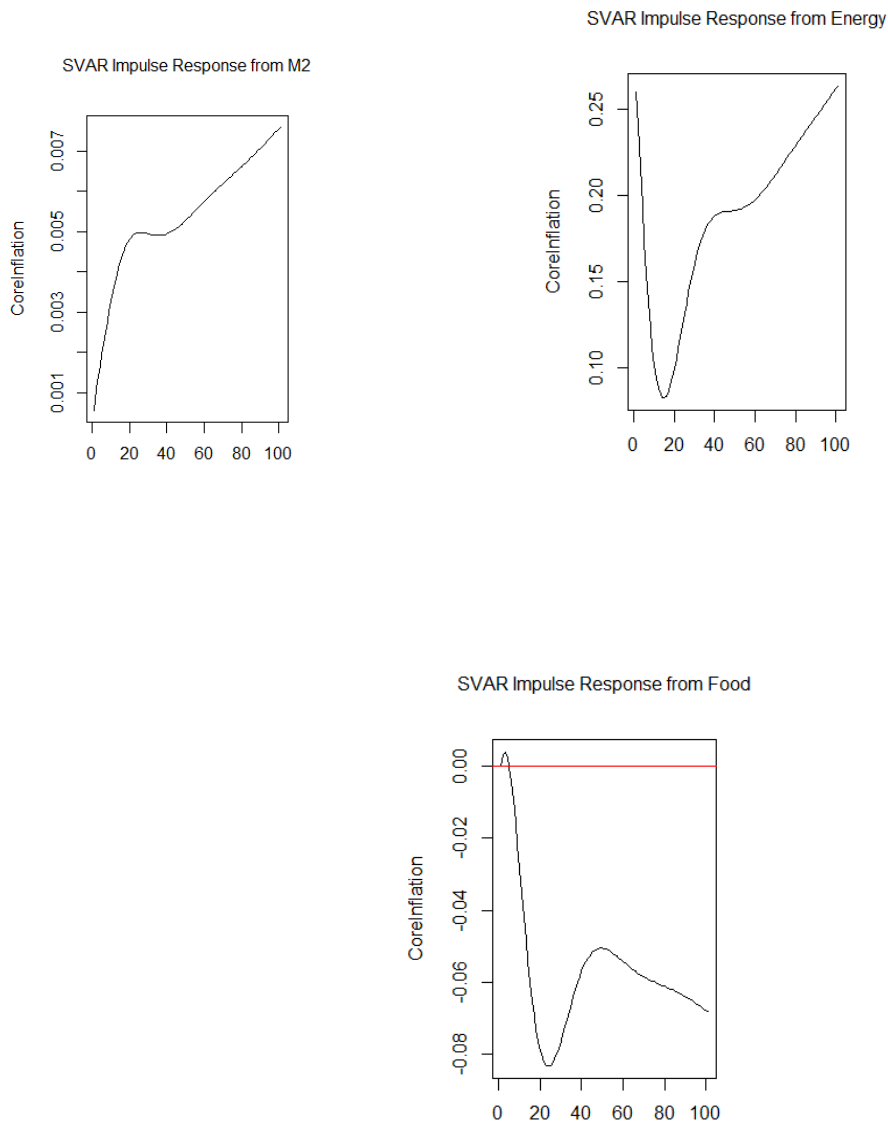


FIGURE 5-29: IRF MODEL 5

The graphs show that the impulse from food inflation has a positive effect on the response variable, core inflation till the tenth month but beyond that, the effect is negative. The effect of impulse from domestic energy prices, international energy prices and money supply have positive effect and the impulse from output gap has negative effect on core inflation up to hundred months (number of runs considered for the response functions is 100). A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core

inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

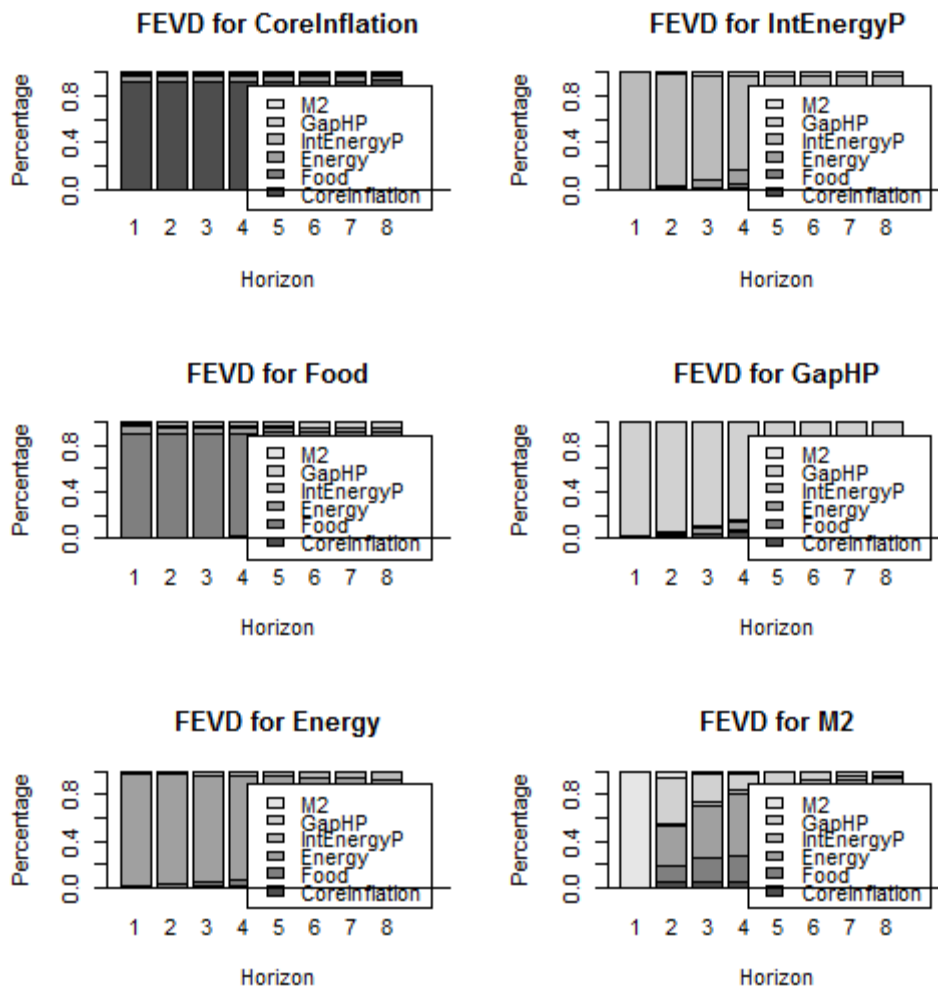


FIGURE 5-30: FEVD MODEL 5

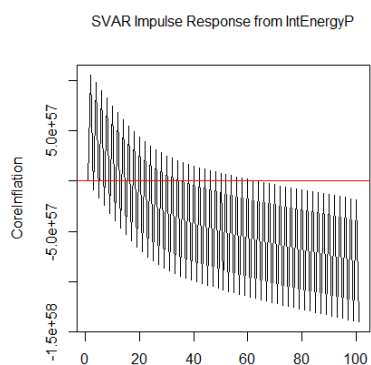
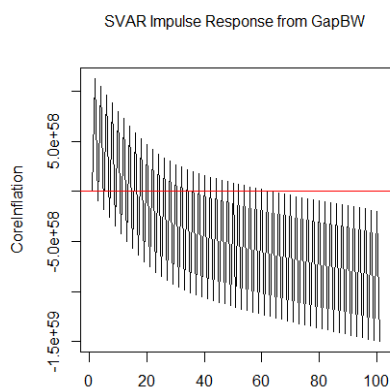
The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression and determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time.

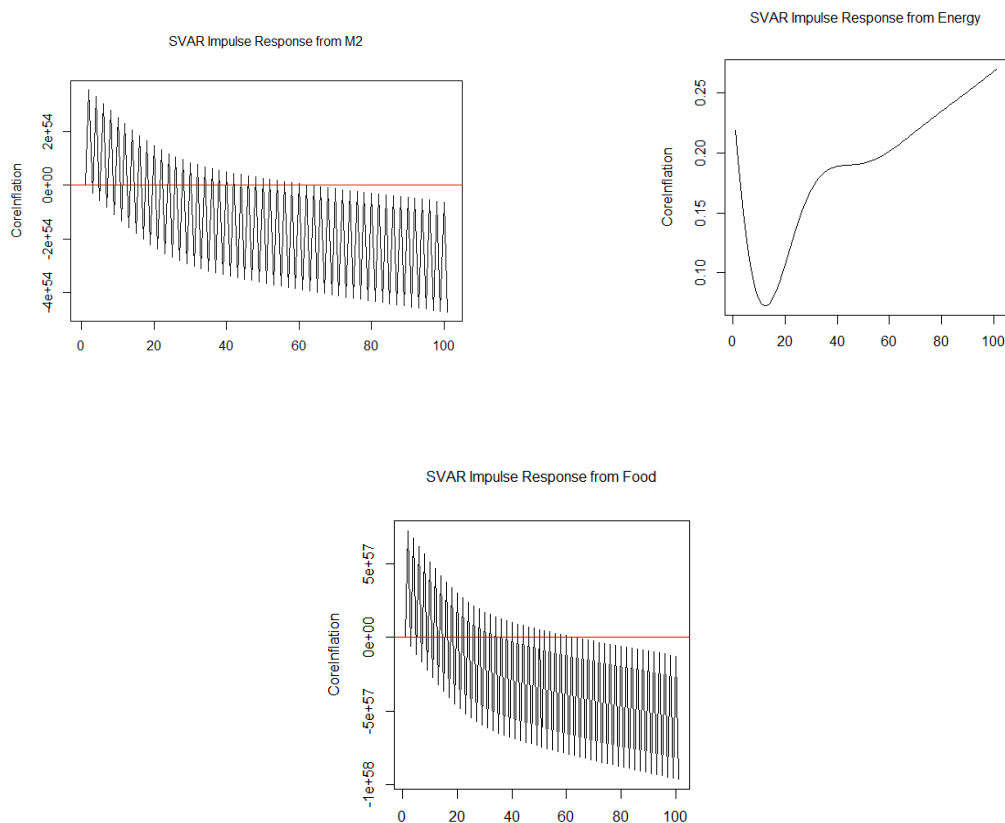
## 5.4.6 Model 6

Model 6 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BW	M2
Core Inflation	1.00	0.00	0.22	0.08	0.23	1.63E-04
Domestic Food Prices	0.00	1.00	0.20	0.05	0.08	-3.79E-03
Domestic Energy Prices	0.00	0.12	1.00	0.16	0.20	-1.03E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BW	0.00	0.06	0.00	0.09	1.00	3.16E-05
M2	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.7: SVAR MODEL 6

All the variables have positive effect on core inflation – the effect of output gap computed through the BW filter is the strongest and the effect of money supply (M2) is the weakest.





**FIGURE 5-31: IRF MODEL 6**

The IRFs from food inflation, output gap BW, M2 and international energy prices show oscillatory behavior – every alternate period the effect rises and falls. For all these variables the effect of the impulse is positive for the first few periods; the effect oscillates between positive and negative in alternate periods for the new few periods and finally becomes negative. Domestic energy prices have positive effect on core inflation throughout, though the effect weakens around the tenth period but catches up by eighteenth period. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (be it positive or negative, the values move away from zero) showing that the effects keep on building up month after month.



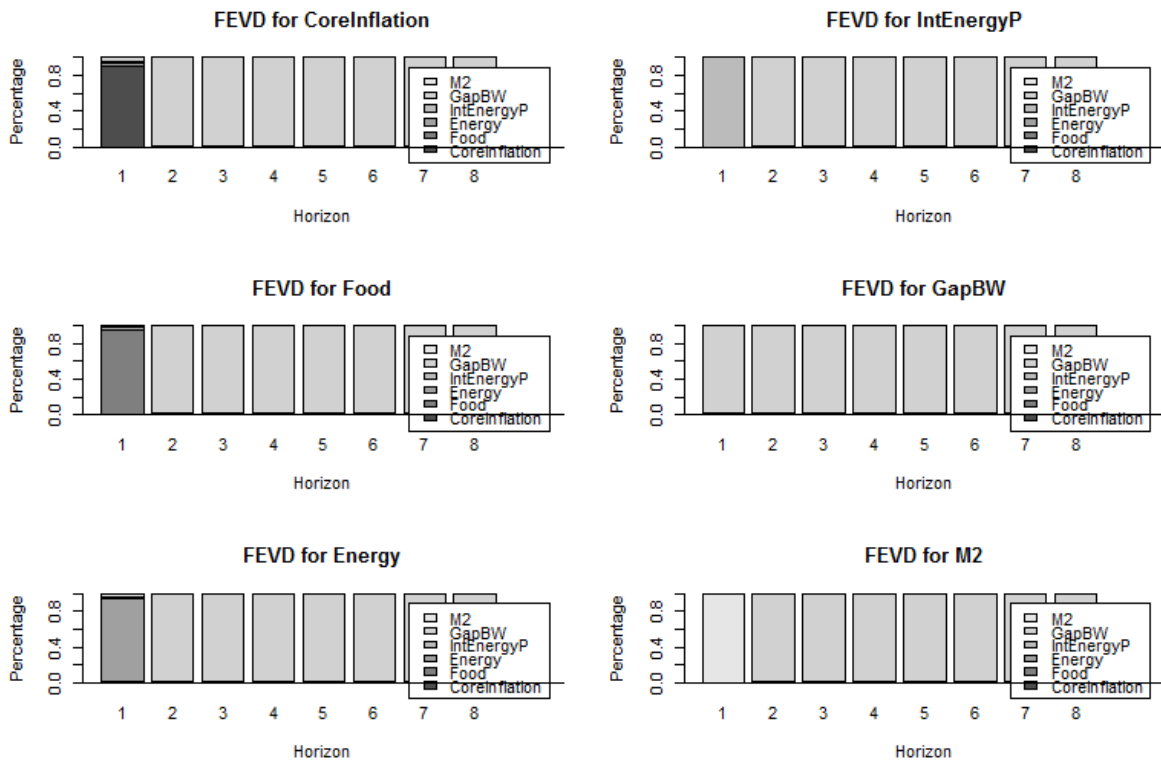


FIGURE 5-32: FEVD MODEL 6

The FEVD results show that a unit rise in the shock of each of the five variables lead to a more or less constant contribution of the variable in the variance share for core inflation over time.

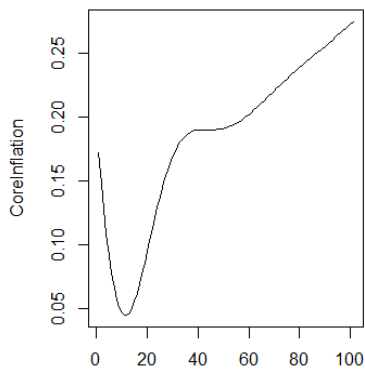
#### 5.4.7 Model 7

Model 7 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BK	M2
Core Inflation	1.00	0.00	0.17	0.11	0.22	-2.00E-03
Domestic Food Prices	0.00	1.00	0.17	0.11	0.02	-4.00E-03
Domestic Energy Prices	0.00	0.05	1.00	0.18	0.16	0.00
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BK	0.00	0.13	0.00	0.12	1.00	-2.00E-03
M2	0.00	0.00	0.00	0.00	0.00	1.00

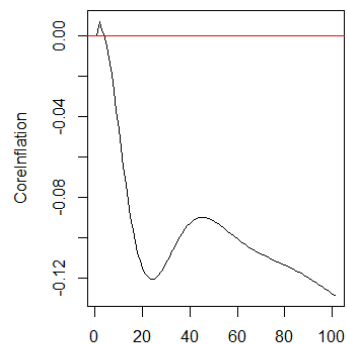
TABLE 5.8: SVAR MODEL 7

Domestic energy inflation, international energy prices and output gap computed through BK filter have positive effects on core inflation – the effect of output gap being the strongest and that of international energy prices being the weakest. Money supply (M2) is found to have a negative effect on core inflation.

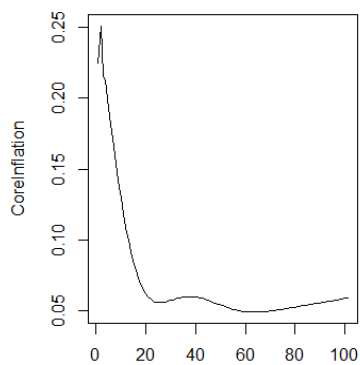
SVAR Impulse Response from Energy



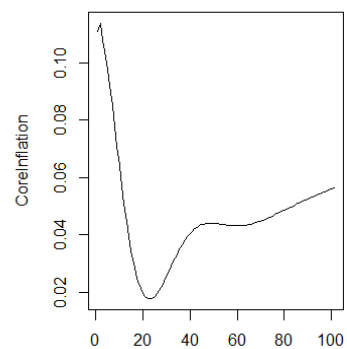
SVAR Impulse Response from Food

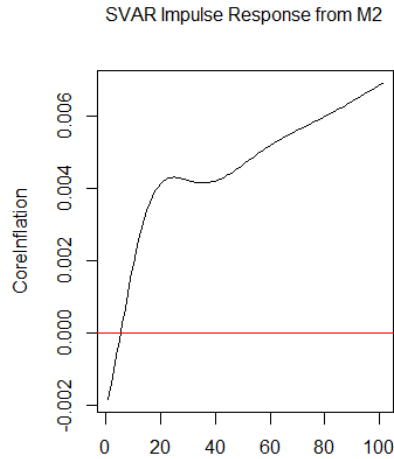


SVAR Impulse Response from GapBK



SVAR Impulse Response from IntEnergyP





**FIGURE 5-33: IRF MODEL 7**

The graphs show that the impulse from domestic energy prices, international energy prices and output gap computed through BK filter have positive effect on core inflation up to hundred months (number of runs considered for the response functions is 100). Money supply (M2) impulse has negative effect in the first eight periods approximately and thereafter has increasingly positive effect. The effect of impulse from food inflation has a positive effect on the response variable, core inflation till the tenth month but beyond that, the effect is negative. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

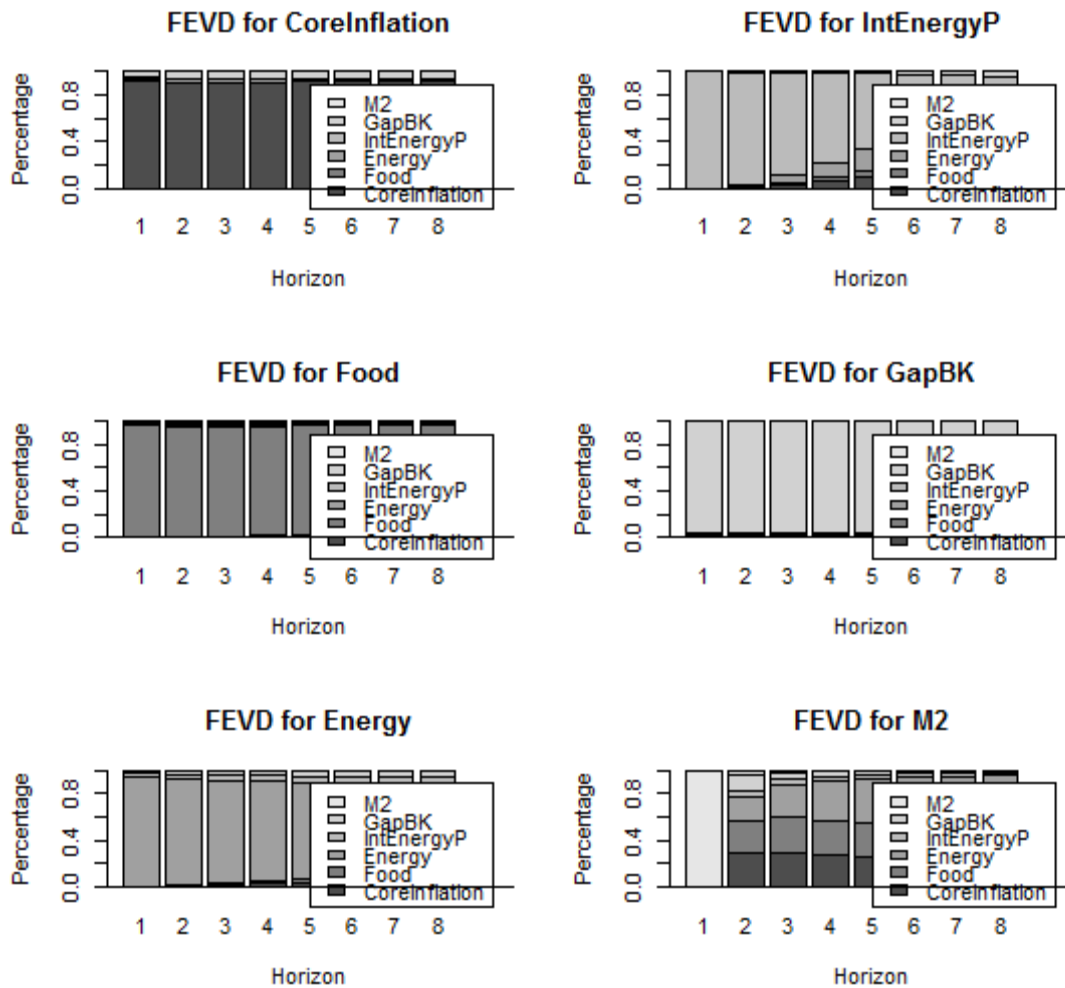


FIGURE 5-34: FEVD MODEL 7

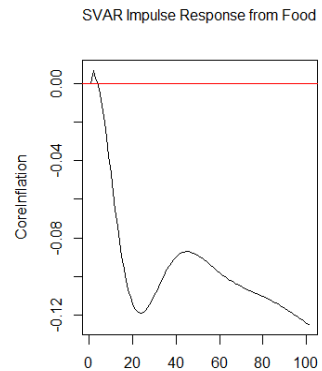
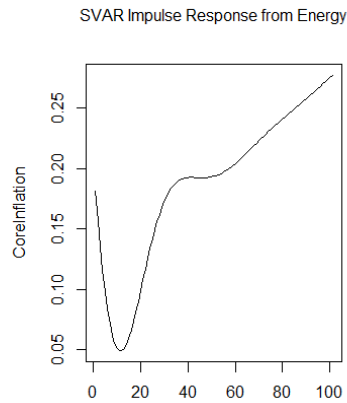
The FEVD results show that a unit rise in the shock of each of the five variables lead to an increasing contribution of the variable in the variance share for core inflation over time. The variance contribution from money supply M2 is substantially high in comparison to other variables.

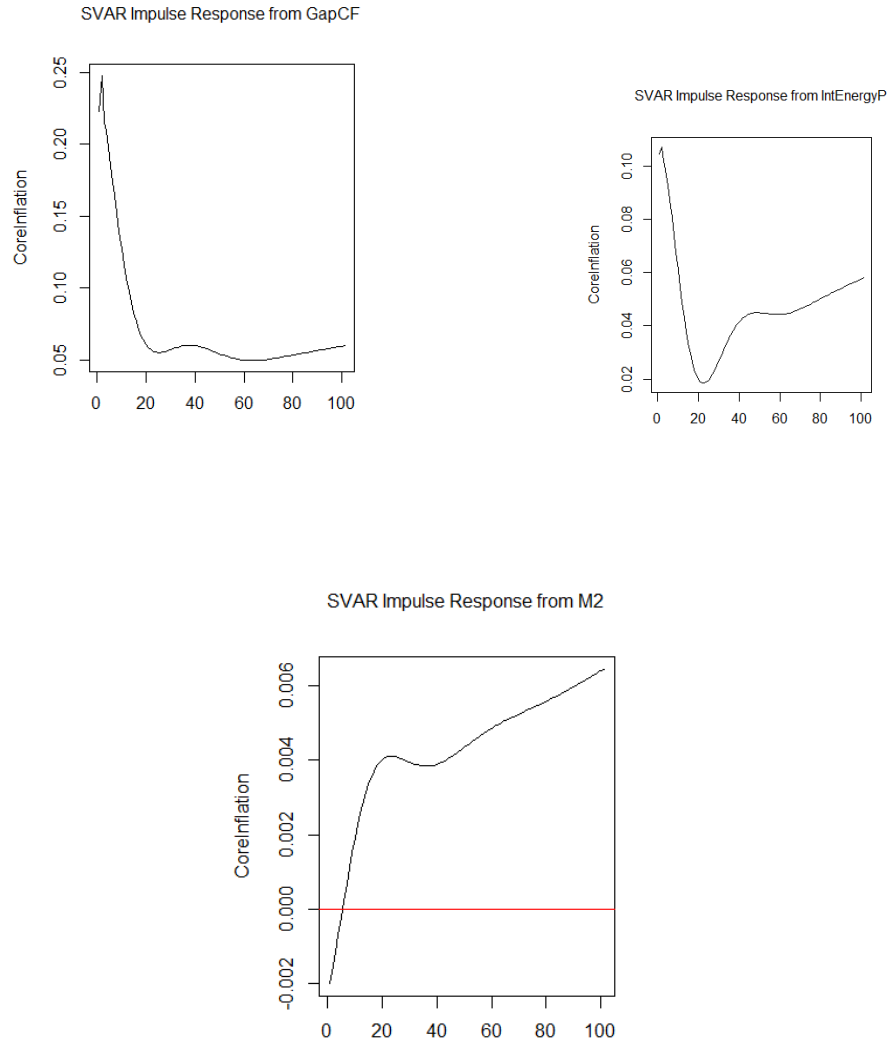
### 5.4.8 Model 8

Model 8 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap CF	M2
Core Inflation	1.00	0.00	0.18	0.10	0.22	-2.00E-03
Domestic Food Prices	0.00	1.00	0.16	0.86	0.03	-5.00E-03
Domestic Energy Prices	0.00	0.07	1.00	0.17	0.16	-3.00E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap CF	0.00	0.13	0.00	0.12	1.00	2.00E-03
M2	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.9: SVAR MODEL 8

Domestic energy price, international energy price and output gap CF have positive effect on core inflation, the greatest effect is seen to come from output gap and the least effect from international energy price. Money supply M2 has negative effect on core inflation.





**FIGURE 5-35: IRF MODEL 8**

The effect of impulse from domestic energy prices, output gap CF and international energy prices have positive effect. Food price has positive effect for the first ten periods and thereafter has negative effect. Money supply M2 is found to have negative effect for the first ten periods approximately and thereafter the effect becomes positive. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation remains significant in value.

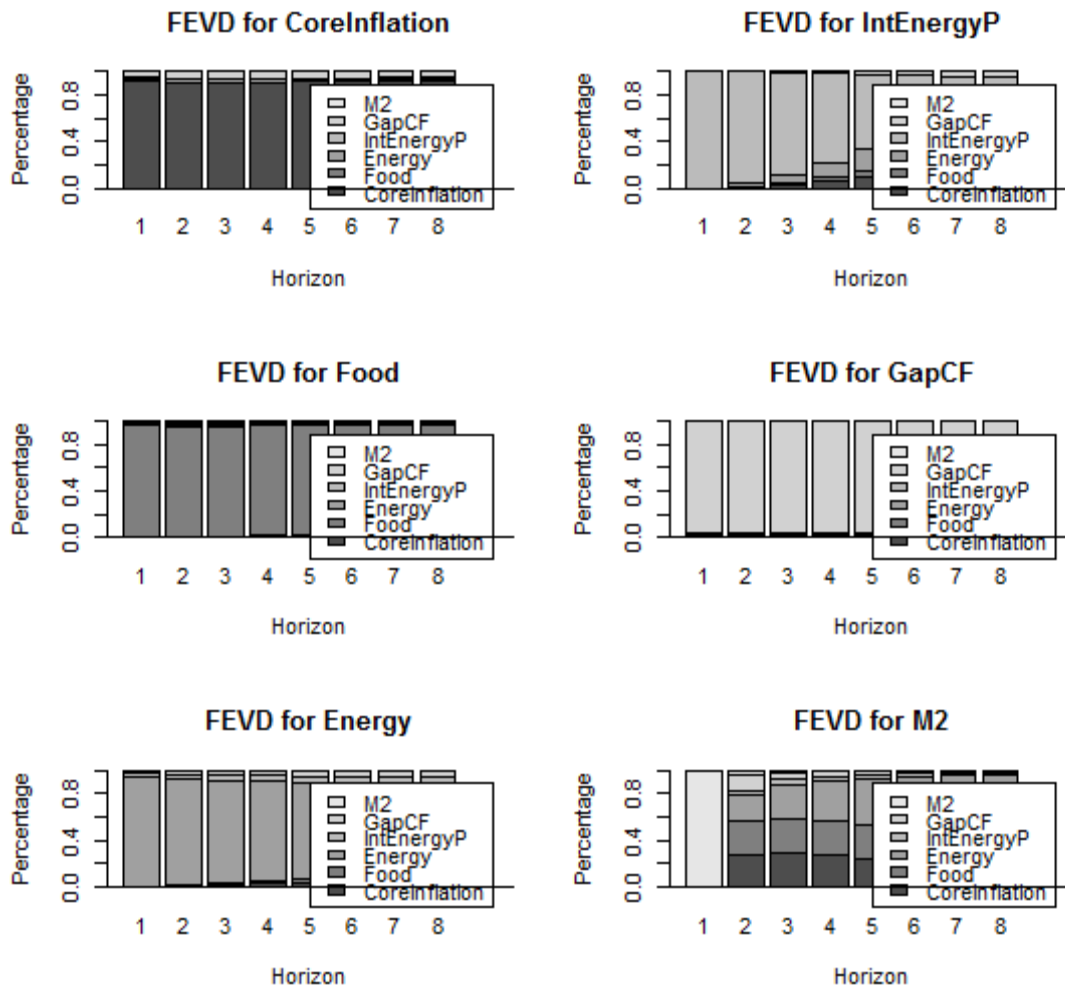


FIGURE 5-36: FEVD MODEL 8

The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time. The variance share is seen to be substantially high from money supply.

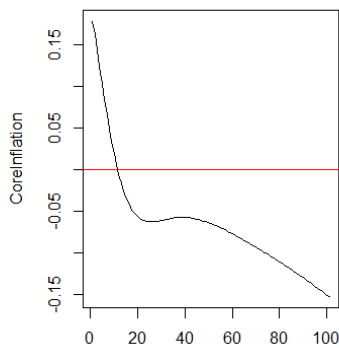
### 5.4.9 Model 9

Model 9 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap HP	M3
Core Inflation	1.00	0.00	0.18	0.11	0.15	1.00E-03
Domestic Food Prices	0.00	1.00	0.16	0.10	0.15	1.00E-03
Domestic Energy Prices	0.00	0.71	1.00	0.20	0.12	-1.00E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap HP	0.00	0.11	0.00	0.16	1.00	5.00E-03
M3	0.00	0.00	0.00	0.00	0.00	1.00

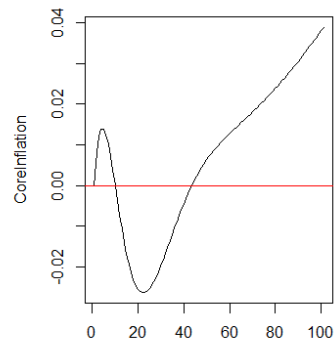
TABLE 5.10: SVAR MODEL 9

All the variables under consideration have positive effect on core inflation – domestic energy price has the highest impact and money supply (M3) the lowest.

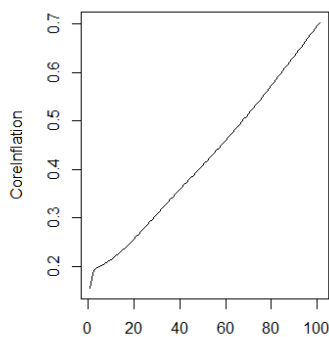
SVAR Impulse Response from Energy



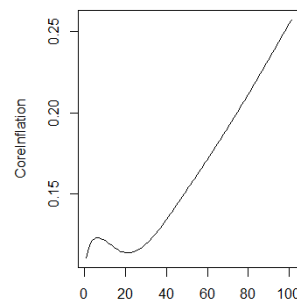
SVAR Impulse Response from Food



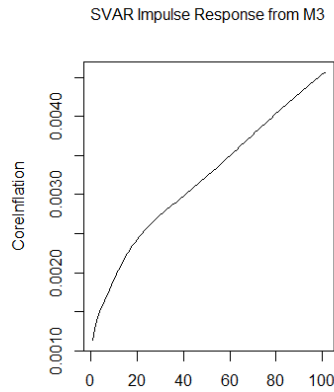
SVAR Impulse Response from GapHP



SVAR Impulse Response from IntEnergyP







**FIGURE 5-37: IRF MODEL 9**

The graphs show that the impulse from food inflation has a positive effect on the response variable, core inflation till the tenth month but beyond that, the effect is negative till about the forty-fifth period and becomes positive again and follows an increasing pattern. The effect of impulse from output gap HP, international energy prices and money supply have positive effect. Impulse from domestic energy price has positive effect till the twelfth period approximately and affects negatively after that. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up.

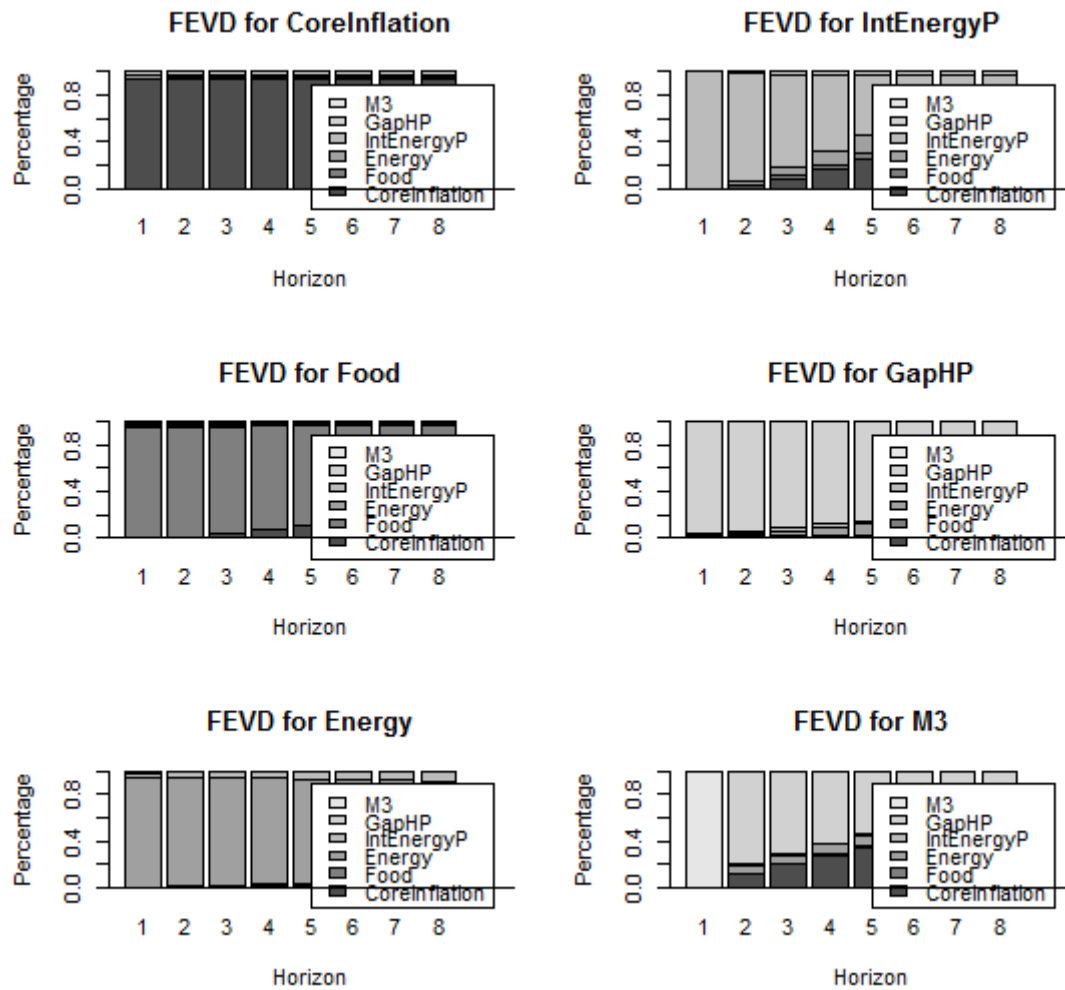


FIGURE 5-38: FEVD MODEL 9

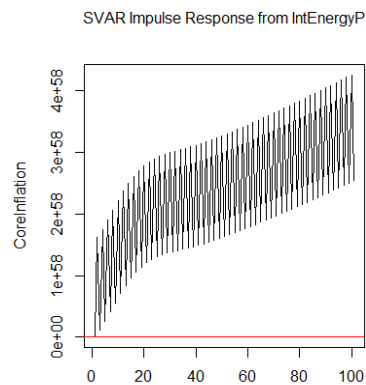
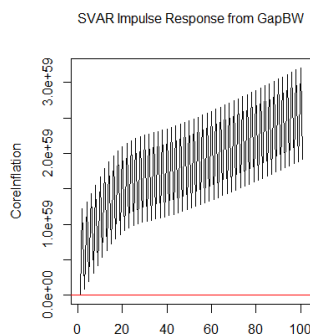
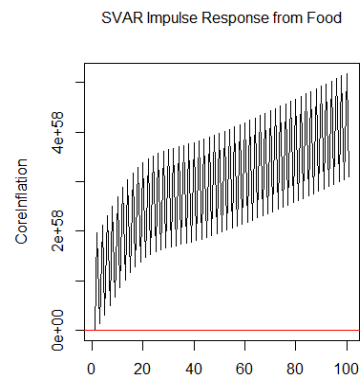
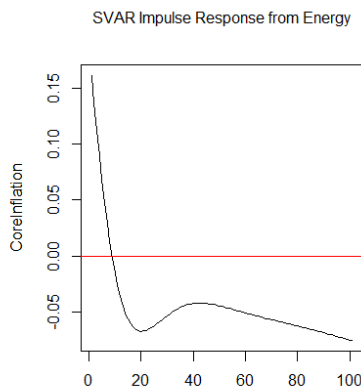
The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time.

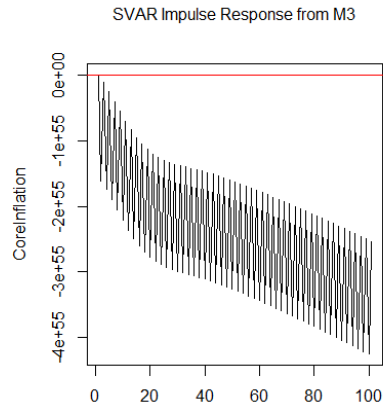
### 5.4.10 Model 10

Model 10 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BW	M3
Core Inflation	1.00	0.00	0.12	0.12	0.21	2.03E-05
Domestic Food Prices	0.00	1.00	0.07	0.09	0.07	-7.92E-05
Domestic Energy Prices	0.00	0.10	1.00	0.19	0.17	-1.30E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BW	0.00	0.16	0.00	0.13	1.00	-1.32E-04
M3	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.11: SVAR MODEL 10

All the variables have positive effect on core inflation – the effect of output gap computed through the BW filter is the strongest and the effect of money supply (M3) is the weakest.





**FIGURE 5-39: IRF MODEL 10**

The IRFs from food inflation, output gap BW, M3 and international energy prices show oscillatory behavior – every alternate period the effect rises and falls. The effects from food inflation, output gap BW and international energy prices are consistently positive and increasing while that of M3 is negative and decreasing. The response for domestic energy price is positive for the first ten periods and then negative. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (be it positive or negative, the values move away from zero) showing that the effects keep on building up month after month.

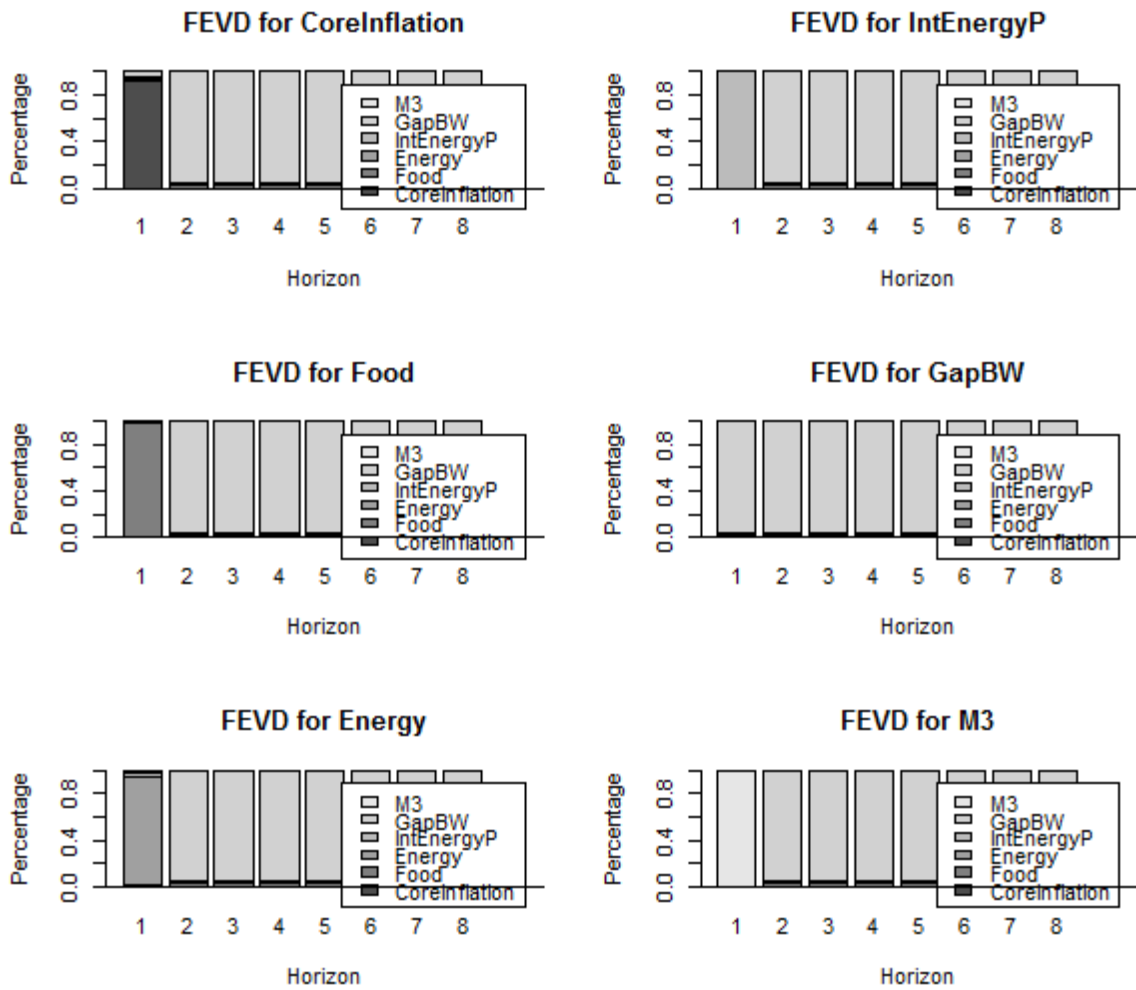


FIGURE 5-40: FEVD MODEL 10

The FEVD results show that a unit rise in the shock of each of the five variables lead to a more or less constant contribution of the variable in the variance share for core inflation over time.

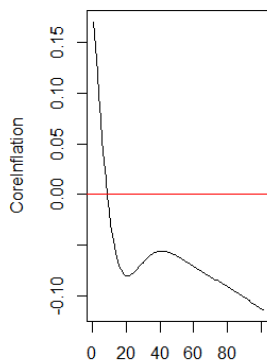
### 5.4.11 Model 11

Model 11 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BK	M3
Core Inflation	1.00	0.00	0.17	0.10	0.21	-7.72E-05
Domestic Food Prices	0.00	1.00	0.17	0.08	0.08	-8.62E-04
Domestic Energy Prices	0.00	0.06	1.00	0.19	0.17	-1.39E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BK	0.00	0.10	0.00	0.12	1.00	3.11E-03
M3	0.00	0.00	0.00	0.00	0.00	1.00

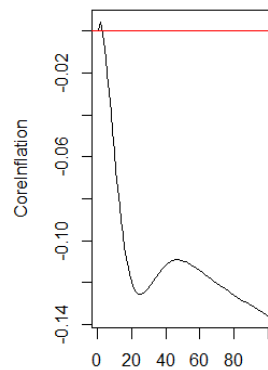
TABLE 5.12: SVAR MODEL 11

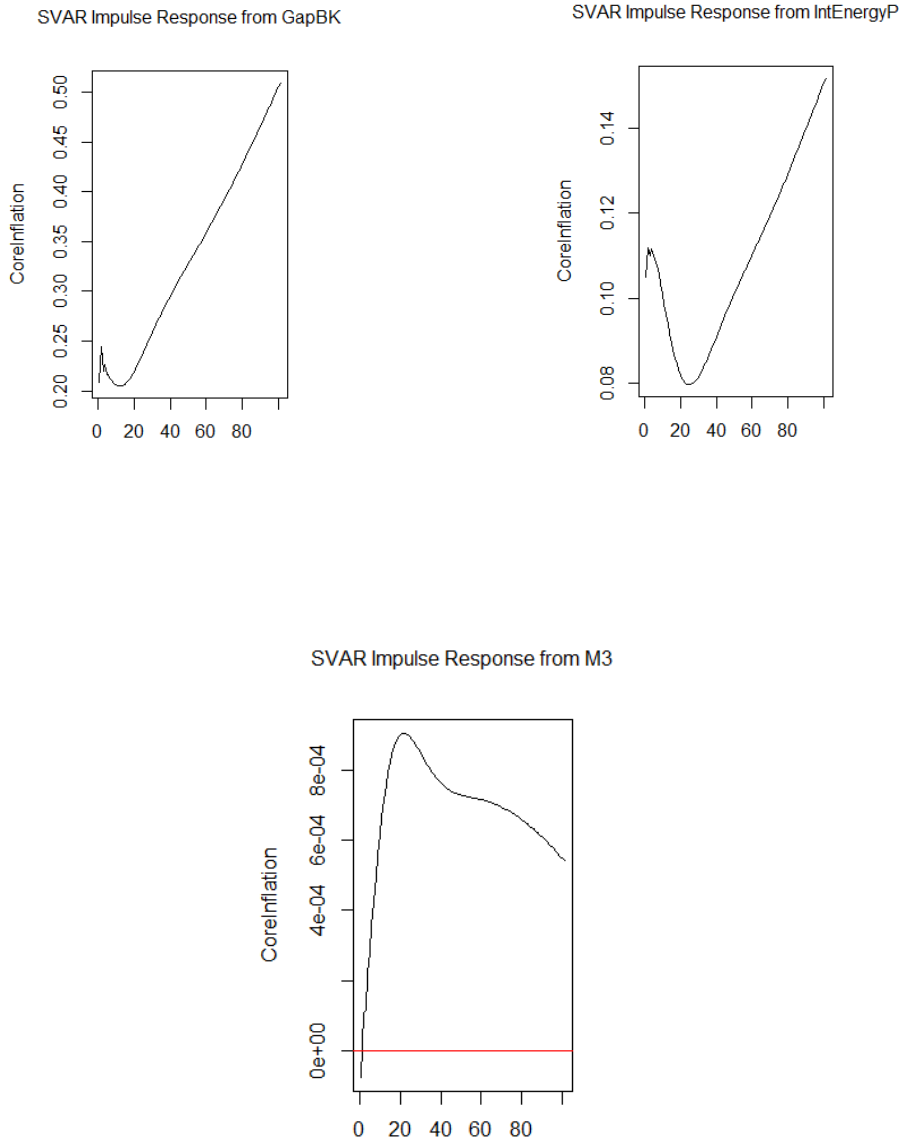
Domestic energy inflation, international energy prices and output gap computed through BK filter have positive effects on core inflation – the effect of output gap being the strongest and that of international energy prices being the weakest. Money supply M3 is found to have a negative effect on core inflation.

SVAR Impulse Response from Energy



SVAR Impulse Response from Food





**FIGURE 5-41: IRF MODEL 11**

The graphs show that the impulse from international energy prices and output gap computed through BK filter have positive effect on core inflation up to hundred months (number of runs considered for the response functions is 100).The effect of impulse from food inflation has a positive effect on the response variable, core inflation till the second month but beyond that, the effect is negative. The effect of impulse from domestic energy price has a positive effect till the tenth month but beyond that, the effect is negative. Money supply impulse has negative effect in the first period and thereafter has increasingly positive effect. A one unit rise in the

shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except M3 to some extent) showing that the effects keep on building up month after month.

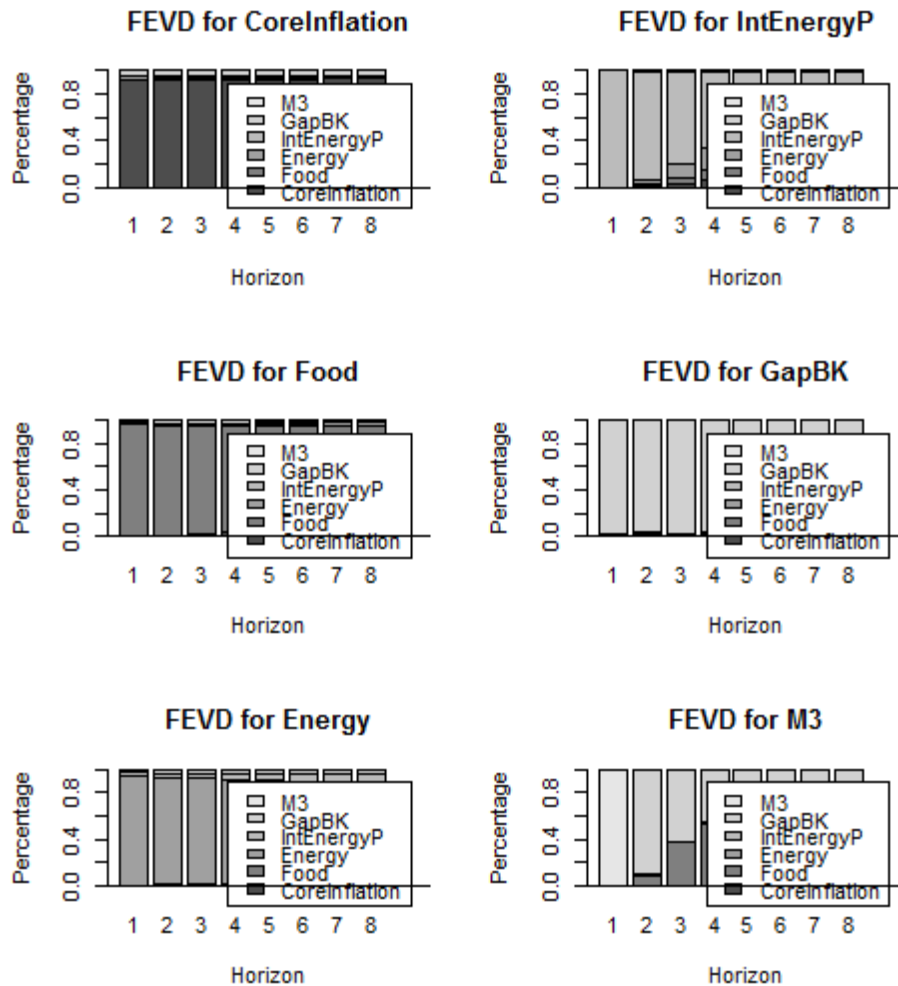


FIGURE 5-42: FEVD MODEL 11

The FEVD results show that a unit rise in the shock of each of the five variables lead to an increasing contribution of the variable in the variance share for core inflation over time.



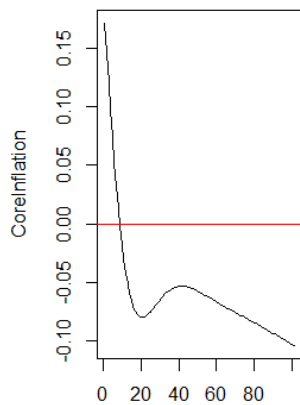
### 5.4.12 Model 12

Model 12 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap CF	M3
Core Inflation	1.00	0.00	0.17	0.11	0.21	8.47E-05
Domestic Food Prices	0.00	1.00	0.17	0.08	0.08	-8.93E-04
Domestic Energy Prices	0.00	0.06	1.00	0.19	0.17	-1.47E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap CF	0.00	0.10	0.00	0.12	1.00	2.74E-03
M3	0.00	0.00	0.00	0.00	0.00	1.00

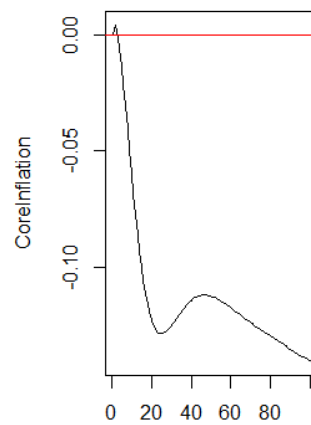
TABLE 5.13: SVAR MODEL 12

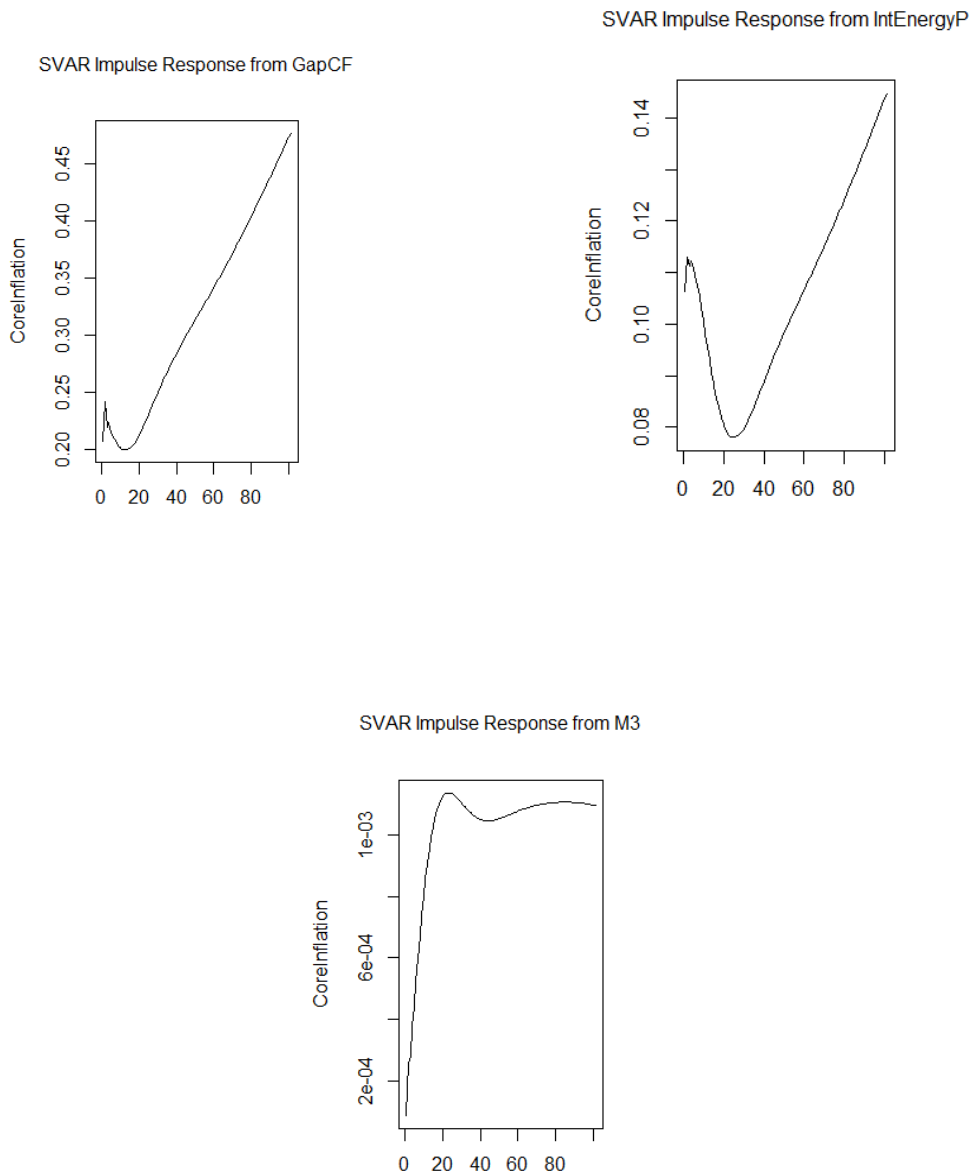
All the four variables have positive effect on core inflation, the greatest effect is seen to come from output gap computed through CF filter and the least effect from money supply M3.

SVAR Impulse Response from Energy



SVAR Impulse Response from Food





**FIGURE 5-43: IRF MODEL 12**

The effect of impulse from domestic energy price has a positive effect till the tenth month but beyond that, the effect is negative. Food price impulse has positive effect in the first two periods and thereafter has increasingly negative effect. The impulse from output gap CF, international energy prices and money supply have positive effect. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly

and the effect doesn't die away with time. Even at 100 runs the effect on core inflation remains significant in value.

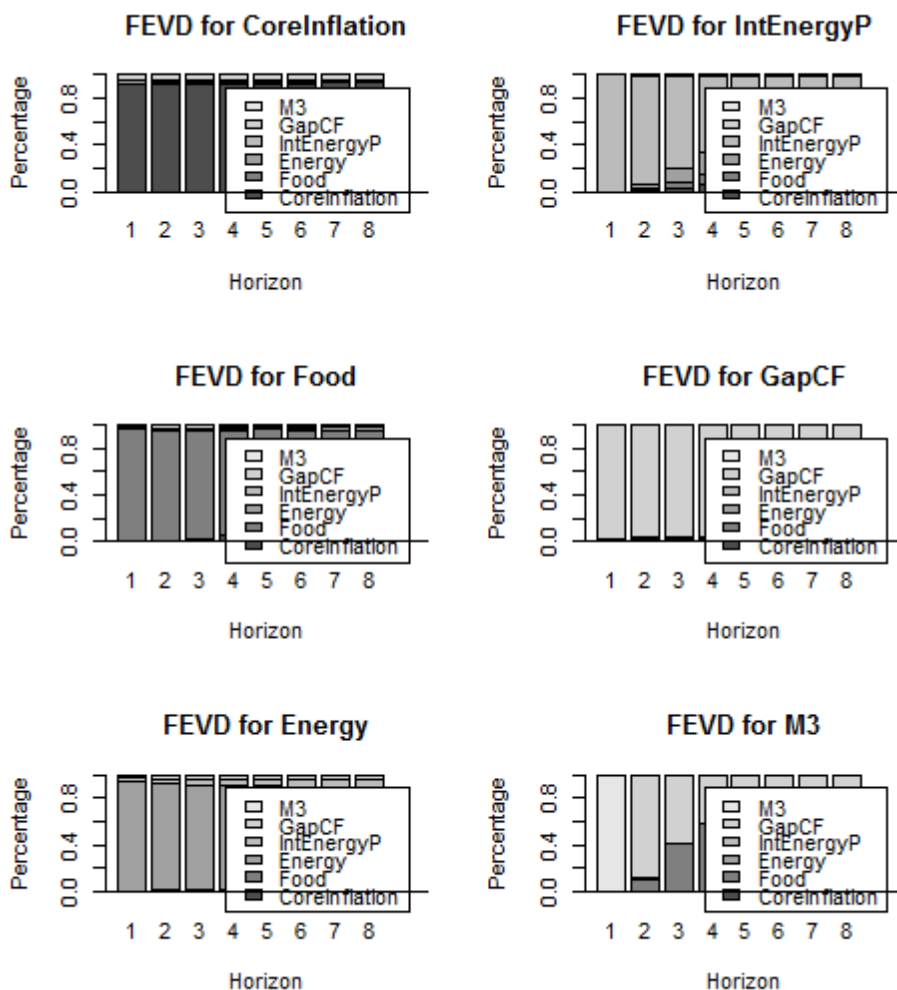


FIGURE 5-44: FEVD MODEL 12

The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time.

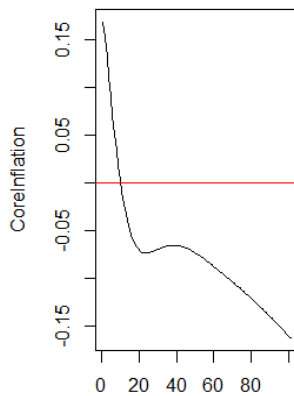
### 5.4.13 Model 13

Model 13 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap HP	M4
Core Inflation	1.00	0.00	0.17	0.11	0.17	3.74E-06
Domestic Food Prices	0.00	1.00	0.16	0.10	0.18	1.00E-03
Domestic Energy Prices	0.00	0.05	1.00	0.18	0.11	-1.30E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap HP	0.00	0.12	0.00	0.16	1.00	4.89E-03
M4	0.00	0.00	0.00	0.00	0.00	1.00

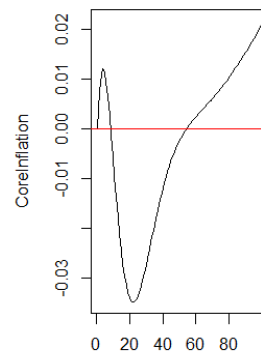
TABLE 5.14: SVAR MODEL 13

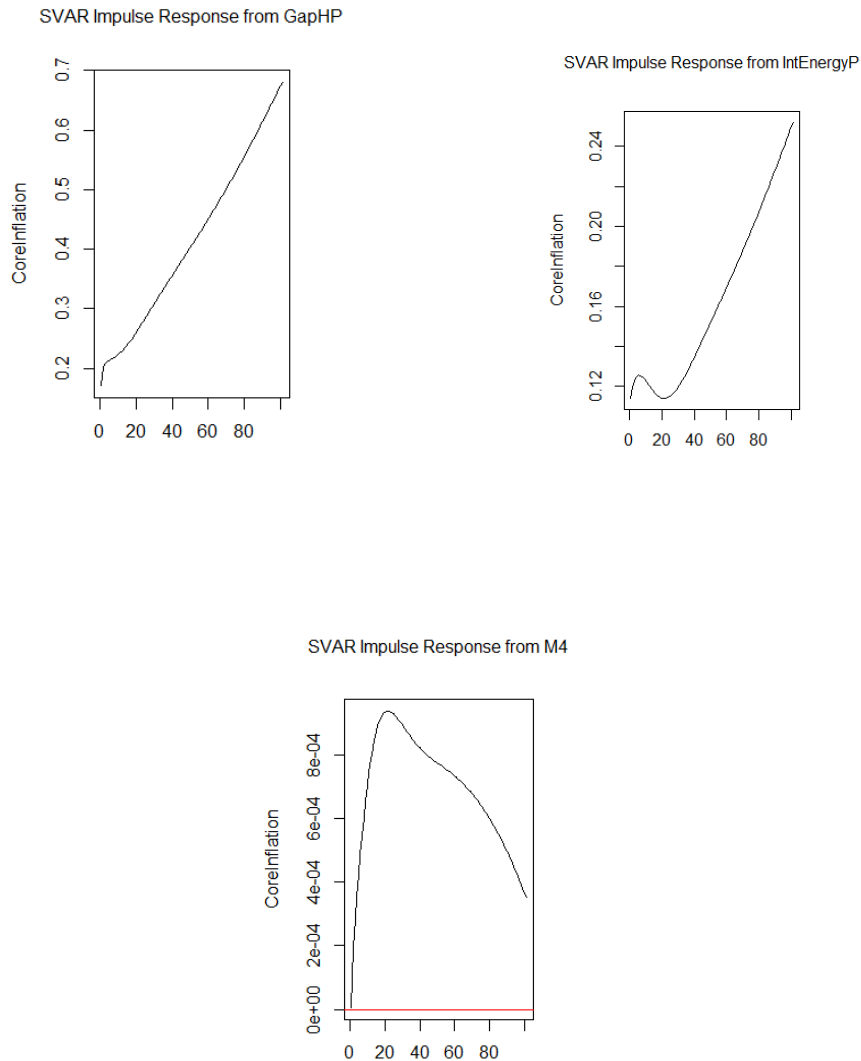
The results show that all the variables have positive effect on core inflation – the effect of output gap computed through the HP filter is the strongest and the effect of money supply (M4) is the weakest.

SVAR Impulse Response from Energy



SVAR Impulse Response from Food





**FIGURE 5-45: IRF MODEL 13**

The impulse from domestic energy price has positive effect on core inflation for the first ten months approximately and thereafter the effect is negative. Food price has positive effect for the first ten months, negative effect between tenth and fiftieth months and thereafter again positive effect. Output gap HP, international energy price and M4 have positive effect. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except money supply M4 to some extent) showing that the effects keep on building up month after month.

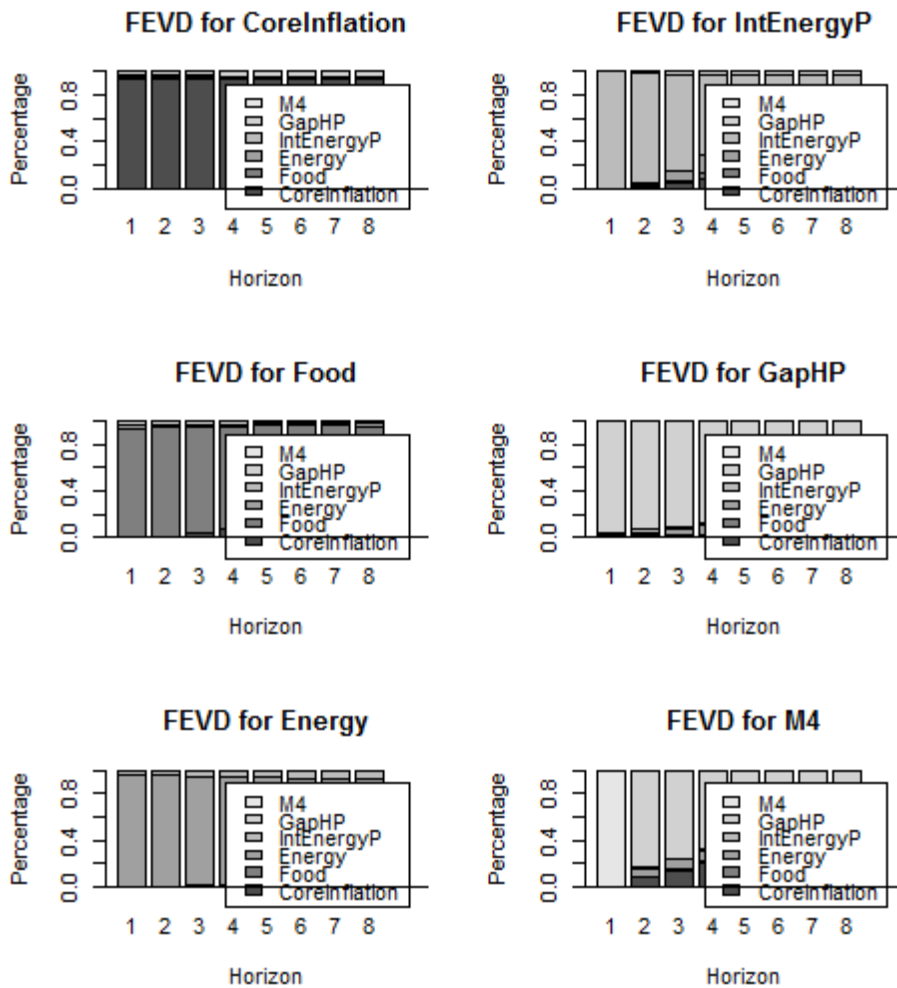


FIGURE 5-46: FEVD MODEL 13

The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time. The variance share is seen to be substantially high from money supply.

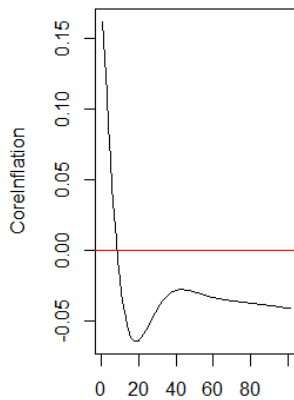
### 5.4.14 Model 14

Model 14 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BW	M4
Core Inflation	1.00	0.00	0.16	0.12	0.21	4.18E-05
Domestic Food Prices	0.00	1.00	0.07	0.09	0.07	-7.82E-06
Domestic Energy Prices	0.00	0.10	1.00	0.19	0.17	-1.21E-03
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BW	0.00	0.16	0.00	0.13	1.00	-4.02E-05
M4	0.00	0.00	0.00	0.00	0.00	1.00

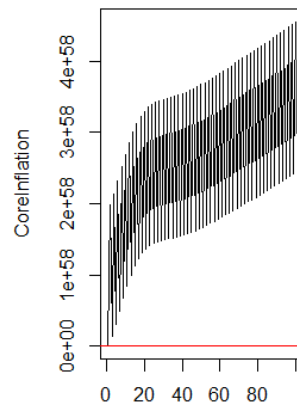
TABLE 5.15: SVAR MODEL 14

All the variables have positive effect on core inflation – the effect of output gap computed through the BW filter is the strongest and the effect of money supply (M4) is the weakest.

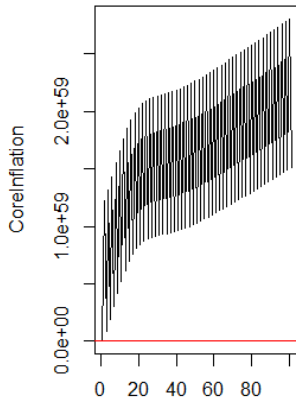
SVAR Impulse Response from Energy



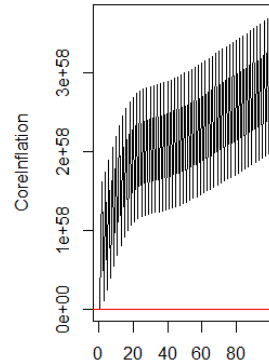
SVAR Impulse Response from Food



SVAR Impulse Response from GapBW



SVAR Impulse Response from IntEnergyP



SVAR Impulse Response from M4

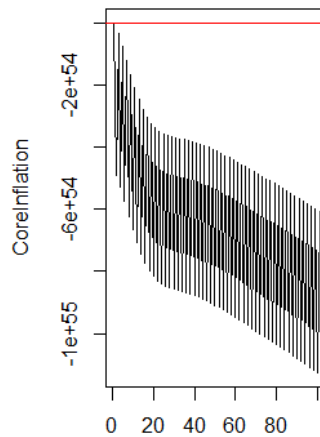


FIGURE 5-47: IRF MODEL 14

The IRFs from food inflation, output gap BW, M4 and international energy prices show oscillatory behaviour – every alternate period the effect rises and falls. Impulses from food price, output gap and international energy price have positive and increasing effect on core inflation; M4 has negative effect and it strengthens over time. Domestic energy has positive effect for the first ten periods approximately after which the effect becomes negative.



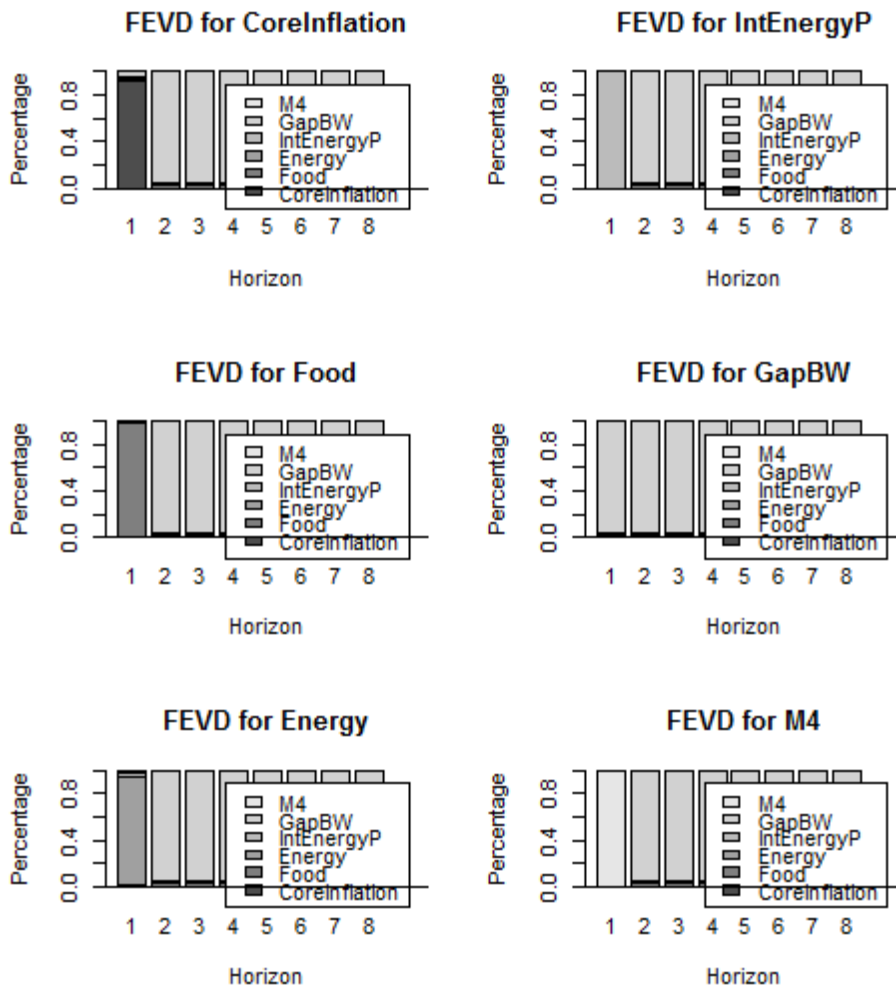


FIGURE 5-48: FEVD MODEL 14

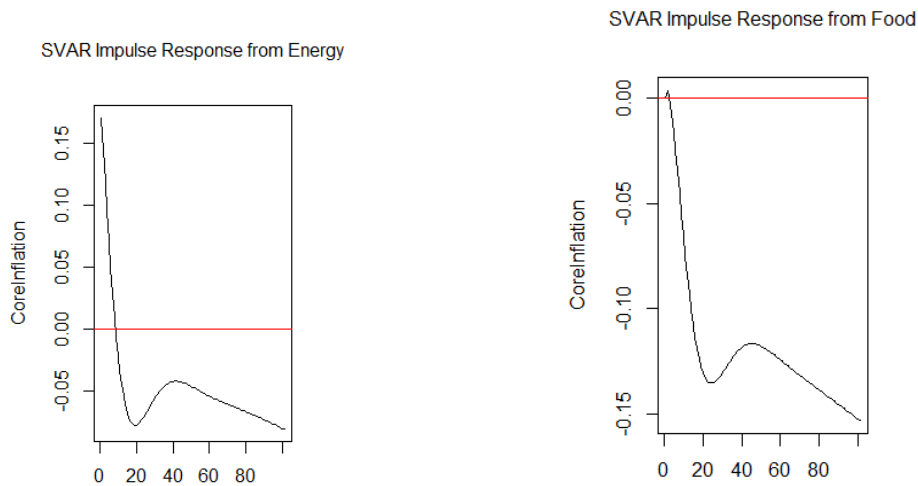
The FEVD results show that a unit rise in the shock of each of the five variables lead to a more or less constant contribution of the variable in the variance share for core inflation over time.

### 5.4.15 Model 15

Model 15 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap BK	M4
Core Inflation	1.00	0.00	0.17	0.11	0.21	0.0002138
Domestic Food Prices	0.00	1.00	0.17	0.08	0.08	0.0006462
Domestic Energy Prices	0.00	0.06	1.00	0.19	0.17	0.0012941
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap BK	0.00	0.10	0.00	0.12	1.00	0.0032981
M4	0.00	0.00	0.00	0.00	0.00	1.00

TABLE 5.16: SVAR MODEL 15

All the variables have positive effect on core inflation – the effect of output gap computed through the BK filter is the strongest and the effect of money supply (M4) is the weakest.



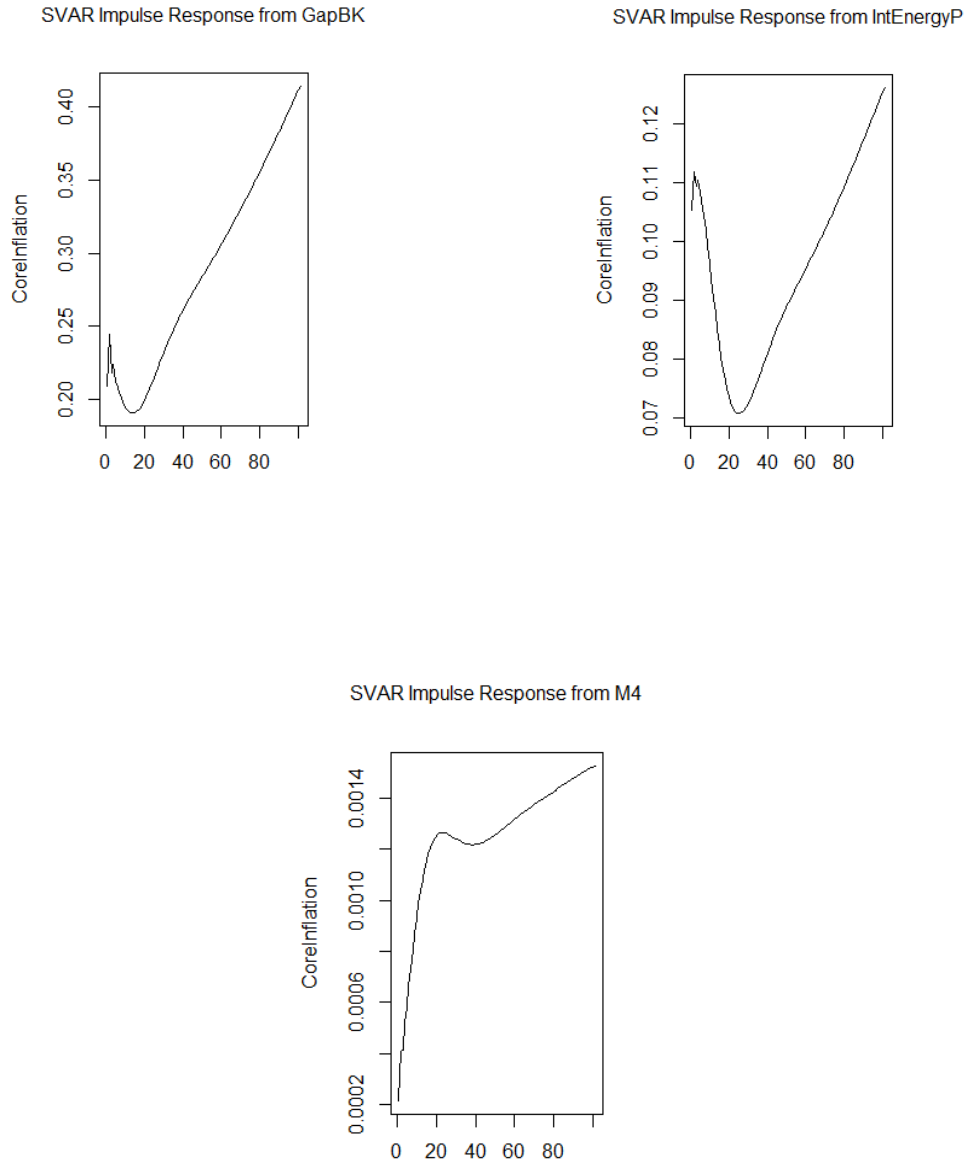


FIGURE 5-49: IRF MODEL 15

The graphs show that the impulse from domestic energy price has positive effect on core inflation for about first ten periods and thereafter becomes negative and keeps on increasing in value. Food price has positive (but very low) effect for the first two periods and then has negative effect on core inflation. The impulses from output gap BK, international energy price and money supply (M4) are found to have positive effect throughout the hundred time periods considered. A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at

100 runs the effect on core inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

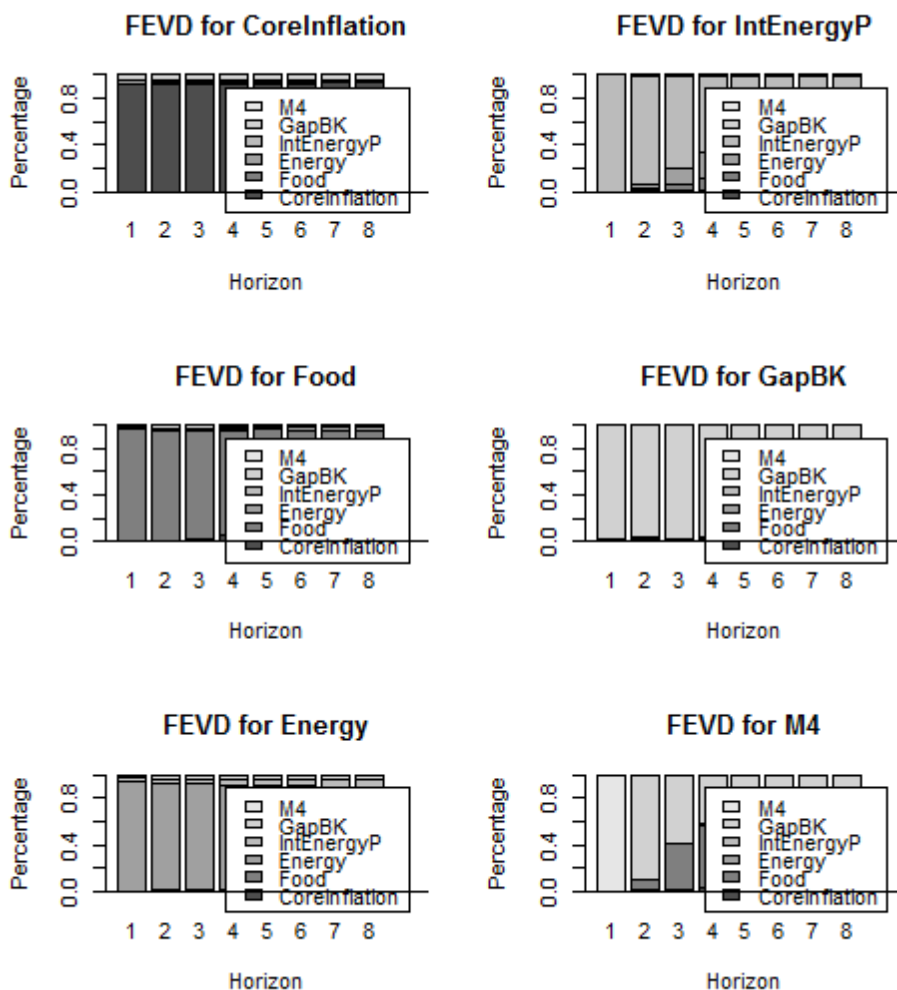


FIGURE 5-50: FEVD MODEL 15

The FEVD results show that a unit rise in the shock of each of the five variables lead to an increasing contribution of the variable in the variance share for core inflation over time.

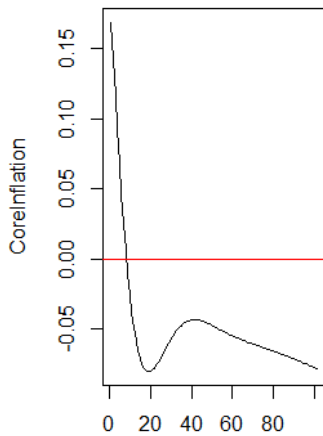
### 5.4.16 Model 16

Model 16 SVAR Estimated B Matrix						
	Core Inflation	Domestic Food Prices	Domestic Energy Prices	International Energy Prices	Output Gap CF	M4
Core Inflation	1.00	0.00	0.17	0.11	0.21	-0.0001307
Domestic Food Prices	0.00	1.00	0.17	0.08	0.08	-0.0003267
Domestic Energy Prices	0.00	0.07	1.00	0.18	0.18	-0.001435
International Energy Prices	0.00	0.00	0.00	1.00	0.00	0.00
Output Gap CF	0.00	0.09	0.00	0.13	1.00	0.0031103
M4	0.00	0.00	0.00	0.00	0.00	1.00

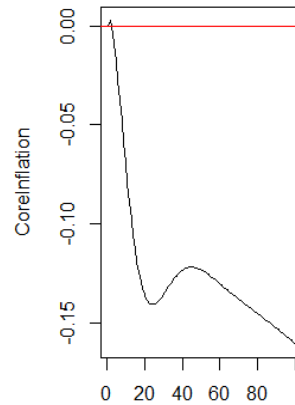
TABLE 5.17: SVAR MODEL 16

Domestic energy inflation, international energy prices and output gap computed through CF filter have positive effects on core inflation – the effect of output gap being the strongest and that of international energy prices being the weakest. Money supply (M4) is found to have a negative effect on core inflation.

SVAR Impulse Response from Energy



SVAR Impulse Response from Food



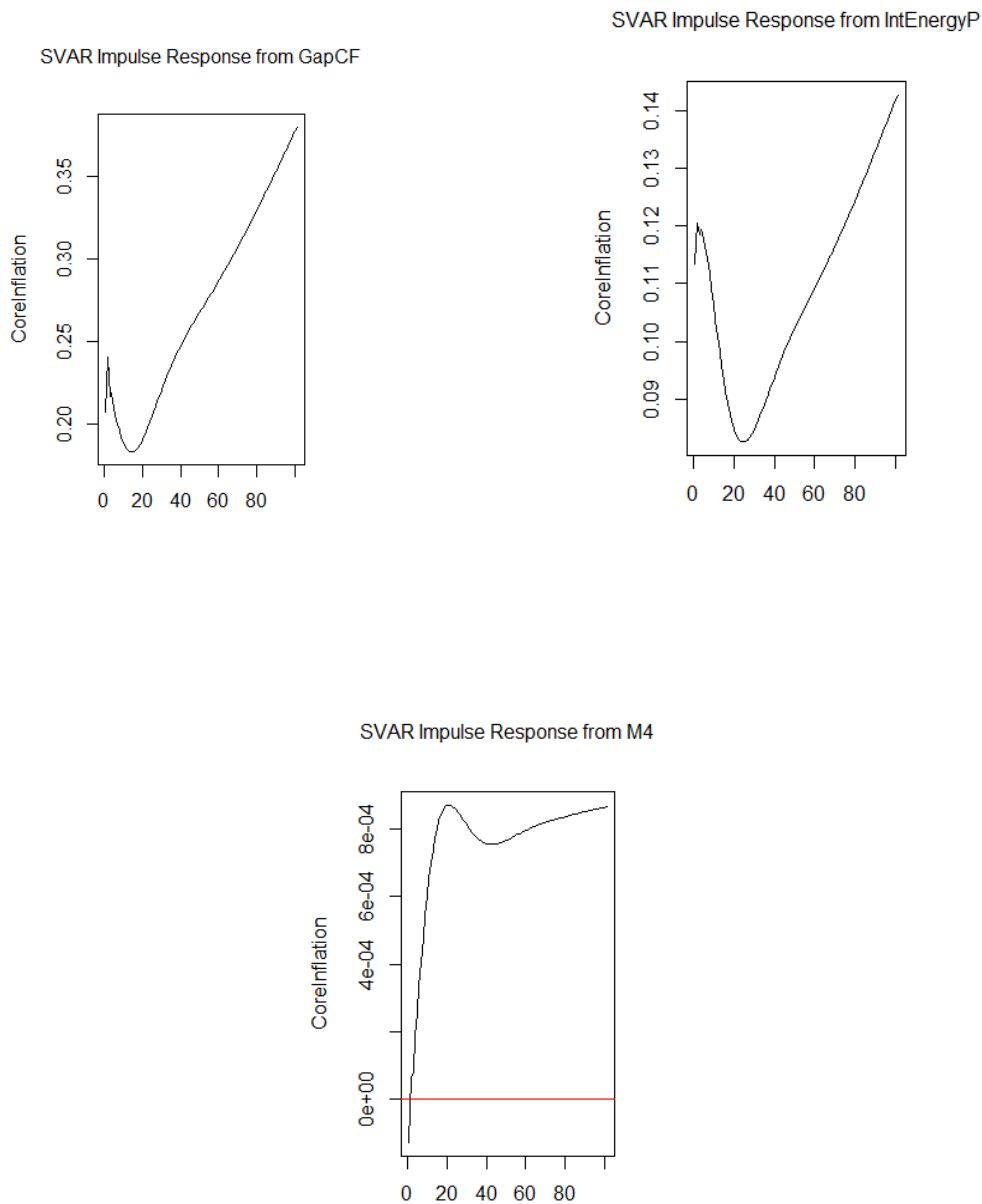


FIGURE 5-51: IRF MODEL 16

The graphs show that the impulse from domestic energy price has positive effect on core inflation for about first ten periods and thereafter becomes negative and keeps on increasing in value. Food price has positive (but very low) effect for the first two periods and then has negative effect on core inflation. The impulses from output gap BK and international energy price are found to have positive effect throughout the hundred time periods considered.

Money supply is found to affect core inflation negatively (but decreasing value) for the first five periods and after that the effect becomes positive (increasing too). A one unit rise in the shock of each of the five variables under consideration, is found to affect core inflation significantly and the effect doesn't die away with time. Even at 100 runs the effect on core inflation doesn't dampen up (except output gap to some extent) showing that the effects keep on building up month after month.

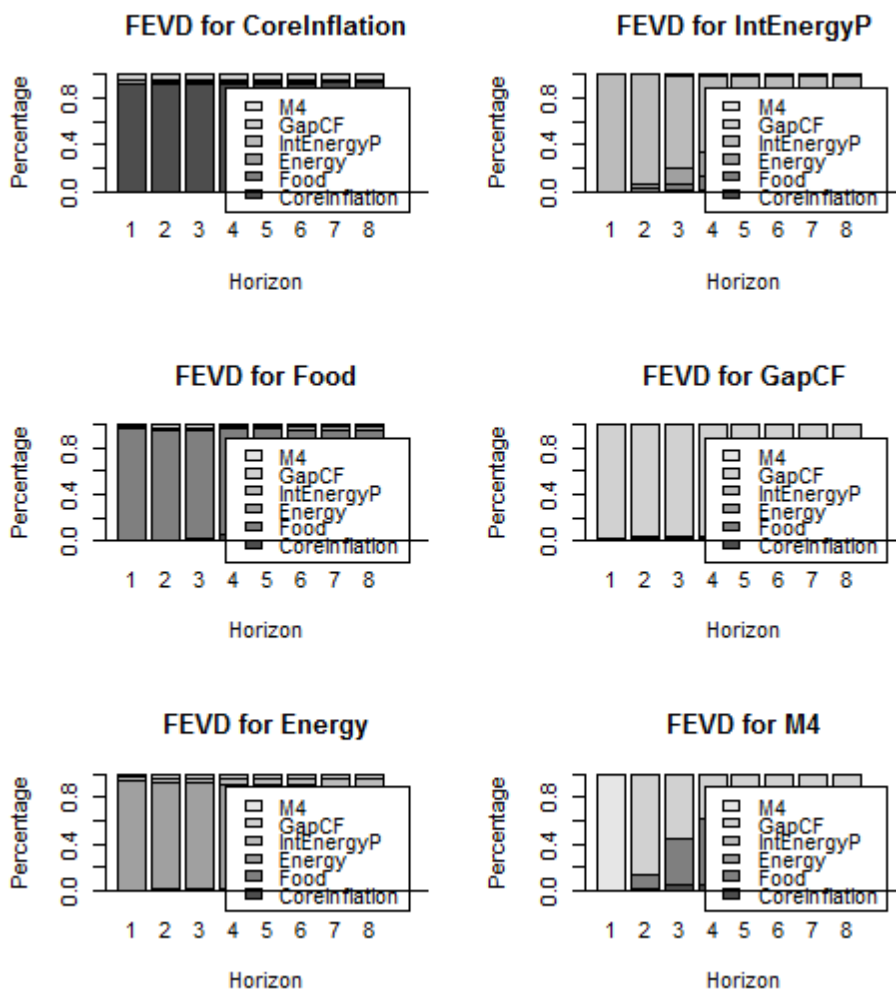


FIGURE 5-52: FEVD MODEL 16

The FEVD results show that a unit rise in the shock of each of the five variables lead to increasing contribution of the variable in the variance share for core inflation over time.

## 6 Chapter 6. Conclusions and Policy Implications of the Study

The spectral or frequency domain analysis of causality help us detect causality (or non-causality) at various frequencies or cycles for the time frame considered for the study. The frequency domain representation provides further crucial insights into the causality relationships by breaking down the time domain representation into frequencies that enables us to identify the existing cyclical relationship, if any.

The results reveal that international energy prices cause core inflation only in the long run but two of the output gaps cause core inflation only in the short run, one of the measures of output gap does not cause core inflation at any frequency and one measure causes core inflation in two and seven month cycles, showing by and large, the short run nature of causality from output gap to inflation. This signifies the differences in the supply side and demand side transmission mechanisms for causing inflation. International energy prices raise domestic cost of production which in turn may reduce incentives for producers to produce as much as they have been producing earlier. This leads to a fall in the supply of the economy as a whole, vis-à-vis the existing demand in the market. As a result, prices go up. On the other hand, output gap, which is the difference of the actual production from the potential production level, is essentially an instrument to determine the extent of excess demand in the market. This excess demand forces market prices to rise, leading to inflation. Given this, it can be argued that international energy price is a supply side variable and output gap is a demand side variable, while analysing their relationships with inflation. The above results allow us to argue that the supply side mechanism for causing inflation has significant effect only in the long run and not in the short run and the demand side mechanism works mostly in the short run. These insights may be able to assist policy-makers in designing more effective policies while trying to combat inflation both in long run and short run. With the knowledge of short run and long run effects of the demand and



supply side forces on inflation, both the central bank as well as the Centre should be in a better position to frame more effective policies to curtail inflation as and when the necessity arises. A rise in the cost push inflation (through international energy prices) should be targeted with a long run perspective in mind, while inflation caused through output gap channel (demand pull) should receive more attention in the short run.

Domestic energy prices cause core inflation only for cycles between seven and nine months. With energy becoming more expensive within the economy, the time for transmission required into the non-food, mineral and manufacturing sectors is at least seven months and the effect survives up to the next two months, the causality effect ceasing post that cycle. In the business cycle, energy price changes will not cause core inflation. If and when the economy suffers from rising energy prices (which has been rampant in the Indian context) the core inflation will be affected only in the short run and not in the long run. Hence, no change in the monetary policy is required for tackling long run inflation. However, if the intention of the central bank is to curb the short run rise in core inflation, only then it would make sense to divert the instruments towards this end. This result also implies the necessity for energy efficiency and the role of the policymakers in controlling energy prices. In recent times in India, the benefits from a fall in internal energy prices has not been passed on to the domestic energy price, however, the adverse effects have been reflected almost over-night. Some amount of prudence on the part of the central government in keeping domestic energy prices under control is expected to go a long way in controlling the core inflation of the country. At the same time, efficient use of existing amount of energy resources and also promoting alternate sources of energy may play a huge role in keeping inflation within the targeted limits.

Unlike the popular belief, our results show that domestic food inflation does not cause core inflation at all, be it at any cycle or frequency. Curbing food inflation with expectations of keeping core inflation under control is hence, not a prudent path to walk down at all.

The causality results from the four measures of money supply shows that the three measures (except M2) cause core inflation only in the short run and not in the long run (only M2 shows significant causality for cycles greater than fifty-two months). Thus, by and large, the causal effect of money supply on core inflation exists statistically significantly only in the short run.

All the domestic variables of the study are found to cause core inflation in the short run (except food inflation which shows no causality) and only international energy price is seen to cause core inflation in the long run. The transmission mechanism for domestic factors is thus found to be fundamentally different from that of the internal factor under consideration in the study.

The SVAR results imply that each of the variables under consideration in the study have positive effect on core inflation. Whether the causality effect is in the short run or in the long run or there exists no causality at all, a one unit rise in each of these variables lead to a rise in core inflation. The IRF analysis implies that any unprecedented rise in any of these variables have non-dampening effect on core inflation for almost all the variables in all of the sixteen models considered. The effect doesn't fade away but persist over significant subsequent periods. FEVD results show that the contribution of each of these variables' variances to the variance of core inflation has increased over time (on an average). This shows the endogenous nature of core inflation in India and the importance of all the variables under consideration – domestic energy price, food price, output gap, money supply and international energy prices in understanding the variability of core inflation in the Indian

economy and also the individual contribution of these variables in explaining the dynamic behaviour of Indian core WPI inflation.

One of the limitations of the study lies in the use of WPI instead of the CPI series as the measure of inflation despite the fact that CPI is usually used as the indicator of inflation in the Indian economy in recent times. Lack of data for the CPI series for the period under investigation, forced the study to be restricted to WPI series. Given the strong correlation between WPI and CPI in the Indian economy, it was inferred that this deviation will not affect the overall essence of the study. However, the study may be extended by using CPI as the measure of inflation (with whatever data is available) to check whether the behaviour of the variables under consideration remain unaltered.

The next limitation may be the macroeconomic variables chosen for the causality analysis. Given the wide reliance of inflation on almost all macroeconomic variables, the study may be extended to include variables like exchange rate, wage rate, rate of interest, foreign exchange reserves, etc. Also, given the nature of the methodology it was not possible to include qualitative variables like implementation of fiscal and trade policies, consumer preferences, standard of living, political scenario, natural calamities, etc. that may have caused inflation significantly.

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## Appendix

APPENDIX 1: DATA-COMPONENTS OF WPI & CONSTRUCTED CORE WPI

<b>Components of WPI and Core WPI</b>						
<b>Month/Year</b>	<b>IA Food</b>	<b>IB Non- food</b>	<b>IC Minerals</b>	<b>II Energy</b>	<b>III Manufactured</b>	<b>Core</b>
INDX012000	86.50	74.85	55.08	59.85	82.86	81.87832
INDX022000	87.08	74.53	55.08	60.85	82.86	81.85481
INDX032000	89.74	74.80	55.18	65.24	83.34	82.3147
INDX042000	91.12	75.23	55.29	69.16	83.58	82.56694
INDX052000	91.55	75.97	55.45	69.09	83.52	82.56921
INDX062000	92.56	77.14	58.75	69.34	83.70	82.86666
INDX072000	91.33	78.63	61.56	69.41	84.25	83.50993
INDX082000	90.54	78.58	61.46	69.81	84.61	83.8336
INDX092000	90.48	76.98	60.98	72.38	85.15	84.20292
INDX102000	91.87	77.72	61.30	78.16	85.51	84.59138
INDX112000	90.80	78.52	61.30	78.52	85.81	84.92439
INDX122000	89.79	79.43	61.40	77.77	86.53	85.65068
INDX012001	89.10	79.53	61.94	78.37	86.59	85.7209
INDX022001	89.05	78.20	61.94	79.59	86.35	85.40356
INDX032001	89.31	78.84	62.73	79.51	86.71	85.79097
INDX042001	91.87	79.48	62.52	79.48	86.71	85.83497
INDX052001	92.77	81.02	62.41	79.44	86.65	85.89223
INDX062001	93.73	83.68	62.47	79.41	86.59	86.03404
INDX072001	92.77	83.79	62.52	79.34	87.13	86.53626
INDX082001	93.62	83.36	62.63	80.69	86.95	86.34188
INDX092001	94.26	83.20	63.16	80.76	86.77	86.17311
INDX102001	95.27	81.77	63.74	82.23	86.83	86.13047
INDX112001	95.16	80.49	64.22	82.30	86.83	86.04322

INDX122001	94.79	79.96	64.81	81.73	86.71	85.90263
INDX012002	92.77	79.37	64.81	81.41	86.71	85.85953
INDX022002	93.04	79.48	64.27	81.12	86.53	85.69529
INDX032002	93.46	79.69	63.80	83.15	86.65	85.81388
INDX042002	94.31	80.70	63.00	82.23	87.13	86.3158
INDX052002	94.15	81.18	62.25	82.23	87.49	86.66961
INDX062002	95.43	83.41	63.16	83.44	88.27	87.56
INDX072002	94.90	85.43	63.80	85.08	88.45	87.88247
INDX082002	96.33	87.77	63.48	84.87	89.30	88.81822
INDX092002	96.81	87.93	63.32	85.22	89.36	88.88256
INDX102002	96.76	86.55	63.26	85.97	89.24	88.67024
INDX112002	96.92	88.62	63.16	85.94	89.30	88.87638
INDX122002	94.26	91.92	63.21	85.22	89.36	89.1749
INDX012003	93.73	91.49	63.26	86.30	89.72	89.4734
INDX022003	94.74	93.89	63.21	87.19	90.38	90.25228
INDX032003	94.79	96.44	63.00	90.69	90.80	90.82127
INDX042003	95.80	97.77	63.21	90.72	91.76	91.79981
INDX052003	96.07	98.83	63.53	88.37	92.78	92.81511
INDX062003	98.46	98.56	63.69	87.83	92.48	92.52354
INDX072003	95.85	98.88	63.85	88.97	92.66	92.71386
INDX082003	95.32	96.65	62.63	89.04	93.27	93.08046
INDX092003	97.29	96.60	62.09	90.86	93.87	93.61749
INDX102003	98.83	96.49	62.15	90.61	93.99	93.72011
INDX112003	98.30	98.19	61.99	91.08	94.53	94.33686
INDX122003	95.80	99.79	62.09	91.76	94.77	94.6753
INDX012004	95.96	101.86	62.04	93.40	95.61	95.59522
INDX022004	95.48	102.82	69.96	93.58	96.57	96.65558
INDX032004	94.42	101.86	78.36	93.72	96.81	96.9235
INDX042004	97.50	100.50	82.00	92.80	98.60	98.50476
INDX052004	98.50	101.30	91.50	93.00	99.00	99.06321

INDX062004	98.80	101.40	94.90	94.80	98.90	99.02755
INDX072004	100.70	103.50	97.10	96.30	99.40	99.66956
INDX082004	103.00	104.90	103.40	99.20	100.00	100.4093
INDX092004	101.10	105.10	104.50	99.80	100.10	100.5308
INDX102004	102.40	101.10	112.30	99.60	100.30	100.529
INDX112004	105.20	99.00	102.30	103.80	100.30	100.2325
INDX122004	99.40	97.60	94.50	103.20	100.40	100.11
INDX012005	97.70	96.20	101.80	105.90	100.80	100.4752
INDX022005	97.60	95.10	103.50	106.40	100.90	100.5094
INDX032005	97.90	93.80	111.50	106.40	101.30	100.8918
INDX042005	100.40	94.70	99.30	107.10	102.80	102.1535
INDX052005	100.30	95.70	95.20	107.20	102.40	101.8042
INDX062005	102.30	95.70	104.70	108.90	102.10	101.6652
INDX072005	106.50	95.90	110.30	112.20	102.00	101.6681
INDX082005	106.20	95.30	123.00	112.10	102.00	101.8039
INDX092005	106.70	95.40	125.30	115.70	102.10	101.935
INDX102005	109.00	97.10	123.00	116.60	102.10	102.0277
INDX112005	109.90	98.00	120.40	116.50	102.20	102.1484
INDX122005	105.50	97.60	125.20	116.30	102.10	102.0957
INDX012006	106.70	98.40	120.80	116.10	102.60	102.5484
INDX022006	106.10	99.80	116.10	116.90	103.10	103.041
INDX032006	105.00	96.50	118.50	117.30	103.50	103.1967
INDX042006	106.40	97.30	135.00	117.60	105.90	105.6786
INDX052006	108.30	98.80	137.00	118.50	106.50	106.3648
INDX062006	111.80	99.70	138.50	121.50	106.80	106.726
INDX072006	112.20	100.60	148.50	122.50	107.50	107.5726
INDX082006	114.90	101.60	146.60	122.90	108.10	108.1666
INDX092006	118.10	102.30	128.60	123.60	108.40	108.2367
INDX102006	119.80	102.00	139.50	123.40	108.60	108.5515
INDX112006	119.90	102.30	139.50	122.60	108.70	108.6649



INDX122006	117.80	105.00	143.00	120.30	108.90	109.0959
INDX012007	118.90	105.30	120.90	120.30	109.50	109.352
INDX022007	119.20	105.90	127.40	119.20	109.70	109.6708
INDX032007	118.90	106.70	134.80	118.60	110.00	110.1083
INDX042007	121.50	110.50	143.40	118.80	111.60	111.9696
INDX052007	122.30	109.10	144.40	118.90	111.70	111.9718
INDX062007	121.80	109.40	146.90	118.90	111.90	112.2118
INDX072007	124.80	111.10	154.40	119.10	112.20	112.717
INDX082007	126.10	113.70	149.20	119.50	112.30	112.9261
INDX092007	125.50	114.70	153.60	119.40	112.40	113.1534
INDX102007	126.00	113.50	144.20	119.80	113.00	113.479
INDX112007	125.20	115.50	157.00	120.80	113.20	113.9902
INDX122007	121.60	116.50	156.60	122.10	113.50	114.3319
INDX012008	119.90	116.50	147.10	122.80	115.10	115.6567
INDX022008	122.50	118.40	163.80	124.00	116.00	116.8543
INDX032008	125.60	124.10	172.80	127.40	117.80	119.0438
INDX042008	128.90	123.50	186.10	130.20	119.20	120.465
INDX052008	130.20	126.80	193.40	131.40	119.20	120.8117
INDX062008	130.30	131.60	231.70	141.70	120.70	123.0764
INDX072008	133.40	135.10	230.20	143.20	121.40	123.9516
INDX082008	134.40	135.10	195.60	145.60	121.80	123.8261
INDX092008	135.80	134.20	173.60	144.60	121.80	123.448
INDX102008	140.30	129.80	176.80	143.10	121.60	122.9866
INDX112008	141.10	129.80	176.90	136.20	120.20	121.7111
INDX122008	136.30	127.00	178.10	129.10	119.30	120.7008
INDX012009	137.20	127.40	163.90	127.20	119.80	120.9851
INDX022009	134.10	124.70	164.00	124.00	119.70	120.6963
INDX032009	135.60	124.80	167.90	123.10	119.80	120.8502
INDX042009	140.10	128.30	182.60	124.20	120.20	121.6813
INDX052009	141.80	131.40	190.20	124.80	120.80	122.5647

INDX062009	145.00	132.00	201.50	125.70	121.00	122.9515
INDX072009	150.40	132.00	187.00	130.50	121.10	122.8372
INDX082009	153.70	132.80	200.70	131.50	122.00	123.9113
INDX092009	154.70	133.00	193.50	132.90	122.60	124.3713
INDX102009	157.80	132.10	197.10	133.40	122.90	124.6296
INDX112009	164.70	136.10	203.30	134.70	123.60	125.6507
INDX122009	164.60	140.30	200.10	135.00	124.20	126.4622
INDX012010	164.90	143.60	223.90	135.80	125.90	128.5933
INDX022010	163.40	142.60	223.50	136.60	126.10	128.6964
INDX032010	163.60	150.30	231.60	140.10	126.20	129.4698
INDX042010	168.80	151.50	245.70	141.10	127.90	131.3087
INDX052010	172.10	150.80	238.40	142.80	127.90	131.1537
INDX062010	175.40	152.90	246.00	143.20	127.80	131.3249
INDX072010	178.20	152.20	246.10	147.80	128.10	131.5484
INDX082010	176.70	153.80	248.40	148.00	128.30	131.8813
INDX092010	179.90	160.60	245.30	147.60	128.70	132.7034
INDX102010	180.90	166.10	255.00	148.10	129.20	133.7023
INDX112010	181.40	170.80	263.20	148.60	129.80	134.7121
INDX122010	189.40	176.00	261.30	150.20	130.90	136.0718
INDX012011	192.40	181.80	260.00	151.30	132.60	138.0314
INDX022011	181.30	191.60	263.10	153.50	134.00	140.0745
INDX032011	179.00	191.40	266.80	157.60	135.60	141.5717
INDX042011	186.80	192.20	303.60	159.50	136.60	143.0643
INDX052011	186.30	183.10	308.90	160.40	137.40	143.1985
INDX062011	188.80	181.10	303.60	161.60	137.90	143.432
INDX072011	192.80	176.20	309.70	165.60	138.00	143.2486
INDX082011	193.70	181.80	301.90	167.10	138.40	143.9156
INDX092011	197.20	184.00	309.30	168.30	139.00	144.7299
INDX102011	199.30	178.40	312.80	170.00	139.60	144.9141
INDX112011	196.50	176.60	322.50	171.60	140.40	145.6486

INDX122011	190.90	179.20	328.70	172.70	140.90	146.3841
INDX012012	191.10	183.10	339.90	177.00	141.50	147.3776
INDX022012	192.40	186.80	348.10	176.70	141.80	148.0401
INDX032012	197.10	189.90	358.80	177.80	142.60	149.1499
INDX042012	207.20	194.90	351.90	178.80	143.80	150.5151
INDX052012	206.10	198.80	344.40	178.90	144.60	151.426
INDX062012	209.40	194.10	326.60	181.10	145.30	151.4658
INDX072012	212.40	199.70	336.50	179.50	146.10	152.7485
INDX082012	211.80	207.40	356.60	181.70	147.20	154.6042
INDX092012	213.10	203.20	352.20	188.50	148.00	154.962
INDX102012	212.70	198.80	339.80	189.80	147.90	154.3708
INDX112012	213.80	201.40	344.70	188.70	148.00	154.7231
INDX122012	211.20	203.50	347.00	190.40	148.00	154.9104
INDX012013	214.70	206.90	353.60	193.40	148.50	155.7106
INDX022013	215.40	206.80	357.80	195.50	148.60	155.854
INDX032013	214.10	207.60	351.80	191.60	148.70	155.9191
INDX042013	219.80	209.70	336.00	193.70	149.10	156.2148
INDX052013	223.10	208.50	320.20	191.90	149.30	156.0849
INDX062013	230.90	209.10	330.90	194.70	149.50	156.4632
INDX072013	238.50	211.10	338.10	199.90	149.90	157.0774
INDX082013	252.40	209.90	363.70	204.70	150.60	157.9903
INDX092013	252.90	213.20	360.40	210.60	151.50	159.0077
INDX102013	251.70	213.00	355.30	209.80	152.10	159.4679
INDX112013	255.90	216.40	352.50	209.60	152.30	159.8612
INDX122013	240.20	215.70	354.60	211.10	152.50	160.0218
INDX012014	233.70	216.40	349.10	212.40	152.90	160.3603
INDX022014	232.50	218.10	351.60	212.60	153.60	161.1595
INDX032014	235.30	217.20	350.90	213.10	153.50	160.9921
INDX042014	238.80	216.30	350.80	211.00	153.80	161.198

**APPENDIX 2: DATA-MONEY SUPPLY**

<b>Time</b>	<b>M1</b>	<b>M2</b>	<b>M3</b>	<b>M4</b>
Jan-00	3,305.41	3379.795	10919.98	11178.59
Feb-00	3,363.98	3438.12	11084.13	11345.02
Mar-00	3,414.61	3490.674	11211.18	11477.97
Apr-00	3,529.70	3608.616	11555.75	11832.09
May-00	3,530.14	3608.269	11576.39	11854.95
Jun-00	3,525.87	3604.282	11673.59	11956.4
Jul-00	3,466.92	3546.492	11774.49	12066.05
Aug-00	3,444.01	3524.95	11843.84	12141.8
Sep-00	3,461.96	3543.88	11967.61	12271.64
Oct-00	3,542.45	3624.98	12205.62	12515.39
Nov-00	3572.07	3655.125	12372.08	12687.5
Dec-00	3615.417	3698.967	12608.42	12928.76
Jan-01	3614.574	3698.674	12753.41	13079.31
Feb-01	3667.715	3751.92	12893.93	13223.26
Mar-01	3779.481	3865.034	13091.65	13427.46
Apr-01	3921.949	4009.874	13485.46	13831.35
May-01	3954.837	4042.527	13653.48	14004.48
Jun-01	3953.331	4041.388	13782.97	14140.05
Jul-01	3904.493	3993.778	13872.2	14239.25
Aug-01	3892.105	3983.635	13961.75	14338.55
Sep-01	3864.729	3957.344	14068.84	14453.69
Oct-01	3912.296	4004.771	14222.04	14613.99
Nov-01	3985.665	4078.492	14342.5	14740.68
Dec-01	4032.023	4125.423	14470.42	14876.64
Jan-02	4011.956	4106.131	14583.34	14996.98

Feb-02	4078.742	4173.442	14709.63	15129.42
Mar-02	4204.719	4301.409	14940.13	15368.34
Apr-02	4360.844	4460.949	15388.73	15830.02
May-02	4402.026	4501.736	15975.84	16421.59
Jun-02	4408.429	4508.234	16073.66	16528.3
Jul-02	4348.412	4449.437	16150.92	16614.73
Aug-02	4309.354	4412.119	16271.57	16744.32
Sep-02	4337.911	4442.161	16404.18	16884.73
Oct-02	4414.712	4520.007	16568.52	17056.94
Nov-02	4472.959	4578.709	16722.25	17217.36
Dec-02	4529.868	4636.513	16798.63	17304.52
Jan-03	4530.931	4638.861	16921.93	17436.95
Feb-03	4636.969	4746.094	17068.66	17596.2
Mar-03	4725.321	4837.015	17184.85	17726.49
Apr-03	4935.922	5050.882	17674.8	18230.38
May-03	4936.404	5050.471	17791.43	18353.41
Jun-03	4982.515	5097.285	17958.33	18534.57
Jul-03	4926.372	5043.017	18063.89	18655.7
Aug-03	4898.473	5017.243	18176.23	18782.27
Sep-03	4929.872	5049.987	18326.18	18943.41
Oct-03	5139.712	5260.892	18524.32	19151.57
Nov-03	5145.464	5268.504	18701.32	19344.28
Dec-03	5258.469	5383.239	18920.5	19577.78
Jan-04	5301.753	5428.118	19232.15	19905.32
Feb-04	5461.481	5589.371	19526.77	20213.34
Mar-04	5706.407	5836.757	19944.54	20643.79
Apr-04	5900.23	6033.72	20493.02	21210.43

May-04	5839.808	5973.218	20564.64	21296.27
Jun-04	5782.365	5916.835	20612.19	21358.82
Jul-04	5720.374	5856.439	20667.24	21429.18
Aug-04	5829.328	5966.933	20798.51	21575.02
Sep-04	5786.135	5924.93	20856.33	21646.47
Oct-04	6005.788	6145.332	21132.56	21933.68
Nov-04	6075.127	6215.562	21150.86	21966.43
Dec-04	6104.597	6246.077	21397.45	22226.26
Jan-05	6162.622	6305.477	21955.23	22797.5
Feb-05	6278.833	6423.223	22180.38	23033.76
Mar-05	6465.396	6613.246	22419.06	23287.01
Apr-05	6798.09	6951.19	23295.67	24185.71
May-05	6737.305	6890.755	23356.1	24261.22
Jun-05	6762.642	6916.712	23424.47	24345.35
Jul-05	6748.032	6904.207	23576.75	24512.98
Aug-05	6892.786	7051.511	23858.48	24809.79
Sep-05	6920.018	7080.248	24264.5	25227.89
Oct-05	7075.305	7237.225	24661.41	25639.74
Nov-05	7170.085	7332.83	24847.11	25838.06
Dec-05	7317.13	7480.395	25100.19	26105.04
Jan-06	7450.029	7613.809	25237.36	26252.52
Feb-06	7689.493	7853.523	25586.87	26606.64
Mar-06	7989.11	8154.364	26443.04	27470.24
Apr-06	8424.776	8592.241	27458.71	28501.8
May-06	8183.522	8350.162	27671.87	28724.63
Jun-06	8120.731	8287.326	27789.08	28854.19
Jul-06	8132.521	8300.401	28209.67	29287.98

Aug-06	8183.053	8352.633	28713.63	29805.75
Sep-06	8317.464	8488.33	29149.71	30252.66
Oct-06	8491.72	8664.525	29327.55	30442.65
Nov-06	8537.36	8711.97	29683.01	30809.2
Dec-06	8686.052	8862.737	30142.12	31280.14
Jan-07	8783.029	8962.754	30601.03	31746.65
Feb-07	9146.277	9328.442	31209	32356.82
Mar-07	9440.527	9624.712	32488.99	33640.76
Apr-07	9348.458	9533.523	33089.61	34245.3
May-07	9259.975	9444.725	33204.73	34363.35
Jun-07	9413.149	9598.654	33756.19	34919.73
Jul-07	9512.669	9699.519	34446.2	35613.44
Aug-07	9392.718	9580.848	34788.01	35956.79
Sep-07	9623.178	9812.428	35393.33	36562.17
Oct-07	9653.948	9843.673	35979.92	37148.76
Nov-07	10107.29	10297.33	36758.22	37927.62
Dec-07	10127.71	10318.98	36957.03	38126.51
Jan-08	10335.91	10528.71	37798.3	38962.16
Feb-08	10727.37	10920.75	38571.45	39725.86
Mar-08	11252.22	11447.34	39732.13	40878.82
Apr-08	11058.13	11255.3	40323.91	41470.65
May-08	11136.27	11333.47	40834.68	41982.82
Jun-08	11123.89	11323.11	41110.56	42263.57
Jul-08	11184.12	11385.86	41525.62	42681.54
Aug-08	11074.6	11277.8	41989.65	43146.1
Sep-08	11303.34	11508.42	42613.22	43768.01
Oct-08	11380.77	11589.14	43431.31	44585.77

Nov-08	11261.61	11471.83	43908.75	45061.74
Dec-08	11238.67	11450.36	44385.34	45536.07
Jan-09	11465.07	11679.35	45398.16	46544.63
Feb-09	11733.44	11951.21	46391.76	47528.94
Mar-09	12391.08	12612.71	47507.5	48644.23
Apr-09	12569.08	12796.25	48914.02	50053.87
May-09	12605.21	12833.26	49454.98	50595.15
Jun-09	12475.12	12704.84	49611.75	50754.59
Jul-09	12545.98	12777	50177.76	51321.65
Aug-09	12806.99	13039.13	50565.38	51707.92
Sep-09	13002.89	13238.77	51066.75	52210.46
Oct-09	13046.72	13286.21	51783.31	52928.19
Nov-09	13084.6	13324.95	52163.83	53308.78
Dec-09	13271.3	13515.66	52506.43	53656.38
Jan-10	13651.87	13900.79	53367.73	54520.53
Feb-10	13845.24	14097.54	54268.85	55419.09
Mar-10	14640.05	14897.51	55738.21	56895.03
Apr-10	14589.01	14855.08	56579.57	57751.59
May-10	14702.46	14970.56	56997.06	58175.18
Jun-10	14854.04	15124.53	57161.63	58346.26
Jul-10	15082.42	15356.55	58148.22	59338.58
Aug-10	14997.45	15276.47	58368.46	59566.76
Sep-10	15109.31	15391.11	58945.35	60148.27
Oct-10	15443.76	15728.22	60354.41	61559.34
Nov-10	15589.15	15875.13	60655.12	61862.62
Dec-10	15577.86	15864.72	61187.7	62397.19
Jan-11	15526.36	15815.66	62324.6	63529.16



Feb-11	15739.37	16030.47	63453.37	64647.28
Mar-11	16266.51	16561.2	64827.19	66019.13
Apr-11	16043.8	16344.55	66444.95	67641.72
May-11	16098.74	16398.76	66638.98	67834.27
Jun-11	15960.27	16263.26	67036.14	68235.84
Jul-11	15954.3	16259.69	68008.27	69210.71
Aug-11	15802.09	16105.17	68442.73	69641.12
Sep-11	15823.08	16126.72	68776.26	69973.13
Oct-11	16040.39	16345.93	69835.02	71033.07
Nov-11	16139.69	16449.14	70344.96	71546.7
Dec-11	16500.18	16814.49	71281.76	72488.61
Jan-12	16747.05	17069.17	71847.9	73062.2
Feb-12	16904.2	17232.05	72453.41	73670.44
Mar-12	17283.43	17616.9	73551.69	74778.07
Apr-12	17600.26	17941.09	75501.99	76747.12
May-12	17532.19	17874.97	75809.64	77066.14
Jun-12	17762.78	18108.81	76943.88	78213.15
Jul-12	17450	17804.01	77643.17	78937.41
Aug-12	17497.43	17860.37	78182.02	79505.95
Sep-12	17426.36	17790.49	78331.98	79662.51
Oct-12	17415.66	17779.8	79225.06	80555.58
Nov-12	17749.57	18115.73	79775.77	81117.17
Dec-12	18065.45	18435.57	80172.41	81529.76
Jan-13	18004.28	18378.82	81133.33	82501.73
Feb-13	18312.11	18690.55	81759.08	83134.65
Mar-13	18749.5	19129.15	83477.27	84859.47
Apr-13	19039.62	19417.01	85199.86	86590.34

May-13	19163.9	19540.13	85750.09	87146.8
Jun-13	19469.11	19846.28	86843.45	88256.69
Jul-13	19151.25	19530.42	87394.79	88823.27
Aug-13	19019.45	19401.05	87582.72	89026.62
Sep-13	19074.77	19459.91	88273.26	89733.81
Oct-13	19261.01	19649.39	90060.94	91537.74
Nov-13	19633.4	20023.92	91353.96	92844.46
Dec-13	19961.71	20357.93	92350.12	93864.56
Jan-14	19956.5	20362.13	92867.97	94401.38
Feb-14	20128.02	20542.67	93549.5	95096.34
Mar-14	20514.01	20933.95	94857.73	96417.58
Apr-14	21134.22	21557.86	96864.43	98436.45

**APPENDIX 3: DATA-OUTPUT GAP**

<b>Time</b>	<b>GapHP</b>	<b>GapBK</b>	<b>GapBW</b>	<b>GapCF</b>
Jan-00	6.477756	NA	3.14E-63	28.37464
Feb-00	5.316711	NA	-9.40E-63	10.0899
Mar-00	11.0244	NA	1.56E-62	4.339655
Apr-00	2.094333	-2.43044	-2.15E-62	-9.07367
May-00	3.348696	0.155535	2.73E-62	-6.26948
Jun-00	0.528652	-1.29515	-3.31E-62	-4.146
Jul-00	0.834361	0.466883	3.88E-62	1.316458
Aug-00	0.949636	1.045328	-4.45E-62	4.322611
Sep-00	1.063734	0.645925	5.02E-62	4.096767
Oct-00	-0.00786	-1.65246	-5.59E-62	0.100355
Nov-00	2.376974	-0.88694	6.16E-62	-1.33731
Dec-00	6.133657	1.472757	-6.72E-62	-0.47731

Jan-01	5.056343	-0.32364	7.30E-62	-2.37153
Feb-01	2.650168	-2.33931	-7.87E-62	-3.40597
Mar-01	8.010001	4.179292	8.43E-62	4.723535
Apr-01	-0.98675	-2.91922	-8.97E-62	-1.2869
May-01	-0.41819	-0.15175	9.50E-62	1.488097
Jun-01	-2.50645	-0.35635	-1.00E-61	0.380921
Jul-01	-2.27801	0.782153	1.05E-61	0.502044
Aug-01	-1.86495	1.259455	-1.11E-61	0.195748
Sep-01	-2.54667	-0.11421	1.16E-61	-1.33412
Oct-01	-2.7603	-1.54687	-1.21E-61	-2.26309
Nov-01	-0.94295	-1.10371	1.26E-61	-1.01389
Dec-01	3.378758	2.056297	-1.31E-61	2.797518
Jan-02	2.814646	0.909175	1.37E-61	1.772479
Feb-02	-0.78817	-2.60297	-1.42E-61	-2.0795
Mar-02	5.312723	4.42451	1.47E-61	4.250435
Apr-02	-3.32644	-2.80047	-1.52E-61	-3.49175
May-02	-2.78373	-0.69198	1.57E-61	-1.44915
Jun-02	-4.7128	-1.26239	-1.62E-61	-1.65218
Jul-02	-2.57679	1.821614	1.66E-61	1.86228
Aug-02	-2.91323	1.5939	-1.71E-61	2.026226
Sep-02	-3.63808	0.102997	1.76E-61	0.684913
Oct-02	-3.33051	-0.95643	-1.80E-61	-0.55629
Nov-02	-3.74347	-2.9233	1.85E-61	-2.89526
Dec-02	2.370544	1.935113	-1.90E-61	1.626999
Jan-03	2.173833	1.16692	1.95E-61	0.763062
Feb-03	-1.53894	-2.12665	-1.99E-61	-2.44199
Mar-03	3.927412	4.471464	2.04E-61	4.545

Apr-03	-6.62867	-4.31145	-2.09E-61	-3.9626
May-03	-4.40591	-0.18944	2.13E-61	0.225156
Jun-03	-6.31592	-0.60865	-2.17E-61	-0.32758
Jul-03	-4.21107	2.100322	2.21E-61	2.237953
Aug-03	-5.33922	0.742043	-2.25E-61	0.664198
Sep-03	-4.77389	0.344322	2.30E-61	0.096893
Oct-03	-5.59421	-1.92157	-2.34E-61	-2.19627
Nov-03	-4.48423	-2.41808	2.38E-61	-2.52998
Dec-03	1.350964	2.146157	-2.42E-61	2.203656
Jan-04	1.537229	1.687988	2.46E-61	1.840396
Feb-04	-2.31476	-2.12352	-2.50E-61	-1.92534
Mar-04	3.295745	4.365661	2.54E-61	4.355761
Apr-04	-5.22189	-2.89907	-2.58E-61	-3.08873
May-04	-4.46639	-0.85396	2.62E-61	-1.14296
Jun-04	-5.9488	-1.47149	-2.65E-61	-1.65192
Jul-04	-2.65812	2.094923	2.69E-61	2.092632
Aug-04	-3.78412	0.516068	-2.72E-61	0.714819
Sep-04	-2.31574	0.942741	2.76E-61	1.220742
Oct-04	-2.65826	-0.80586	-2.79E-61	-0.59981
Nov-04	-3.76927	-3.39852	2.83E-61	-3.34642
Dec-04	3.825646	3.032032	-2.86E-61	2.890717
Jan-05	2.173205	0.767159	2.90E-61	0.559344
Feb-05	-2.99446	-4.15184	-2.94E-61	-4.34996
Mar-05	8.171291	8.015124	2.97E-61	8.04992
Apr-05	-8.02141	-6.38215	-3.00E-61	-6.14095
May-05	-4.90001	-0.98025	3.03E-61	-0.67067
Jun-05	-4.91707	1.277977	-3.06E-61	1.466055

Jul-05	-7.34341	0.398645	3.09E-61	0.467374
Aug-05	-6.59595	1.619407	-3.11E-61	1.5406
Sep-05	-7.20376	0.240221	3.14E-61	0.05258
Oct-05	-5.21289	0.365919	-3.17E-61	0.174689
Nov-05	-8.83605	-5.77259	3.20E-61	-5.80875
Dec-05	2.407699	3.084425	-3.23E-61	3.228864
Jan-06	3.110406	2.314381	3.27E-61	2.488338
Feb-06	-3.88014	-4.92334	-3.30E-61	-4.79298
Mar-06	9.455962	9.559965	3.33E-61	9.457262
Apr-06	-9.37864	-7.28654	-3.35E-61	-7.55641
May-06	-4.35253	-0.06913	3.37E-61	-0.35749
Jun-06	-5.93201	0.086853	-3.39E-61	-0.05895
Jul-06	-3.5071	3.394038	3.41E-61	3.389485
Aug-06	-7.81446	-1.20635	-3.43E-61	-1.08508
Sep-06	-4.87199	0.246047	3.45E-61	0.448864
Oct-06	-6.3396	-3.62941	-3.47E-61	-3.44666
Nov-06	0.5492	0.377888	3.48E-61	0.422642
Dec-06	6.814656	3.729419	-3.50E-61	3.617975
Jan-07	7.936469	2.350086	3.52E-61	2.172764
Feb-07	-0.06709	-7.26625	-3.53E-61	-7.43039
Mar-07	16.03413	8.300513	3.54E-61	8.312618
Apr-07	-1.59106	-8.6217	-3.55E-61	-8.43246
May-07	6.117395	0.801078	3.55E-61	1.071526
Jun-07	5.057117	1.920004	-3.56E-61	2.115775
Jul-07	4.026186	2.622861	3.56E-61	2.744425
Aug-07	1.051	0.320236	-3.56E-61	0.299776
Sep-07	-0.48802	-2.05722	3.56E-61	-2.21618

Oct-07	5.337072	1.425428	-3.57E-61	1.215859
Nov-07	1.634554	-5.59449	3.57E-61	-5.72109
Dec-07	13.54537	2.968146	-3.58E-61	3.008203
Jan-08	14.44658	1.521801	3.59E-61	1.700559
Feb-08	10.36851	-3.22689	-3.59E-61	-2.98369
Mar-08	22.06572	9.688353	3.60E-61	9.839724
Apr-08	1.652999	-8.07105	-3.60E-61	-8.10407
May-08	5.220695	-1.25317	3.60E-61	-1.4556
Jun-08	6.013337	2.519241	-3.59E-61	2.252474
Jul-08	1.107216	-0.2559	3.59E-61	-0.44412
Aug-08	-2.1431	-2.33833	-3.59E-61	-2.34167
Sep-08	3.769104	4.08333	3.59E-61	4.276381
Oct-08	0.555041	1.225209	-3.58E-61	1.515885
Nov-08	-6.75449	-5.49958	3.58E-61	-5.23612
Dec-08	1.096483	3.341073	-3.57E-61	3.43502
Jan-09	-3.58836	-0.09992	3.57E-61	-0.23478
Feb-09	-10.2162	-5.58558	-3.57E-61	-5.85353
Mar-09	4.058217	9.486673	3.57E-61	9.233495
Apr-09	-10.6303	-4.82698	-3.56E-61	-4.91729
May-09	-6.68455	-0.80259	3.55E-61	-0.67114
Jun-09	-5.94241	-0.08057	-3.54E-61	0.199655
Jul-09	-5.6831	0.112683	3.53E-61	0.396353
Aug-09	-3.6888	1.849389	-3.52E-61	1.977815
Sep-09	-2.80199	1.974263	3.51E-61	1.858656
Oct-09	-4.85301	-1.64978	-3.50E-61	-1.96776
Nov-09	-6.68293	-5.90332	3.49E-61	-6.28325
Dec-09	6.52622	4.339038	-3.48E-61	4.113263

Jan-10	7.107632	2.137959	3.48E-61	2.202133
Feb-10	0.357929	-6.31063	-3.47E-61	-6.014
Mar-10	18.67557	12.00212	3.46E-61	12.35464
Apr-10	-0.57929	-5.48309	-3.44E-61	-5.28028
May-10	-2.49801	-4.40198	3.42E-61	-4.47269
Jun-10	-3.09177	-1.79534	-3.40E-61	-2.09435
Jul-10	1.060842	4.644182	3.38E-61	4.284532
Aug-10	-4.72071	-0.6002	-3.36E-61	-0.82083
Sep-10	-1.09061	1.500552	3.34E-61	1.573337
Oct-10	4.6513	4.018629	-3.32E-61	4.355677
Nov-10	-4.49482	-9.26352	3.30E-61	-8.79612
Dec-10	12.57116	3.849663	-3.28E-61	4.188555
Jan-11	12.3494	0.799382	3.27E-61	0.812603
Feb-11	3.939968	-8.74231	-3.26E-61	-9.03994
Mar-11	28.54283	16.61701	3.24E-61	16.21027
Apr-11	1.157919	-8.29276	-3.21E-61	-8.55176
May-11	0.684962	-5.04837	3.18E-61	-5.01797
Jun-11	5.423667	3.843233	-3.15E-61	4.165233
Jul-11	0.773737	2.86897	3.12E-61	3.309744
Aug-11	-5.46516	-1.02987	-3.09E-61	-0.74525
Sep-11	-2.99338	1.801367	3.06E-61	1.734107
Oct-11	-9.41121	-6.47244	-3.03E-61	-6.83405
Nov-11	-0.61894	-1.2268	3.00E-61	-1.70769
Dec-11	11.78323	6.963771	-2.97E-61	6.631253
Jan-12	8.6951	0.370138	2.94E-61	0.364136
Feb-12	5.916379	-3.92538	-2.91E-61	-3.65493
Mar-12	17.94671	9.232017	2.87E-61	9.559495

Apr-12	-5.91432	-11.1075	-2.84E-61	-10.947
May-12	-0.06725	-0.42129	2.79E-61	-0.50253
Jun-12	-2.71257	1.742145	-2.75E-61	1.377803
Jul-12	-3.95079	3.721858	2.71E-61	3.303665
Aug-12	-6.68237	1.797101	-2.66E-61	1.5068
Sep-12	-8.60777	-1.9789	2.62E-61	-1.90576
Oct-12	-0.42737	2.5024	-2.58E-61	2.883029
Nov-12	-6.54151	-8.02599	2.54E-61	-7.4802
Dec-12	6.649491	1.459757	-2.50E-61	1.856767
Jan-13	9.04536	1.892693	2.47E-61	1.892418
Feb-13	2.945773	-4.06943	-2.43E-61	-4.41816
Mar-13	20.65033	15.72588	2.39E-61	15.28797
Apr-13	-7.34138	-8.79584	-2.34E-61	-9.00246
May-13	-8.12993	-5.48338	2.29E-61	-5.31874
Jun-13	-9.51585	-3.02023	-2.24E-61	-2.55333
Jul-13	-3.2996	6.028696	2.19E-61	6.516961
Aug-13	-9.58155	0.902924	-2.13E-61	1.168285
Sep-13	-7.76206	2.052879	2.08E-61	1.870318
Oct-13	-5.94143	1.350555	-2.03E-61	0.898226
Nov-13	-12.2199	-8.34343	1.97E-61	-9.08336
Dec-13	3.402429	3.479312	-1.92E-61	2.870596
Jan-14	7.625394	4.410614	1.87E-61	4.344066
Feb-14	-3.95109	-8.73708	-1.82E-61	-8.44635
Mar-14	16.37281	11.97175	1.77E-61	12.42821
Apr-14	-4.50305	-6.59188	-1.70E-61	-6.30786



**APPENDIX 4: DATA-NON-CORE COMPONENTS OF WPI, INTERNATIONAL ENERGY PRICES**

<b>Time</b>	<b>Food</b>	<b>Energy</b>	<b>IntEnergyP</b>	<b>CoreInflation</b>
Jan-00	86.50	59.85	47.46	81.88
Feb-00	87.08	60.85	50.64	81.85
Mar-00	89.74	65.24	51.39	82.31
Apr-00	91.12	69.16	45.30	82.57
May-00	91.55	69.09	51.36	82.57
Jun-00	92.56	69.34	55.62	82.87
Jul-00	91.33	69.41	53.61	83.51
Aug-00	90.54	69.81	55.80	83.83
Sep-00	90.48	72.38	60.39	84.20
Oct-00	91.87	78.16	59.81	84.59
Nov-00	90.80	78.52	61.34	84.92
Dec-00	89.79	77.77	51.48	85.65
Jan-01	89.10	78.37	52.31	85.72
Feb-01	89.05	79.59	53.42	85.40
Mar-01	89.31	79.51	49.94	85.79
Apr-01	91.87	79.48	51.03	85.83
May-01	92.77	79.44	53.78	85.89
Jun-01	93.73	79.41	52.81	86.03
Jul-01	92.77	79.34	48.70	86.54
Aug-01	93.62	80.69	50.10	86.34
Sep-01	94.26	80.76	48.52	86.17
Oct-01	95.27	82.23	41.25	86.13
Nov-01	95.16	82.30	37.44	86.04
Dec-01	94.79	81.73	36.92	85.90
Jan-02	92.77	81.41	37.58	85.86

Feb-02	93.04	81.12	38.96	85.70
Mar-02	93.46	83.15	45.06	85.81
Apr-02	94.31	82.23	47.93	86.32
May-02	94.15	82.23	48.46	86.67
Jun-02	95.43	83.44	46.38	87.56
Jul-02	94.90	85.08	48.62	87.88
Aug-02	96.33	84.87	49.65	88.82
Sep-02	96.81	85.22	52.34	88.88
Oct-02	96.76	85.97	51.79	88.67
Nov-02	96.92	85.94	47.40	88.88
Dec-02	94.26	85.22	52.53	89.17
Jan-03	93.73	86.30	57.77	89.47
Feb-03	94.74	87.19	62.02	90.25
Mar-03	94.79	90.69	57.35	90.82
Apr-03	95.80	90.72	49.59	91.80
May-03	96.07	88.37	50.55	92.82
Jun-03	98.46	87.83	53.51	92.52
Jul-03	95.85	88.97	54.44	92.71
Aug-03	95.32	89.04	56.27	93.08
Sep-03	97.29	90.86	51.97	93.62
Oct-03	98.83	90.61	55.40	93.72
Nov-03	98.30	91.08	55.84	94.34
Dec-03	95.80	91.76	57.96	94.68
Jan-04	95.96	93.40	60.35	95.60
Feb-04	95.48	93.58	60.34	96.66
Mar-04	94.42	93.72	64.60	96.92
Apr-04	97.50	92.80	65.38	98.50

May-04	98.50	93.00	72.01	99.06
Jun-04	98.80	94.80	69.39	99.03
Jul-04	100.70	96.30	73.40	99.67
Aug-04	103.00	99.20	79.73	100.41
Sep-04	101.10	99.80	78.63	100.53
Oct-04	102.40	99.60	87.84	100.53
Nov-04	105.20	103.80	80.19	100.23
Dec-04	99.40	103.20	75.26	100.11
Jan-05	97.70	105.90	81.68	100.48
Feb-05	97.60	106.40	83.88	100.51
Mar-05	97.90	106.40	94.58	100.89
Apr-05	100.40	107.10	95.06	102.15
May-05	100.30	107.20	90.45	101.80
Jun-05	102.30	108.90	100.11	101.67
Jul-05	106.50	112.20	104.96	101.67
Aug-05	106.20	112.10	114.21	101.80
Sep-05	106.70	115.70	114.72	101.94
Oct-05	109.00	116.60	110.14	102.03
Nov-05	109.90	116.50	103.71	102.15
Dec-05	105.50	116.30	106.51	102.10
Jan-06	106.70	116.10	115.73	102.55
Feb-06	106.10	116.90	111.73	103.04
Mar-06	105.00	117.30	113.64	103.20
Apr-06	106.40	117.60	125.61	105.68
May-06	108.30	118.50	126.57	106.36
Jun-06	111.80	121.50	126.02	106.73
Jul-06	112.20	122.50	132.83	107.57

Aug-06	114.90	122.90	132.01	108.17
Sep-06	118.10	123.60	115.67	108.24
Oct-06	119.80	123.40	108.96	108.55
Nov-06	119.90	122.60	109.79	108.66
Dec-06	117.80	120.30	114.28	109.10
Jan-07	118.90	120.30	102.36	109.35
Feb-07	119.20	119.20	109.21	109.67
Mar-07	118.90	118.60	114.09	110.11
Apr-07	121.50	118.80	121.10	111.97
May-07	122.30	118.90	121.49	111.97
Jun-07	121.80	118.90	126.74	112.21
Jul-07	124.80	119.10	135.17	112.72
Aug-07	126.10	119.50	130.01	112.93
Sep-07	125.50	119.40	140.45	113.15
Oct-07	126.00	119.80	150.53	113.48
Nov-07	125.20	120.80	166.68	113.99
Dec-07	121.60	122.10	164.70	114.33
Jan-08	119.90	122.80	168.58	115.66
Feb-08	122.50	124.00	176.27	116.85
Mar-08	125.60	127.40	188.85	119.04
Apr-08	128.90	130.20	202.30	120.47
May-08	130.20	131.40	226.24	120.81
Jun-08	130.30	141.70	243.39	123.08
Jul-08	133.40	143.20	249.40	123.95
Aug-08	134.40	145.60	217.46	123.83
Sep-08	135.80	144.60	192.02	123.45
Oct-08	140.30	143.10	146.68	122.99

Nov-08	141.10	136.20	113.70	121.71
Dec-08	136.30	129.10	91.55	120.70
Jan-09	137.20	127.20	94.95	120.99
Feb-09	134.10	124.00	89.70	120.70
Mar-09	135.60	123.10	93.64	120.85
Apr-09	140.10	124.20	97.05	121.68
May-09	141.80	124.80	109.78	122.56
Jun-09	145.00	125.70	127.94	122.95
Jul-09	150.40	130.50	119.83	122.84
Aug-09	153.70	131.50	130.44	123.91
Sep-09	154.70	132.90	124.74	124.37
Oct-09	157.80	133.40	134.81	124.63
Nov-09	164.70	134.70	140.82	125.65
Dec-09	164.60	135.00	137.84	126.46
Jan-10	164.90	135.80	143.74	128.59
Feb-10	163.40	136.60	139.30	128.70
Mar-10	163.60	140.10	146.29	129.47
Apr-10	168.80	141.10	155.22	131.31
May-10	172.10	142.80	141.62	131.15
Jun-10	175.40	143.20	140.14	131.32
Jul-10	178.20	147.80	139.75	131.55
Aug-10	176.70	148.00	141.35	131.88
Sep-10	179.90	147.60	141.95	132.70
Oct-10	180.90	148.10	151.33	133.70
Nov-10	181.40	148.60	157.12	134.71
Dec-10	189.40	150.20	167.13	136.07
Jan-11	192.40	151.30	173.30	138.03

Feb-11	181.30	153.50	181.53	140.07
Mar-11	179.00	157.60	198.75	141.57
Apr-11	186.80	159.50	212.57	143.06
May-11	186.30	160.40	199.95	143.20
Jun-11	188.80	161.60	196.65	143.43
Jul-11	192.80	165.60	200.92	143.25
Aug-11	193.70	167.10	189.65	143.92
Sep-11	197.20	168.30	190.45	144.73
Oct-11	199.30	170.00	189.22	144.91
Nov-11	196.50	171.60	197.22	145.65
Dec-11	190.90	172.70	195.28	146.38
Jan-12	191.10	177.00	199.69	147.38
Feb-12	192.40	176.70	208.65	148.04
Mar-12	197.10	177.80	216.98	149.15
Apr-12	207.20	178.80	210.62	150.52
May-12	206.10	178.90	194.23	151.43
Jun-12	209.40	181.10	172.47	151.47
Jul-12	212.40	179.50	181.19	152.75
Aug-12	211.80	181.70	194.79	154.60
Sep-12	213.10	188.50	196.48	154.96
Oct-12	212.70	189.80	191.02	154.37
Nov-12	213.80	188.70	187.80	154.72
Dec-12	211.20	190.40	188.46	154.91
Jan-13	214.70	193.40	194.33	155.71
Feb-13	215.40	195.50	198.68	155.85
Mar-13	214.10	191.60	190.62	155.92
Apr-13	219.80	193.70	184.44	156.21

May-13	223.10	191.90	184.52	156.08
Jun-13	230.90	194.70	184.85	156.46
Jul-13	238.50	199.90	192.26	157.08
Aug-13	252.40	204.70	196.77	157.99
Sep-13	252.90	210.60	198.10	159.01
Oct-13	251.70	209.80	192.95	159.47
Nov-13	255.90	209.60	188.91	159.86
Dec-13	240.20	211.10	194.30	160.02
Jan-14	233.70	212.40	189.04	160.36
Feb-14	232.50	212.60	192.90	161.16
Mar-14	235.30	213.10	190.84	160.99
Apr-14	238.80	211.00	192.18	161.20

**APPENDIX 5: SVAR MODELS WITH DETAILED EQUATIONS**

**Model 1**

$$\begin{aligned}
&Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapHP_t + b_{16}M1_t = \\
&b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
&\gamma_{15}OutputGapHP_{t-1} + \gamma_{16}M1_{t-1} + \epsilon_{(core)t} \quad (1A)
\end{aligned}$$

$$\begin{aligned}
&b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapHP_t + b_{26}M1_t = \\
&b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
&\gamma_{25}OutputGapHP_{t-1} + \gamma_{26}M1_{t-1} + \epsilon_{(food)t} \quad (1B)
\end{aligned}$$

$$\begin{aligned}
&b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapHP_t + b_{36}M1_t = \\
&b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
&\gamma_{35}OutputGapHP_{t-1} + \gamma_{36}M1_{t-1} + \epsilon_{(energy)t} \quad (1C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapHP_t + b_{46}M1_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapHP_{t-1} + \gamma_{46}M1_{t-1} + \epsilon_{(intenergyP)t} \quad (1D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapHP_t + b_{56}M1_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapHP_{t-1} + \gamma_{56}M1_{t-1} + \epsilon_{(outputgapHP)t} \quad (1E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M1_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M1_{t-1} + \epsilon_{(M1)t} \quad (1F)
\end{aligned}$$

## Model 2

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBW_t + b_{16}M1_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBW_{t-1} + \gamma_{16}M1_{t-1} + \epsilon_{(core)t} \quad (2A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBW_t + b_{26}M1_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBW_{t-1} + \gamma_{26}M1_{t-1} + \epsilon_{(food)t} \quad (2B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBW_t + b_{36}M1_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapBW_{t-1} + \gamma_{36}M1_{t-1} + \epsilon_{(energy)t} \quad (2C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBW_t + b_{46}M1_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBW_{t-1} + \gamma_{46}M1_{t-1} + \epsilon_{(intenergyP)t} \quad (2D)
\end{aligned}$$



$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBW_t + b_{56}M1_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBW_{t-1} + \gamma_{56}M1_{t-1} + \epsilon_{(outputgapBW)t} \quad (2E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapBW_t + M1_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapBW_{t-1} + \gamma_{66}M1_{t-1} + \epsilon_{(M1)t} \quad (2F)
\end{aligned}$$

### Model 3

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBK_t + b_{16}M1_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBK_{t-1} + \gamma_{16}M1_{t-1} + \epsilon_{(core)t} \quad (3A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBK_t + b_{26}M1_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBK_{t-1} + \gamma_{26}M1_{t-1} + \epsilon_{(food)t} \quad (3B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBK_t + b_{36}M1_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapBK_{t-1} + \gamma_{36}M1_{t-1} + \epsilon_{(energy)t} \quad (3C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBK_t + b_{46}M1_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBK_{t-1} + \gamma_{46}M1_{t-1} + \epsilon_{(intenergyP)t} \quad (3D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBK_t + b_{56}M1_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBK_{t-1} + \gamma_{56}M1_{t-1} + \epsilon_{(outputgapBK)t} \quad (3E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M1_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M1_{t-1} + \epsilon_{(M1)t} \quad (3F)
\end{aligned}$$

#### Model 4

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapCF_t + b_{16}M1_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapCF_{t-1} + \gamma_{16}M1_{t-1} + \epsilon_{(core)t} \quad (4A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapCF_t + b_{26}M1_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapCF_{t-1} + \gamma_{26}M1_{t-1} + \epsilon_{(food)t} \quad (4B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapCF_t + b_{36}M1_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapCF_{t-1} + \gamma_{36}M1_{t-1} + \epsilon_{(energy)t} \quad (4C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapCF_t + b_{46}M1_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapCF_{t-1} + \gamma_{46}M1_{t-1} + \epsilon_{(intenergyP)t} \quad (4D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapCF_t + b_{56}M1_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapCF_{t-1} + \gamma_{56}M1_{t-1} + \epsilon_{(outputgapCF)t} \quad (4E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapCF_t + M1_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapCF_{t-1} + \gamma_{66}M1_{t-1} + \epsilon_{(M1)t} \quad (4F)
\end{aligned}$$

#### Model 5

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapHP_t + b_{16}M2_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapHP_{t-1} + \gamma_{16}M2_{t-1} + \epsilon_{(core)t} \quad (5A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapHP_t + b_{26}M2_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapHP_{t-1} + \gamma_{26}M2_{t-1} + \epsilon_{(food)t} \quad (5B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapHP_t + b_{36}M2_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapHP_{t-1} + \gamma_{36}M2_{t-1} + \epsilon_{(energy)t} \quad (5C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapHP_t + b_{46}M2_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapHP_{t-1} + \gamma_{46}M2_{t-1} + \epsilon_{(intenergyP)t} \quad (5D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapHP_t + b_{56}M2_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapHP_{t-1} + \gamma_{56}M2_{t-1} + \epsilon_{(outputgapHP)t} \quad (5E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M2_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M2_{t-1} + \epsilon_{(M2)t} \quad (5F)
\end{aligned}$$

## Model 6

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBW_t + b_{16}M2_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBW_{t-1} + \gamma_{16}M2_{t-1} + \epsilon_{(core)t} \quad (6A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBW_t + b_{26}M2_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBW_{t-1} + \gamma_{26}M2_{t-1} + \epsilon_{(food)t} \quad (6B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBW_t + b_{36}M2_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapBW_{t-1} + \gamma_{36}M2_{t-1} + \epsilon_{(energy)t} \quad (6C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBW_t + b_{46}M2_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBW_{t-1} + \gamma_{46}M2_{t-1} + \epsilon_{(intenergyP)t} \quad (6D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBW_t + b_{56}M2_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBW_{t-1} + \gamma_{56}M2_{t-1} + \epsilon_{(outputgapBW)t} \quad (6E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapBW_t + M2_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapBW_{t-1} + \gamma_{66}M2_{t-1} + \epsilon_{(M2)t} \quad (6F)
\end{aligned}$$

### Model 7

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBK_t + b_{16}M2_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBK_{t-1} + \gamma_{16}M2_{t-1} + \epsilon_{(core)t} \quad (7A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBK_t + b_{26}M2_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBK_{t-1} + \gamma_{26}M2_{t-1} + \epsilon_{(food)t} \quad (7B)
\end{aligned}$$

$$b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBK_t + b_{36}M2_t =$$

$$b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} +$$

$$\gamma_{35}OutputGapBK_{t-1} + \gamma_{36}M2_{t-1} + \epsilon_{(energy)t} \quad (7C)$$

$$b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBK_t + b_{46}M2_t =$$

$$b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} +$$

$$\gamma_{45}OutputGapBK_{t-1} + \gamma_{46}M2_{t-1} + \epsilon_{(intenergyP)t} \quad (7D)$$

$$b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBK_t + b_{56}M2_t =$$

$$b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} +$$

$$\gamma_{55}OutputGapBK_{t-1} + \gamma_{56}M2_{t-1} + \epsilon_{(outputgapBK)t} \quad (7E)$$

$$b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M2_t =$$

$$b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} +$$

$$\gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M2_{t-1} + \epsilon_{(M2)t} \quad (7F)$$

### Model 8

$$Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapCF_t + b_{16}M2_t =$$

$$b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} +$$

$$\gamma_{15}OutputGapCF_{t-1} + \gamma_{16}M2_{t-1} + \epsilon_{(core)t} \quad (8A)$$

$$b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapCF_t + b_{26}M2_t =$$

$$b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} +$$

$$\gamma_{25}OutputGapCF_{t-1} + \gamma_{26}M2_{t-1} + \epsilon_{(food)t} \quad (8B)$$

$$b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapCF_t + b_{36}M2_t =$$

$$b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} +$$

$$\gamma_{35}OutputGapCF_{t-1} + \gamma_{36}M2_{t-1} + \epsilon_{(energy)t} \quad (8C)$$

$$b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapCF_t + b_{46}M2_t =$$

$$b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} +$$

$$\gamma_{45}OutputGapCF_{t-1} + \gamma_{46}M2_{t-1} + \epsilon_{(intenergyP)t} \quad (8D)$$

$$b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapCF_t + b_{56}M2_t =$$

$$b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} +$$

$$\gamma_{55}OutputGapCF_{t-1} + \gamma_{56}M2_{t-1} + \epsilon_{(outputgapCF)t} \quad (8E)$$

$$b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapCF_t + M2_t =$$

$$b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} +$$

$$\gamma_{65}OutputGapCF_{t-1} + \gamma_{66}M2_{t-1} + \epsilon_{(M2)t} \quad (8F)$$

### Model 9

$$Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapHP_t + b_{16}M3_t =$$

$$b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} +$$

$$\gamma_{15}OutputGapHP_{t-1} + \gamma_{16}M3_{t-1} + \epsilon_{(core)t} \quad (9A)$$

$$b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapHP_t + b_{26}M3_t =$$

$$b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} +$$

$$\gamma_{25}OutputGapHP_{t-1} + \gamma_{26}M3_{t-1} + \epsilon_{(food)t} \quad (9B)$$

$$b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapHP_t + b_{36}M3_t =$$

$$b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} +$$

$$\gamma_{35}OutputGapHP_{t-1} + \gamma_{36}M3_{t-1} + \epsilon_{(energy)t} \quad (9C)$$

$$b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapHP_t + b_{46}M3_t =$$

$$b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} +$$

$$\gamma_{45}OutputGapHP_{t-1} + \gamma_{46}M3_{t-1} + \epsilon_{(intenergyP)t} \quad (9D)$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapHP_t + b_{56}M3_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapHP_{t-1} + \gamma_{56}M3_{t-1} + \epsilon_{(outputgapHP)t} \quad (9E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M3_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M3_{t-1} + \epsilon_{(M3)t} \quad (9F)
\end{aligned}$$

### Model 10

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBW_t + b_{16}M3_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBW_{t-1} + \gamma_{16}M3_{t-1} + \epsilon_{(core)t} \quad (10A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBW_t + b_{26}M3_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBW_{t-1} + \gamma_{26}M3_{t-1} + \epsilon_{(food)t} \quad (10B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBW_t + b_{36}M3_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapBW_{t-1} + \gamma_{36}M3_{t-1} + \epsilon_{(energy)t} \quad (10C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBW_t + b_{46}M3_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBW_{t-1} + \gamma_{46}M3_{t-1} + \epsilon_{(intenergyP)t} \quad (10D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBW_t + b_{56}M3_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBW_{t-1} + \gamma_{56}M3_{t-1} + \epsilon_{(outputgapBW)t} \quad (10E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapBW_t + M3_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapBW_{t-1} + \gamma_{66}M3_{t-1} + \epsilon_{(M3)t} \quad (10F)
\end{aligned}$$

### Model 11

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBK_t + b_{16}M3_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBK_{t-1} + \gamma_{16}M3_{t-1} + \epsilon_{(core)t} \quad (11A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBK_t + b_{26}M3_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBK_{t-1} + \gamma_{26}M3_{t-1} + \epsilon_{(food)t} \quad (11B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBK_t + b_{36}M3_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapBK_{t-1} + \gamma_{36}M3_{t-1} + \epsilon_{(energy)t} \quad (11C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBK_t + b_{46}M3_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBK_{t-1} + \gamma_{46}M3_{t-1} + \epsilon_{(intenergyP)t} \quad (11D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBK_t + b_{56}M3_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBK_{t-1} + \gamma_{56}M3_{t-1} + \epsilon_{(outputgapBK)t} \quad (11E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M3_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M3_{t-1} + \epsilon_{(M3)t} \quad (11F)
\end{aligned}$$

### Model 12



$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapCF_t + b_{16}M3_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapCF_{t-1} + \gamma_{16}M3_{t-1} + \epsilon_{(core)t} \quad (12A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapCF_t + b_{26}M3_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapCF_{t-1} + \gamma_{26}M3_{t-1} + \epsilon_{(food)t} \quad (12B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapCF_t + b_{36}M3_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapCF_{t-1} + \gamma_{36}M3_{t-1} + \epsilon_{(energy)t} \quad (12C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapCF_t + b_{46}M3_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapCF_{t-1} + \gamma_{46}M3_{t-1} + \epsilon_{(intenergyP)t} \quad (12D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapCF_t + b_{56}M3_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapCF_{t-1} + \gamma_{56}M3_{t-1} + \epsilon_{(outputgapCF)t} \quad (12E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapCF_t + M3_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapCF_{t-1} + \gamma_{66}M3_{t-1} + \epsilon_{(M3)t} \quad (12F)
\end{aligned}$$

### Model 13

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapHP_t + b_{16}M4_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapHP_{t-1} + \gamma_{16}M4_{t-1} + \epsilon_{(core)t} \quad (13A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapHP_t + b_{26}M4_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapHP_{t-1} + \gamma_{26}M4_{t-1} + \epsilon_{(food)t} \quad (13B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapHP_t + b_{36}M4_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapHP_{t-1} + \gamma_{36}M4_{t-1} + \epsilon_{(energy)t} \quad (13C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapHP_t + b_{46}M4_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapHP_{t-1} + \gamma_{46}M4_{t-1} + \epsilon_{(intenergyP)t} \quad (13D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapHP_t + b_{56}M4_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapHP_{t-1} + \gamma_{56}M4_{t-1} + \epsilon_{(outputgapHP)t} \quad (13E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M4_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M4_{t-1} + \epsilon_{(M4)t} \quad (13F)
\end{aligned}$$

#### Model 14

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBW_t + b_{16}M4_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapBW_{t-1} + \gamma_{16}M4_{t-1} + \epsilon_{(core)t} \quad (14A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBW_t + b_{26}M4_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapBW_{t-1} + \gamma_{26}M4_{t-1} + \epsilon_{(food)t} \quad (14B)
\end{aligned}$$

$$b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBW_t + b_{36}M4_t =$$

$$b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} +$$

$$\gamma_{35}OutputGapBW_{t-1} + \gamma_{36}M4_{t-1} + \epsilon_{(energy)t} \quad (14C)$$

$$b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBW_t + b_{46}M4_t =$$

$$b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} +$$

$$\gamma_{45}OutputGapBW_{t-1} + \gamma_{46}M4_{t-1} + \epsilon_{(intenergyP)t} \quad (14D)$$

$$b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBW_t + b_{56}M4_t =$$

$$b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} +$$

$$\gamma_{55}OutputGapBW_{t-1} + \gamma_{56}M4_{t-1} + \epsilon_{(outputgapBW)t} \quad (14E)$$

$$b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapBW_t + M4_t =$$

$$b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} +$$

$$\gamma_{65}OutputGapBW_{t-1} + \gamma_{66}M4_{t-1} + \epsilon_{(M4)t} \quad (14F)$$

### Model 15

$$Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapBK_t + b_{16}M4_t =$$

$$b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} +$$

$$\gamma_{15}OutputGapBK_{t-1} + \gamma_{16}M4_{t-1} + \epsilon_{(core)t} \quad (15A)$$

$$b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapBK_t + b_{26}M4_t =$$

$$b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} +$$

$$\gamma_{25}OutputGapBK_{t-1} + \gamma_{26}M4_{t-1} + \epsilon_{(food)t} \quad (15B)$$

$$b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapBK_t + b_{36}M4_t =$$

$$b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} +$$

$$\gamma_{35}OutputGapBK_{t-1} + \gamma_{36}M4_{t-1} + \epsilon_{(energy)t} \quad (15C)$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapBK_t + b_{46}M4_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapBK_{t-1} + \gamma_{46}M4_{t-1} + \epsilon_{(intenergyP)t} \quad (15D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapBK_t + b_{56}M4_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapBK_{t-1} + \gamma_{56}M4_{t-1} + \epsilon_{(outputgapBK)t} \quad (15E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapHP_t + M4_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapHP_{t-1} + \gamma_{66}M4_{t-1} + \epsilon_{(M4)t} \quad (15F)
\end{aligned}$$

### Model 16

$$\begin{aligned}
& Core_t + b_{12}Food_t + b_{13}Energy_t + b_{14}IntEnergyP_t + b_{15}OutputGapCF_t + b_{16}M4_t = \\
& b_{10} + \gamma_{11}Core_{t-1} + \gamma_{12}Food_{t-1} + \gamma_{13}Energy_{t-1} + \gamma_{14}IntEnergy_{t-1} + \\
& \gamma_{15}OutputGapCF_{t-1} + \gamma_{16}M4_{t-1} + \epsilon_{(core)t} \quad (16A)
\end{aligned}$$

$$\begin{aligned}
& b_{21}Core_t + Food_t + b_{23}Energy_t + b_{24}IntEnergyP_t + b_{25}OutputGapCF_t + b_{26}M4_t = \\
& b_{20} + \gamma_{21}Core_{t-1} + \gamma_{22}Food_{t-1} + \gamma_{23}Energy_{t-1} + \gamma_{24}IntEnergy_{t-1} + \\
& \gamma_{25}OutputGapCF_{t-1} + \gamma_{26}M4_{t-1} + \epsilon_{(food)t} \quad (16B)
\end{aligned}$$

$$\begin{aligned}
& b_{31}Core_t + b_{32}Food_t + Energy_t + b_{34}IntEnergyP_t + b_{35}OutputGapCF_t + b_{36}M4_t = \\
& b_{30} + \gamma_{31}Core_{t-1} + \gamma_{32}Food_{t-1} + \gamma_{33}Energy_{t-1} + \gamma_{34}IntEnergy_{t-1} + \\
& \gamma_{35}OutputGapCF_{t-1} + \gamma_{36}M4_{t-1} + \epsilon_{(energy)t} \quad (16C)
\end{aligned}$$

$$\begin{aligned}
& b_{41}Core_t + b_{42}Food_t + b_{43}Energy_t + IntEnergyP_t + b_{45}OutputGapCF_t + b_{46}M4_t = \\
& b_{40} + \gamma_{41}Core_{t-1} + \gamma_{42}Food_{t-1} + \gamma_{43}Energy_{t-1} + \gamma_{44}IntEnergy_{t-1} + \\
& \gamma_{45}OutputGapCF_{t-1} + \gamma_{46}M4_{t-1} + \epsilon_{(intenergyP)t} \quad (16D)
\end{aligned}$$

$$\begin{aligned}
& b_{51}Core_t + b_{52}Food_t + b_{53}Energy_t + b_{54}IntEnergyP_t + OutputGapCF_t + b_{56}M4_t = \\
& b_{50} + \gamma_{51}Core_{t-1} + \gamma_{52}Food_{t-1} + \gamma_{53}Energy_{t-1} + \gamma_{54}IntEnergy_{t-1} + \\
& \gamma_{55}OutputGapCF_{t-1} + \gamma_{56}M4_{t-1} + \epsilon_{(outputgapCF)t} \quad (16E)
\end{aligned}$$

$$\begin{aligned}
& b_{61}Core_t + b_{62}Food_t + b_{63}Energy_t + b_{64}IntEnergyP_t + b_{65}OutputGapCF_t + M4_t = \\
& b_{60} + \gamma_{61}Core_{t-1} + \gamma_{62}Food_{t-1} + \gamma_{63}Energy_{t-1} + \gamma_{64}IntEnergy_{t-1} + \\
& \gamma_{65}OutputGapCF_{t-1} + \gamma_{66}M4_{t-1} + \epsilon_{(M4)t} \quad (16F)
\end{aligned}$$