**Inflation Volatility of Advanced and Developing Economies:**

**A New Keynesian Perspective**

Shesadri Banerjee**[[1]](#footnote-2)\***

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**ABSTRACT**

Empirical regularities show that inflation in developing countries is highly volatile in nature, compared to the advanced countries. Frequency domain analysis confirms robustness of this stylized fact for a sample of thirty countries. Given the stylized fact and its potential welfare consequences, the paper intends to study the striking difference in inflation volatility between advanced and developing economies which lacks attention so far. Introducing a two-sector New Keynesian model (Gali, 2002, 2008, 2009) of food and non-food, premised over composite consumption and labour index, heterogeneous Calvo type price adjustment and interest rate rule with exogenous shocks, study shows that demand side disturbances are the fundamental forces for greater inflation volatility in developing countries. Simulation analysis reveals that inflation targeting coefficient, nominal frictions and preferential bias are the determining factors for greater volatility in developing economies.

**JEL classification:** E31, E32, E37, E52

**Keywords:** Inflation volatility, Cyclical Components, New Keynesian Phillips Curve, Preferential bias

**Introduction**

The behaviour of macroeconomic variables has received considerable attention in the literature and inflation is no exception of this trend. Empirical regularities underline the fact that inflation volatility in developing countries is substantially higher than the developed countries. Exploring the inflation regularities by cyclical attributes recurring at various frequencies using the Christiano and Fitzgerald (2003) method of symmetric type band pass frequency filter, it is shown that over the medium term cycle across the different frequency bands inflation volatility is statistically significantly greater for developing economies than the advanced economies. This observation stands robust for analytical group data and country wise data of advanced and developing blocks over the sample period of 1968, First Quarter to 2011, Second Quarter.

This striking feature of inflation dynamics in developing countries lacks attention in the existing literature. Indeed, extensive research is done on inflation dynamics addressing the level of inflation or inflation persistence, while less emphasis is given to its second order behaviour. Moreover, existing studies on inflation volatility are done typically for the advanced countries and very few are available which critically analyze the same for the developing countries. Besides, works available in the relevant literature fail to shed light on the fundamental sources or the structural factors of inflation volatility. To fill this gap in the literature, this paper attempts to explain the stylized fact by theorizing food and non-food inflation as the key constituents of aggregate inflation from New Keynesian perspective.

Using a two sector sticky price model of food and non-food, premised over composite consumption and labour index, the dynamic IS equations and inflation equations are derived for individual sectors and aggregate level. A simple Taylor type interest rate rule is taken as the stand of monetary authority. The structural shocks, namely, preference shock and productivity shock and monetary shock as the policy shock are introduced to study the transmission mechanism. It is demonstrated that the generalized New Keynesian Phillips curve for aggregate inflation is characterized by heterogeneous nominal rigidity associated with output gap across the sectors. Calibrating the baseline model, it is observed that demand disturbances are the fundamental force for inflation volatility. From numerical simulation of structural and policy parameters, further, it is found that lack of inflation targeting in the policy framework, frequency of price adjustment and preferential bias are the potential factors responsible for greater inflation volatility in developing economies.

The rest of this paper is composed by a number of sections and sub-sections. In Section 2, empirical facts, figures and welfare consequences of inflation volatility are discussed. Section 3 provides the motivation behind the theoretical model. In Section 4, Two Sector New Keynesian model is illustrated. In Section 5, the calibration of baseline model is described. Finally, Section 6 provides conclusion of the paper with the key observations and future directions of research.

**2. Fact, Figures and Consequences of Inflation Volatility**

**2.1 Stylized Fact of Inflation Volatility: An Evaluation by Frequency Domain Analysis**

Lucas (1977) has described the ‘stylized fact’s as the statistical properties of the movements of the deviations from trend. Following this notion, frequency domain analysis is deployed to unveil the stylized fact on inflation volatility from the angle of cyclical component. The frequency domain analysis provides a deeper insight into the structure, cyclical actions and amplitude of fluctuations of inflation in different time scales (Poměnkova & Maršalek, 2011). Using the quarterly CPI inflation data during the period of Q1, 1968 to Q2, 2011, the medium term business cycle component has been extracted as a “synchronized choice between short run fluctuations to long run oscillations” (Comin & Gertler, 2006). Motivation behind this exercise is to identify the volatility embedded in the persistent fluctuations of inflation emerging from the business cycle phenomenon. Given the span of sample period, following Basu, P., et al. (2012), the medium term fluctuation is defined by the periodicity of 2 to 100 quarters. Since the actions taken by the agents in an economy have different ‘term objectives’ associated with different time horizon, the extracted medium term cycle of the concerned series contains data of different frequencies. Therefore, it is important to decompose the medium term cycle into different frequency bands and expose the heterogeneity of volatility across the frequencies. The medium term cycle is decomposed into three different bands of frequency, viz. high frequency with the periodicity of 2 to 6 quarters, standard business cycle frequency with the periodicity of 6 to 32 quarters and low frequency with the periodicity of 32 to 100 quarters.

Extraction of medium term business cycle and its segregation into different frequencies are done by using the Christiano and Fitzgerald (2003) method of symmetric type band pass frequency filter. A brief outline of the CF filter methodology is provided in the Appendix A.1. This analysis is run on the aggregate CPI inflation data of two analytical groups as well as each of the thirty countries chosen in the samples of advanced and developing groups. First, the movements of inflation for analytical group data at original series, medium term cycle, high frequency, standard business cycle and low frequency are depicted in Figure 1 (A to E) respectively. Thereafter, observations on volatility are summarized in Table: 1 (A, B, C & D). From Figure 1, one can easily identify that the trajectory of inflation is remarkably different between developed and developing countries. Almost for the entire the sample period, inflation remains higher for the developing and emerging countries than advanced group. No matter whether we look at the original series or cyclical components or different frequency bands, incidence of high spikes of the shocks, amplitude of fluctuations and their persistent behaviour confers the distinguishing feature for inflationary process in developing economies. A closer look further discloses that such idiosyncrasies have intensified particularly during the period of 1980’s to 2005. This observation underscores that inflation variability is substantially greater for the developing economies that it’s advanced neighbours.

**Figure1A**

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**Figure1B**

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**Figure1C**

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**Figure1D**

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**Figure1E**

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The primary observation based on eyeballing through Figure 1 (A to E) gains support from the conventional statistical tests. Applying the tools of descriptive statistics, inflation volatility is defined by instantaneous standard deviation and computed from the filtered inflation series of the advanced and developing countries data. Then, the null hypothesis of equal inflation variance is tested against the alternative of higher inflation variability for developing countries. The test is done by standard F-test procedure. Comparing the computed F-statistic with its theoretical value, it is found that null hypothesis can be rejected in all cases at 1% level of significance. This re-emphasizes the fact that inflation variability is statistically significantly higher in the developing countries than the developed countries, both at different data frequencies and for medium term cycle. In Table 1 (A to D), values of inflation volatility are enumerated corresponding to different cyclical components and frequency bands followed by the calculated F-test statistic for analytical group data and for the individual samples of advanced and developing countries.

**Table: 1A**

|  |
| --- |
| Comparison of Inflation Volatility from Analytical Group Level Data |
| Data Frequency | Adv | Dev | Observations | Computed F- statistic |
| Medium term Cycle | 0.0074 | 0.0217 | 149 | 0.116\*\* |
| High | 0.0046 | 0.0147 | 149 | 0.098\*\* |
| Business Cycle | 0.0037 | 0.0135 | 149 | 0.075\*\* |
| Low | 0.0045 | 0.0054 | 149 | 0.694\*\* |

*Note: Computed F-statistic, significant at 1% level are given by ‘\*\*’*[[2]](#footnote-3)*.*

**Table: 1B**

|  |
| --- |
| Sample of Advanced Countries: Inflation Volatility from Frequency Filter |
| Countries | Observations | Medium Term Cycle | High Frequency | Business Cycle Frequency | Low Frequency |
| Austria | 149 | 0.0066 | 0.0054 | 0.0025 | 0.0030 |
| Australia | 149 | 0.0091 | 0.0058 | 0.0048 | 0.0055 |
| Belgium | 149 | 0.0064 | 0.0034 | 0.0035 | 0.0041 |
| Canada | 149 | 0.0067 | 0.0039 | 0.0034 | 0.0046 |
| Denmark | 149 | 0.0088 | 0.0062 | 0.0041 | 0.0054 |
| Finland | 149 | 0.0087 | 0.0048 | 0.0039 | 0.0065 |
| France | 149 | 0.0067 | 0.0029 | 0.0033 | 0.0059 |
| Germany | 57 | 0.0034 | 0.0030 | 0.0016 | 0.0005 |
| Italy | 149 | 0.0102 | 0.0044 | 0.0056 | 0.0083 |
| Japan | 149 | 0.0105 | 0.0074 | 0.0067 | 0.0057 |
| Norway | 149 | 0.0082 | 0.0057 | 0.0041 | 0.0049 |
| New Zealand | 149 | 0.0110 | 0.0055 | 0.0068 | 0.0076 |
| Switzerland | 149 | 0.0069 | 0.0050 | 0.0032 | 0.0031 |
| UK | 69 | 0.0068 | 0.0059 | 0.0021 | 0.0016 |
| US | 149 | 0.0065 | 0.0037 | 0.0040 | 0.0037 |

**Table: 1C**

|  |
| --- |
| Sample of Developing Countries: Inflation Volatility from Frequency Filter  |
| Countries | Observations | Medium Term Cycle | High Frequency | Business Cycle Frequency | Low Frequency |
| Bangladesh | 47 | 0.0128 | 0.0111 | 0.0051 | 0.0023 |
| Cambodia | 42 | 0.0258 | 0.018 | 0.0165 | 0.0046 |
| China | 98 | 0.0090 | 0.0047 | 0.0046 | 0.0068 |
| Fiji | 144 | 0.0133 | 0.0115 | 0.0066 | 0.0051 |
| India | 149 | 0.0217 | 0.0158 | 0.0131 | 0.0037 |
| Indonesia | 149 | 0.031 | 0.0177 | 0.0229 | 0.0073 |
| Malaysia | 149 | 0.0093 | 0.0054 | 0.0063 | 0.003 |
| Myanmar | 141 | 0.0466 | 0.0326 | 0.0308 | 0.0124 |
| Nepal | 148 | 0.0307 | 0.0274 | 0.0121 | 0.0036 |
| Pakistan | 149 | 0.0187 | 0.0136 | 0.0104 | 0.0053 |
| Philippines | 149 | 0.025 | 0.0128 | 0.0198 | 0.007 |
| Papua New Guinea | 135 | 0.0195 | 0.0151 | 0.0103 | 0.0042 |
| Srilanka | 148 | 0.0199 | 0.0135 | 0.0131 | 0.0043 |
| Thailand | 149 | 0.0133 | 0.0073 | 0.0092 | 0.0049 |
| Vietnam | 41 | 0.019 | 0.0116 | 0.012 | 0.0056 |

**Table: 1D**

|  |
| --- |
| Inflation Volatility Obtained from Pooled Standard Deviation based on Sample |
| Data Frequency | Advanced Countries  | Developing Countries | Computed F- statistic |
| Medium Run | 0.0082 | 0.0238 | 0.119\*\* |
| High  | 0.0051 | 0.0167 | 0.092\*\* |
| Business Cycle  | 0.0044 | 0.0151 | 0.084\*\* |
| Low  | 0.0053 | 0.006 | 0.789\*\* |

*Note: Computed F-statistic, significant at 1% level are given by ‘\*\*’*[[3]](#footnote-4)*.*

**2.2 Economic Consequences of Inflation Volatility: Evidence from Literature**

Scholars, economists and policymakers have unanimously recognized the adverse economic consequences of inflation and documented in details how inflation can tax an economy by eroding the purchasing power, jolting the economic growth and depreciating the societal welfare. While the inflationary consequences have received considerable attention from the researchers, relatively less effort has been given to study the upshots of inflation variability. Nevertheless, evidences are available in the literature revealing the facts of distressful effects of volatile inflation.

Literature suggests that volatile inflation creates uncertainty in the economy. Often, inflation volatility is treated synonymously with inflation uncertainty. Lucas (1973) argued that increased inflation uncertainty accentuates firm’s real responses to observed price variation and worsens the trade-off between output and inflation. According to Friedman (1977), inflation volatility leaves the economy in a less efficient state by adding frictions in the markets. It produces a wedge between relative prices prevailing in the economy and those which would have been determined solely by market forces in the absence of inflation volatility. Moreover, if nominal rigidities are in place, volatile inflation can generate greater uncertainty about the relative price of final goods and input costs. This leads to misallocation of resources and finally impairs the economic growth.

Ragan (1994) has argued that inflation volatility would exert its negative impact on the real activities by raising the cost of financial intermediation. It is also noticed that inﬂation volatility can alter the nominal returns of assets and induce portfolio adjustment for optimizing individuals. Such adjustments can be costly in terms of economic growth and welfare effects. Using a general equilibrium model, Dibooglu & Kenc (2009) studied the growth and welfare effects of variances and found that a substantial welfare gain is possible if inﬂation is stabilized at the socially optimum level. Fisher (2011) showed that during the periods of highly volatile inflation, investment in fixed asset declines. One percentage point increase in inflation uncertainty is associated with a reduction in fixed asset investment of between 15% and 37% relative to the mean.

In sum, evidences indicate that high volatility of inflation set out a systemic risk which has nontrivial and problematic consequences for economic welfare. Such theoretical conjecture regarding the effects of volatile inflation can be well supported by the empirical evidences from Froyen and Waud (1987), Holland (1993), Al-Marhubi (1998), Judson and Orphanides (1999), Fatás and Mihov (2005), Grier and Grier (2006). All of these studies conclude that greater volatility of inflation can depress the economic growth.

**2.3 Welfare Cost of Inflation Volatility: An Assessment by Welfare Loss Function**

In this context, it would be worthy to look at the welfare cost of volatile inflation for advanced and developing economies. Given the static measure of inflation variance over the medium term cycle given in Table 1A, instrumenting the standard loss function of a central bank proposed by Gali (2008, pp. 82), the average welfare loss per period can be assessed and compared between two groups of economies. The loss function is defined in equation (i) as:

 ……………….. (i)

Where, and are the relative weights of output gap and inflation variance in the above function. Clearly, the coefficient of inflation variance, i.e. , is our concern to compute the welfare cost. According to Gali (2008), the coefficient of inflation variance is expressed as a function of different structural parameters and defined as:

 ………….. (ii)

**Table: 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Countries | Structural Parameters |  |  | Welfare Cost |
|  |  |  |  |
| Advanced | 0.99 | 0.42 | 7.17 | 0.67 | 5.1 | 5.5E-05 | 2.8E-04 |
| Developing | 0.98 | 0.33 | 7.01 | 0.57 | 4.08 | 4.7E-04 | 1.9E-03 |

The definition and estimates of the structural parameters constituting are taken from the existing Dynamic Stochastic General Equilibrium literature (Gabrial, V., et al., 2011) and given in Table 2. On the basis of these estimates, is calculated for both set of countries and their respective welfare cost. From Table 2, it appears that even the coefficient of inflation variance is lower, due to greater magnitude of inflation volatility developing countries are incurring greater welfare cost. In comparison to the advanced group, the welfare cost of inflation volatility is nearly seven times larger for the emerging economies. This measure of welfare cost indicates the severity of inflation volatility as a major economic problem and calls for further research on this issue.

Starting from Engle (1982, 1983) several instances are available on modeling inflation volatility for the advanced countries like UK and US. Some of them are e.g. Bruner and Hess (1993) for US CPI data, Grier and Perry (1998) for G7 countries, Kontonikas (2004) for UK, etc. In contrast, few studies are on hand for developing economies, such as Della Mea and Pena (1996) for Uruguay, Grier and Grier (1998) for Mexican Inflation, Magendzo (1998) for Inflation in Chile etc. These studies, however, overlooked the striking difference in inflation variability in two types of economies. Besides, the studies did not pay necessary attention to the fundamental sources of this problem. According to Fielding (2008), “While studies on the determinants of inflation are abundant in the literature, scholars have not yet extensively investigated the causes of inflation volatility - surprisingly so, given its potential ill effects on growth”. The stylized fact that inflation volatility is remarkably different between developed and developing countries[[4]](#footnote-5), has not been treated seriously, neither empirically nor theoretically. Therefore, this paper intends to investigate *why inflation is more volatile in the developing countries than the developed countries?* *Is this because of structural factors or inability of monetary policy to stabilize the economy or both?* The paper seeks answer to these questions using a two sector New Keynesian model.

**3. Motivations for Theoretical Model**

**3.1 Inflation and New Keynesian Paradigm**

Since early 1980’s, New Keynesian theory has started to emerge as a new class of models that aims to appraise the relationship between inflation, business cycle and monetary policy rules in macroeconomic research[[5]](#footnote-6). This new generation models are based on dynamic stochastic general equilibrium framework, characterized by imperfect competition and nominal rigidities, and micro-founded with rational expectations. Following the optimization behavior of consumers and firms, the equilibrium conditions for aggregate variables are derived. In recent years, this trend of research has received a broad academic consensus on the use of *New-Keynesian Phillips Curve* (NKPC) to study the dynamics of inflation. NKPC considers the output gap derived from the real marginal cost and forward looking expectation as the key driving force of underlying fluctuations in inflation (Christiano, Eichenbaum and Evans, 2005; Gali, 2008, 2009).

 **3.1.1. Real Marginal Cost, Output Gap and Inflation:**

The concept of output gap, which is derived from the real marginal cost, occupies the central role in the new optimizing sticky price models as the driving force for underlying fluctuations of inflation. Essentially, the coefficient of real marginal cost constructed on several structural parameters captures the inherited inflation persistence that propels the inflation process, outside of the nominal price setting practice. Previously, the traditional models of Phillips curve which were keen to find some empirical support for inflation-output gap relation, were naïve due to their ad-hoc and mostly a-theoretical nature. In the new paradigm, however, the output gap has a specific meaning: it is the deviation of output from its equilibrium level in absence of nominal rigidities. Under some assumptions on technology and preferences, it is possible to measure the output gap that is theoretically comprehensive. The benefits of using output gap as the source of inflationary pressure are of two folds. First, if inflation is induced by non-monetary factors such as supply shocks, the natural level of output will alter and change the output gap subsequently. Second, if there is a dominant role of demand side factors, the actual output will deviate from its natural level and the transmission mechanism can be captured in the inflation process. Therefore, it appears that the standard output gap model of NKPC provide an improvised theoretical explanation of inflation fluctuations (Domaç & Yücel, 2003; Dua, 2009).

**3.1.2. Nature of Expectation and Inflation:**

Comparing the traditional or neo-classical expectation augmented Phillips curve with NKPC, the main difference lies in the nature of expectation, i.e. forward looking expectation. Such difference has crucial implication. Under rational expectation, future expected inflation can differ from the actual inflation which can make a wedge between actual output and the natural level of output and therefore leaves room for active policy intervention. In NK models, firm’s price setting behavior is subject to future expectations on cost and demand conditions. As consequence of current pricing decisions of firm, the aggregate price level changes and generates inflation which contains forward looking component. This property is expressed through formal presentation of NKPC. It is evident from the works of Gali and Gertler (1999), Gali, Gertler and Lopez-Salido (2001, 2005) and Sbordone (2002, 2005) that when the coefficient of real marginal costs becomes more significant the NKPC tends to become more forward looking. This is consistent with the idea that if inflation dynamics is not intrinsic to the model but driven largely by marginal costs, then expectations about future prices should matter more (Bratsiotis & Robinson, 2009).

**3.1.3. Evidence for Relation between Inflation and Output gap**

There is abundance of evidence in favour of inflation and output gap relation as explained by NKPC for different developed countries like US, UK, Euro areas, Australia etc, mainly at the aggregate level and partly for the disaggregated level of the economy. In particular, it is almost customary to analyze the inflation by output gap with some form of Phillips curve relation for developed economies. This underlines the fact that in case of developed economies movement of inflation can be predicted from the movement of output gap. However, the scenario is quite different in the case developing countries and indeed, it is relatively difficult to find the inflation and output gap relation for these economies. This can probably be attributed to the idiosyncratic traits of the developing economies as against the developed economies. One line of argument emphasizes the role of different supply side shocks. Due to dominance of supply shocks, often inflation and output gap trade off are obscured. Yet, if the years of supply shocks are adjusted in the dataset, the usual relation of inflation and output gap can be obtained. Another explanation is that developing countries have relatively underdeveloped financial markets and therefore the relationship between interest rates and aggregate demand is weak (Dua, 2009).

Restricting the discussion within the periphery of developing South-East Asian countries, it can be observed that output gap models of inflation are less commonly applied and the results are mixed. Coe andMcDermott (1997) in their study of output gap model in Asia found that this model did not work well for Thailand, China and India. However, Bhanthumnavin (2002) in case of Thailand, Paul (2009) and Majumdar (2011) for India, and Funke (2006) for China have obtained the support for this relation. Dua (2009) has estimated the traditional Phillips curve specification for South-East Asia, have found a positive relationship between inflation and output gap.

**3.1.4. Nominal rigidities and Inflation:**

Following the inception of rational expectations in the literature, macroeconomic research has been focused on investigating micro foundations of macroeconomic theory to elucidate the transmission channels of monetary policy. For this purpose, New Keynesian macroeconomists have instrumented the assumption of nominal rigidity with explicit modeling on optimal behaviour of individuals and firms (Rotemberg & Woodford, 1997; McCallum and Nelson, 1999; Woodford, 2003). In order to have real effects on monetary policy in the short run, New Keynesian models heavily rely on nominal frictions such as price or wage stickiness. This provides a clear demarcation between NK models and classical monetary frameworks in explaining the behavior of inflation. In the NK model, the transmission of monetary policy shocks to real variables works through the conventional interest rate channel. Many New Keynesian authors, including Taylor (1980) and Mankiw (1990), have pointed out that nominal disturbances can have effects on real economic activity if prices are sticky and output is demand-determined. In addition to being a source of monetary non-neutralities, the presence of sticky prices may also have strong implications for the economy’s response to non- monetary shocks. The economic agents, although optimize rationally their wage-setting and price making decision inter-temporally, are not able to adjust wages and prices immediately as shocks occur due to presence of nominal rigidities within the economy. These rigidities give rise to the trade-off between inflation and excess demand in the short run, which allows monetary policy to affect real variables (Dua, 2009). The inﬂation is more responsive to departures of output from its natural level if the current price level becomes less sticky. Thus, in the formal expression of NKPC, the index of price stickiness appears as a crucial parameter, associated to the output gap and reveals the response of the economy on the face of structural or policy shocks.

**3.1.5 Evidence for Micro Level Price Stickiness**

There are convincing empirical evidences for price stickiness based on both aggregated data and micro level data. The results although vary depending on the assumptions used and the methodology employed, nevertheless the presence of nominal rigidity and therefore, the sluggish adjustment in price setting behaviour is recognized in the literature. Under a wide range of identifying assumptions, Christiano, Eichenbaum and Evans (1999) found, that following an unexpected monetary policy tightening, aggregate price indices remain unchanged for about a year and a half and start declining thereafter. Bills and Klenow (2002) showed that the median duration for a price change was only 4.3 months. From micro-data analysis, Dhyne et al. (2005) has documented the average monthly frequency of price adjustment is 15% for Euro area, which clearly suggests that prices are more rigid in the euro area than US. All of these works suggest that a sizeable fraction of prices remain constant for many months. For developing economies, limited numbers of studies are available on price stickiness. A case study work is done for Sierra Leone by Kovanen (2006). Morandey and Tejada (2008) found similar evidence for Latin American countries. They observed that prices in these economies were maintained fixed for a period of approximately three months. In case of Pakistan, a micro level study is done by Malik, Satti and Sagir (2010) who have found that firms are changing their price once in a year. Further, it is observed that stickiness can be heterogeneous across the sectors within an economy. Examples can be found in Dhyne et al. (2005), Morandey and Tejada (2008). Such empirical features of heterogeneity in price stickiness need to be incorporated in a fully specified DSGE models.

**3.2 Economy - as a Composition of Food and Non-food Sector**

In this paper, the economy is viewed as a composition of food and non-food sector. There are different approaches to build a two sector model where the sectors are defined in various ways, such as tradable - non tradable, durable - non durable, formal - informal, domestic - export sector etc and such instances are available in New Keynesian framework. However, there are few reasons to consider the economy as a composition of food and non-food sectors.

Firstly, food takes up a considerable share in composition of CPI for all the developing countries, specifically in Asia compared with other regions. This share is comparatively larger than that of advanced countries. The share of food consumption in the emerging Asian CPI basket varies between forty to sixty percent. In India and Indonesia, the CPI share of food is higher than the Asian average (Arora & Cardarelli, 2010). Supporting evidences are provided in Table: 3. While the average share of expenditure on food consumption is around 21% for the advanced countries, it remains more than 50% for the developing countries.

**Table: 3**

|  |  |  |  |
| --- | --- | --- | --- |
| **Advanced Countries** | **Share of Expenditure****on Food (%)** | **Developing Countries** | **Share of Expenditure****on Food (%)** |
| Australia | 21.69 | Bangladesh | 59.24 |
| Austria | 20.02 | Cambodia | 63.45 |
| Belgium | 20.58 | China | 45.92 |
| Canada | 21.48 | India | 56.75 |
| Denmark | 18.39 | Indonesia | 52.90 |
| Finland | 21.31 | Malaysia | 37.10 |
| France | 20.23 | Myanmar | 72.63 |
| Germany | 19.35 | Nepal | 54.00 |
| Italy | 27.05 | Pakistan | 46.21 |
| Japan | 28.80 | Philippines | 49.28 |
| New Zealand | 19.20 | Sri Lanka | 53.68 |
| Norway | 18.58 | Thailand | 39.67 |
| Switzerland | 21.89 | Viet Nam | 51.08 |
| UK | 22.55 | Lao's People's Democratic | 56.30 |
| US | 16.05 | Fiji | 39.75 |
| **Overall Average** | **21.14** | **Overall Average** | **51.86** |

Moreover, in addition to the dominance in CPI basket, food price inflation is significantly variable than that of non-food items owing to the influence of natural factors. In Figure: 2, the coefficient of variation is plotted for food and non-food inflation for advanced and developing economies, over a sample of thirteen countries in each group. It is evident from the plot that food inflation is considerably volatile than non-food inflation. From Figure 2, it is apparent that irrespective of economy, twenty one countries out of twenty six are subjected to greater inflation variability in the food sector.

**Figure 2: Coefficient of Variation of Food & Non-food Inflation**

*Source: ILO Database & Author’s Calculation*

Looking into the variability further it is observed that variance of aggregate inflation and food price inflation; both of them are highly correlated with value of 0.96 which is statistically significant at 0.1% level for developing countries. Interesting to note that such correlation takes the value of 0.48 with significance level at 10% for advanced economies. Intuitively, it appears that structural idiosyncrasies of developing economies would be responsible to transmit the exogenous shocks impinging on food sector across the economy and exacerbate inflationary fluctuations at the aggregate level.

Mohanty and Klau (2001), who studied the experience of 14 emerging market economies in the 1980s and 1990s, found that exogenous supply shocks, in particular those to food prices, play an important role in the inflation process. Thus, the movement of food price inflation, not only can affect short-run inflation according to their high weight in CPI, but also produce a sustained increase in the inflation rate via inflationary expectations (Dua, 2009). As a result, the necessity to consider the ‘food items’ exclusively as a sector in the analysis is quite prominent.

Secondly, due to high economic growth rate in the developing countries, per capita GDP has risen over time. This has two effects in the consumption pattern; due to the re-distribution effect the low income group is expected to demand for more food while following Engel’s Law, the high income group will likely to lean towards luxurious consumption of non-food items. In other words, as income growth takes place we can expect a shift in the pattern of consumption substitutability between food and non-food commodities and gradually consumption of food appears to be ‘inferior’ in comparison of non-food. Such changing demand would alter the internal resource allocation, terms of trade and finally accelerate the inflation. Hence, it is also important to categorize the items other than food as ‘non-food’.

Based on the reasons mentioned above, the model economy in this paper is shaped by combining the food and non-food as two distinct sectors. To the best of author’s knowledge, this is the first attempt to analyze the aggregate inflation by food and non-food inflation in a New Keynesian set up.

**4. Two Sector New Keynesian Model**

**4.1 Environment of the Model**

In this sub-section, following Gali (2008), a two sector sticky price model is developed with Calvo (1983) - type price adjustment to explicate the stylized fact. The two sectors of the model economy are food (F) and non-food (N). There are six building blocks of the model, namely,

* A representative household.
* A representative of final goods producing firm of food sector.
* A representative from the continuum of intermediate goods producing firms of food sector, indexed by .
* A representative of finished goods producing firm of non-food sector.
* A representative from the continuum of intermediate goods producing firms of non-food sector, indexed by .
* Central Bank.

Each sector of the economy is characterized by nominal rigidity emerges from the imperfect competition and price setting behaviour of intermediate goods producing firms. Imperfect competition in the goods market is introduced with the assumption that each firm produces differentiated good for which it can set the price. Further, the price setting behavior of firms is constrained through price adjustment mechanism with the assumption that only a fraction of firms can reset their prices in any given period. Following the literature and the empirical evidence, Calvo (1983) type staggered price setting with random price duration is adopted. The probability of adjusting the price level in each period remains same within the sector but varies across the sector i.e. heterogeneous nominal rigidity. The resulting framework is used to analyze the difference in inflation variability between advanced and developing economies with help of dynamic simulation exercise.

**4.2 Description of Model**

**4.2.1 Representative Household**

The economy is populated by a continuum of households within a unit interval. The representative household enters each period t = 0, 1, 2 ...∞ with bonds . At the beginning of the period, the household receives a lump-sum monetary transfer from the central bank. During the period ‘t’, household’s bonds mature, providing additional units of money. At the same period, household supplies the total and units of labor to the various intermediate goods-producing firms of food and non-food sector respectively. In return, it earns the labour income of and , where and denote the nominal wages of both the sectors. The household also consumes and units of the finished goods purchased at the nominal prices of and from the representative finished goods-producing firms of food and non-food sectors. Besides, the household uses some of this money to purchase new bonds of value , where 1/ denotes the gross nominal interest rate between t and t + 1. The representative household chooses the sequences for , , , , and , to maximize the present value of life time expected utility function which is given by:

…………….. (1); subject to the periodical budget constraint of:

 …………… (2)

Here, the utility function of aggregate consumption and labour supply of the household is taken as additively separable which is commensurate to the balanced growth path of the economy and specified as:

 ………………… (3)

The utility function, given by (3) reveals that representative household derives utility from consumption of food and non-food basket and bears the disutility for supplying labour to both the sectors. Further, the aggregate consumption ‘’ and aggregate labour supply ‘’ over two sectors are considered as a generalized CES function of food and non-food component and presented in (4) and (5).

…………….. (4); ; ; ;

*………………………..* (5);

Considering the consumption aggregator in (4), it can be observed that this sub-utility function exhibits *Non-homothetic* preference in consumption between food and non-food. This feature is incorporated by introducing a subsistence level of consumption of food. In (4), the subsistence level of food consumption is given by ‘’. It implies that utility from food consumption is only generated when this consumption is greater than a specified level ‘’, i.e. the minimum consumption requirement for subsistence. By contrast, any positive unit of non-food consumption creates utility for household[[6]](#footnote-7). The parameter ‘’ controls the degree of inter-temporal non-homotheticity in the model. The key implication of non-homotheticity is to capture the transitional dynamics in the expenditure pattern on food and non-food goods in course of economic growth, as indicated by Engel’s law. Note that, in case of the aggregate labour index, , the composition of labour supply to the food and non-food sectors holds the property of homotheticity.

Consumption aggregator reveals the household’s preference and adjustability between food and non-food consumption. Similarly, labour supply aggregator shows the preference pattern to diversify the activities across the sector. The parameters ‘’ and ‘’ captures the preferential bias or household’s inclination for food consumption and supplying labour to the food sector respectively. Further, the parameters ‘’ and ‘’ denote the inter sector elasticity of substitution for consumption and labour supply. While the possibility of elastic consumption substitutability is allowed, restriction is taken on the substitutability of labour supply between the sectors. The intuition is household would like to substitute its food consumption by non-food or vice versa but would not like to do the same in case of labour supply. Any kind of reallocation of labour adds more disutility and therefore, it is hard to rescheduling the labour allocation decision. Finally, the generalized CES form of consumption and labour aggregator for two sectors allows the elasticity of substitution terms (i.e. ‘’ and ‘’) to take any value in its parametric space and gives more freedom in the calibration process.

Again, the consumption bundle of food and non-food is constituted by a variety of differentiated items produced by the continuum of identical firms, distributed over unit interval. Equations (6) and (7) express the composition of aggregate food and non-food consumption respectively.

……….. (6) and ……… (7)

Here, the parameters, and represent the elasticity of substitution in consumption, within food and non-food sector respectively.

Similar to the consumption, labour supplied to each sector, are aggregated over the continuum of firms and given by (8) and (9):

……………… (8);

 ……………… (9);

In the utility function of household, a preference shock, ‘’, to consumption is considered as:

 ………………….. (10); where, is an *i.i.d* with .

Further to note for budget constraint, given by (2):

 = …… (11);

 = ……. (12);

 …… (13);

 ……… (14);

Where, (11) – (14) are implying the aggregate expenditure on food consumption, non-food consumption, earnings by working in food sector and from non-food sector. Finally, is the price of bonds and is the number of bonds held by the representative individual at period‘t’. The household decides on optimal allocations of consumption expenditures among the different goods of both food and non-food sectors. This involves minimization of aggregate expenditures for both sectors subject to one unit of aggregate consumption. Such optimization exercise yields two sets of demand equations for food and non-food sectors, given in equations (15) and (16) respectively.

........................ (15)

 ......................... (16)

The price indices of food and non-food are:

 .......................... (17)

 ............................ (18)

The price aggregator[[7]](#footnote-8) for the economy is:

 ………………. (19)

The dynamic optimization of representative household will yield: a pair of consumption Euler equations and a pair of marginal rate of substitutions (MRS) conditions for food and non-food sector. The log-linear versions of the consumption Euler equations are as follows:

For Food Sector:

…………………. (20)

where,

For non-food sector:

……………………. (21)

The log-linear versions of MRS conditions are as follows:

For food sector:

...……………… (22)

For non-food sector:

 ….……………… (23)

Note that, equations (20) and (21) come from the inter-temporal optimization of food and non-food consumption and equations (22) and (23) come from optimal choice of consumption to labour supply for food and non-food sector.

**4.2.2 Representative Final Goods Producing Firm**

The production functions of final goods producing firms for food and non-food sector are defined in the following way:

………….. (24)

…………… (25)

Note that, the aggregate output in the economy is given by the sum of two sector’s output, i.e.

 …………………… (26)

The competitive firms in both sectors take its price as given and combine intermediate inputs such as to minimize their production costs. This yields the following demand schedule for each intermediate goods producing firms in each sector:

 …………… (27)

 …………… (28)

**4.2.3 Representative Intermediate Goods Producing Firm**

Intermediate goods producing firms are monopolistically competitive, facing iso-elastic demand function and producing differentiated goods for consumption. The production functions for food and non-food sector are as follows:

 ……………………… (29)

 …………………….. (30)

Here, represents the aggregative productivity shock experienced all intermediate firms existing in the food sector, represents the output produced as food items by *i*th firm in food sector, denotes the labour input employed for food production, shows share of labour across the firms. Similarly, , , and represents the aggregative productivity shock, output produced, necessary labour input for the *i*-th firm of non-food sector respectively. Here, we assume that the laws of motion of productivity shocks are following an autoregressive processes of order one. These are specified as:

 ……………. (31)

 ……………… (32)

where, ; and the terms and are white noise process with and .

From the relations of (14a) and (14b), by aggregation, one can obtain the following relations:

 ……………….. (33)

 ……………….. (34)

Since the production functions are identical across all firms of the food sector, the expression of average marginal productivity of labour of a generic *i*-th firm obtained from (29) and (30) will remain same for the aggregate level in both the sectors of the economy. The log-linear expression of average marginal productivity of labour for food and non-food are:

 ………………….. (35)

 ………………….. (36)

Using these relations, the expression for the deviation of real marginal cost from steady state can be obtained.

Following Calvo type random price duration, it is assumed that intermediate firms in food and non food sector reset their prices in any given period with probability and which is independent of other firms pricing strategy and the time elapsed since the last adjustment. Thus, and measure the fraction of firms who keep their prices unchanged.

If and denote the optimal price set by the firm of food and non-food sector in period ‘t’, the evolution of food and non-food prices can be specified in the following way.

 ……………….. (37)

 ………………….. (38)

Log-linearizing the specifications of (37) and (38) around the zero inflation steady-state, the dynamics food and non-food price inflation can be approximated by the following difference equations:

 ……………………….. (39)

 ………………………. (40)

It should be noted that the exact form of the equation describing aggregate inflation dynamics depends on the way sticky prices are modelled. To solve the optimal price setting problem, firm has to maximize the discounted value of its expected profit subject to the sequence of its demand constraints. This can be written in the following way:

For Food Sector:

 …………… (41)

Subject to ; where, is the cost function of food sector and is the stochastic discount factor.

For Non-food Sector:

 …………………. (42)

Subject to the sequence of demand constraints: ; where, is the cost function of non-food sector and is the stochastic discount factor.

This re-optimization will yield the optimal price in a log-linearized approximated form as given below:

 ………………. (43)

 ……………….. (44)

Hence, firms resetting their prices in the food and non-food sector will opt a price that corresponds to their desired mark up () over a weighted average of their current and expected nominal marginal costs, with the weights being proportional to the probability of the price remaining effective at each horizon.

Combining the re-optimized price schedule with the log-linear inflation equation for each sector the inflation in food and non-food sectors can be obtained in terms of the deviation of real marginal cost from its steady state. These are:

 ……………… (45)

………………. (46)

where, ; and

The equations of (45) and (46) exhibit the relation between inflation and real marginal cost including forward looking element of expectation. It underlines that any deviation of real marginal cost from its steady state level leads to fluctuation of inflation.

**4.2.4 Central Bank**

Central bank constitutes the monetary block for the model. It is assumed that the central bank follows simple Taylor type interest rate rule which is specified below.

 ........................ (47)

where, and are the coefficients of inflation and output gap stabilization. ‘’ denotes the monetary policy shock which features of an autoregressive process of order one.

 …………… (48); where, is a white noise process with .

**4.3 Equilibrium Determination**

**4.3.1 Dynamic IS Equation**

Assuming that at steady state share of food production in total output is constant , from (26) aggregate output gap () can be approximated as a linear combination of food () and non-food sector output gap ().

 ……………. (49); where,

Further, using (26), one can express the change of natural level of aggregate output as a linear combination of the same of food and non-food sector.

 ……………. (50)

Now, using the market clearing conditions of food sector: and the aggregate level: in (20), the dynamic IS equation for food sector[[8]](#footnote-9) can be obtained as:

 ……….. (51)

where, ..………… (52)

In the similar fashion, the dynamic IS equation for non-food sector can be obtained from (21):

 ………… (53)

where, …..……….. (54)

Note that, and are real natural rate of interest for food and non-food sector. In other words, these are the shadow prices corresponding to the natural level of output of food and non-food sector. Inserting (51) and (53) in (49), the dynamic IS equation for aggregate output gap can be obtained.

**4.3.2 Equations of NKPC**

Firm’s inability to adjust prices optimally every period implies the existence of a wedge between output and its natural level (Gali, 2002) for which the deviation of real marginal cost from its steady state can be substituted by output gap under specific assumptions. Following that, expressions of and are derived in terms of output gap[[9]](#footnote-10) and replaced in (45) and (46) to obtain the standard forms of NKPC for each sector. These are as follows:

 ……………….. (55)

 ………………. (56)

Finally from (19) the expression of aggregate inflation is obtained as:

 ………………… (57)

Replacing and in (57) by (55) and (56) respectively, the generalized form of NKPC has been derived as:

………….. (58)

Using the definition of real marginal cost, further, the natural level of output in each sector can be expressed in terms of productivity shocks.

These are as follows:

 .......................... (59)

 ......................... (60)

**4.3.3 Forcing Process**

In this model there are four exogenous variables. Such as: preference shock on aggregate consumption (), productivity shock in the food () and non-food () sector and monetary policy shock (). Contemporaneous covariances among the shocks are assumed to be zero. The model contains twelve endogenous and four exogenous variables. Therefore, the equilibrium of this model is obtained by solving the system of sixteen equations: (10), (31), (32), (47), (48), (49), (50), (51), (52), (53), (54), (55), (56), (57), (59) and (60).

**5 Calibration of Baseline Model**

**5.1 Parameterization**

All parameters in our model are calibrated for quarterly data frequency. In the baseline model, there are twenty structural parameters and eight parameters for the shock process. Two different sets of parametric configuration are taken to construct the baseline model for the advanced and developing economy. For the purpose of individual characterization of developed and developing economies, the values of the parameters are taken mostly from the literature and few of them are calculated by author. Since the variables are taken as the log-deviation from their steady state level, so at steady state, their values are zero. Therefore, instead of level, the second order moments of the major seven endogenous variables of the model are targeted to match with data of advanced and developing countries, such as: aggregate output gap, individual output gaps of food and non-food sectors, aggregate inflation and individual inflation of food and non-food sectors and interest rate. Given the target, the baseline model has been parameterized and calibrated. Table: 4A, 4B, and 4C, provide complete parameterization of the model.

Starting with relative risk aversion coefficient, it is considered that economic agents in the developing economies are more risk averse in nature than the advanced economies. Gali (2005) showed that the value of this coefficient can vary from 1 to 5. Discount factor, the benchmark of forward looking behavior, is taken as 0.99 and 0.98 for developed and developing economies respectively to keep the consistency with real interest rate differential. In case of inverse of the Frisch elasticity of labour supply, value is taken from Gali and Blanchard (2005, 2007) for developed countries. For developing economies, elasticity of employment is measured by Goldberg (2010) as 0.15-0.17 and following this, the baseline value is taken as 6. Following Brooks (2010), the steady state share of food production in total output for developing countries (0.18) is taken substantially larger than the developed countries (0.04). The share of food consumption in aggregate consumption basket varies between 50-65% for East and South-East Asian developing countries and therefore, the bias in food consumption is taken as 0.55 for these economies (Hoyos & Lessem, 2008). As the evidence suggests in Seale, et al., (2003), share of food consumption in aggregate consumption expenditure is significantly lower in developed countries, so, the food consumption bias is set at 0.17. However, the level of subsistence consumption is remained same for both economies and it is taken following Gollin et al., (2004). In case of the parameter of preferential bias in labour supply, values are chosen from the numerical experiment.

Regarding the elasticity of substitution between food and non-food consumption, it depends on the per capita income of households. Since, developed countries have higher per-capita income and developing countries are on the way of catching up, it is more likely to find elastic nature of substitutability in consumption and accordingly, the value is chosen. As economy grows, labour becomes more sector specific and substitution of labour between two sectors will be difficult. So, the substitutability of labour between the sectors is kept inelastic. This explains the difference in the values assigned for elasticity of labour substitution. The two parameters, preferential bias and elasticity of labour substitution, govern the movement of labour supply within economy.

The share of fixed capital for food and non-food sector, for both economies, is picked up from Gollin et al., (2004). The difference in choice reflects the greater share of labour for developing economies. The intra-sector elasticity of substitution for both sectors is chosen with the perception that intermediate goods producing firms of advanced economies are facing more competition and have less market power than that of developing economics. The values are taken to keep a clear demarcation of mark up between two economies. Moreover, due to lack of close substitutes of food compared to non-food, monopolistic power can indulge the firms to charge greater mark up in the food sector than that of non-food sector.

Considering the degree of price stickiness for advanced group, food sector exhibits less stickiness of price compared to non-food and therefore, the values are chosen for developed countries capture reasonable difference in price stickiness. On the other hand, for developing countries, the same have been taken in line with our own empirical findings. Using the historical commodity prices collected from different markets of developing countries (the monthly dataset during the period of January, 1960 – May, 2011, Source: Pink data, World Bank), stickiness of prices have been measured categorically for food and non-food sectors following the *Indirect Estimation of Price Duration* under *Frequency Approach* as in Kovanen (2006) and Morandey and Tejada (2008). It is found that food price, on an average, lasts for a quarter approximately while the price of non-food item remains unchanged for more than three quarters[[10]](#footnote-11).

The coefficients of inflation and output gap for monetary policy rule is considered as suggested by Gali (2005), with a reasonable difference between advanced and developing economies. The intention is to produce the relative priority of output stabilization in the policy rule. Besides, the difference of inflation coefficient in the policy rule between advanced and developing economies is taken due to credibility gap or lack of willingness to pursue a transparent monetary policy. Finally, the shock process is structured following the standard DSGE literature of advanced and developing economies. In Table: 5, results are produced on data and model generated values of the relevant macroeconomic aggregates. Although the results are not same with data, it has been possible to replicate the basic nature of the data.

**Table: 4A - Baseline Model for Developed Economy**

|  |  |
| --- | --- |
| Parameters | Values |
|  | Risk aversion coefficient | 1 |
|  | Inverse of the elasticity of labour supply | 4 |
|  | Discount Factor | 0.99 |
|  |  | 0.01 |
|  | Share of Food production in Aggregate output at steady state | 0.04 |
|  | Share of food in consumption | 0.21 |
|  | Elasticity of substitution between food to non-food consumption | 1.8 |
|  | Preferential bias supply labour in food sector | 0.1 |
|  | Elasticity of substitution of labour supply between food and non-food sector | 0.3 |
|  | Subsistence level of food consumption | 0.35 |
|  | Intra-sectoral elasticity of substitution for food sector | 11 |
|  | Intra-sectoral elasticity of substitution for non-food sector | 15 |
|  | Degree of price stickiness in food sector | 0.25 |
|  | Degree of price stickiness in non-food sector | 0.75 |
|  | Share of labour in food sector in the aggregate labour supply at steady state | 0.07 |
|  | Share of labour in non-food sector in the aggregate labour supply at steady state | 0.93 |
|  | Fixed share of capital in food sector production | 0.33 |
|  | Fixed share of capital in non-food sector production | 0.6 |
|  | Coefficient of inflation stabilization | 1.5 |
|  | Coefficient of output gap stabilization | 0.0125 |

**Table: 4B - Baseline Model for Developing Economy**

|  |  |
| --- | --- |
| Parameters | Values |
|  | Risk aversion coefficient | 2.2 |
|  | Inverse of the elasticity of labour supply | 6 |
|  | Discount Factor | 0.98 |
|  |  | 0.02 |
|  | Share of Food production in Aggregate output at steady state | 0.12 |
|  | Share of food in consumption | 0.55 |
|  | Elasticity of substitution between food to non-food consumption | 1.2 |
|  | Preferential bias supply labour in food sector | 0.25 |
|  | Elasticity of substitution of labour supply between food and non-food sector | 0.45 |
|  | Subsistence level of food consumption | 0.4 |
|  | Intra-sectoral elasticity of substitution for food sector | 5 |
|  | Intra-sectoral elasticity of substitution for non-food sector | 10 |
|  | Degree of price stickiness in food sector | 0.2 |
|  | Degree of price stickiness in non-food sector | 0.8 |
|  | Share of labour in food sector in the aggregate labour supply at steady state  | 0.45 |
|  | Share of labour in non-food sector in the aggregate labour supply at steady state | 0.55 |
|  | Fixed share of capital in food sector production | 0.2 |
|  | Fixed share of capital in non-food sector production | 0.5 |
|  | Coefficient of inflation stabilization | 1.2 |
|  | Coefficient of output gap stabilization | 0.015 |

**Table: 4C – Parameterization of Shock Structure**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Shock Parameters | Values for Advanced Economy | Source | Values for Developing Economy | Source |
|  | 0.947 | Ireland, 2004 | 0.78 | Peiris & Saxegaard, 2007 |
|  | 0.95 | Ireland, 2004 | 0.85 | Annicchiarico, et al., 2008 |
|  | 0.962 | - | 0.9 | Ahmad, et al., 2012 |
|  | 0.7 | - | 0.5 | Peiris & Saxegaard, 2007 |
|  | 0.0405 | Ireland, 2004 | 0.065 | Peiris & Saxegaard, 2007 |
|  | 0.0212 | - | 0.0212 | Annicchiarico, et al., 2008 |
|  | 0.0109 | Ireland, 2004 | 0.02 | Ahmad, et al., 2012 |
|  | 0.0031 | Ireland, 2004 | 0.013 | Peiris & Saxegaard, 2007 |

**Table: 5 - Second Order Moments of Target Variable**

|  |  |  |
| --- | --- | --- |
|  | Quarterly Data | Model |
|  | Advanced | Developing | Advanced | Developing |
| Aggregate Output Gap | 0.1579 | 0.1921 | 0.0061 | 0.0121 |
| Food Sector Output Gap | 0.007 | 0.0079 | 0.0451 | 0.0873 |
| Non-food Sector Output Gap | 0.0274 | 0.0216 | 0.0045 | 0.0019 |
| Aggregate Inflation | 0.0087 | 0.0212 | 0.0097 | 0.0236 |
| Food Sector Inflation | 0.0096 | 0.0256 | 0.0104 | 0.032 |
| Non-food Sector Inflation | 0.0095 | 0.0215 | 0.0085 | 0.0097 |
| Interest Rate | 0.897 | 0.4951 | 0.014 | 0.0254 |

**5.2 Impulse Response Analysis**

Given the parameterization of model, effects of shocks on seven major macroeconomic variables are analyzed. The variables are: , , , , , , . To see these effects, impulse response functions are produced in Figure 3A & 3B for advanced and developing economies respectively.

**Figure: 3A - Impulse Responses for Advanced Economy**

Impulse responses in percent of standard error of an orthogonalized shock to



Impulse responses in percent of standard error of an orthogonalized shock to

****

Impulse responses in percent of standard error of an orthogonalized shock to

****

Impulse responses in percent of standard error of an orthogonalized shock to

****

**Figure: 3B** - **Impulse Responses for Developing Economy**

Impulse responses in percent of standard error of an orthogonalized shock to



Impulse responses in percent of standard error of an orthogonalized shock to



Impulse responses in percent of standard error of an orthogonalized shock to

****

Impulse responses in percent of standard error of an orthogonalized shock to



A positive preference shock on consumption raises aggregate demand via increasing the demand for food and non-food consumption. Such rising demand will be anticipated by the intermediate goods producing firms and to meet the excess demand, production in each sector will rise. This will induce the real marginal cost of food and non-food production to surpass their steady state level. Following the positive deviation of real marginal cost from steady state, output gap for both sectors and aggregate level will rise and lead to rising inflation across the economy. Given the upsurge of inflation, nominal interest rate will be raised by the central bank to keep real rate unaffected. In case of a positive monetary policy shock through the nominal interest rate hike, current consumption will become costly and aggregate demand will be depressed due to dynamic IS relation. This will reduce the output gap and inflation across the sectors and at the aggregate level. Again, if there appears a productivity shock, the natural level of output will go up for each sector and trim down the output gap. The decline in output gap will be followed by the decline in inflation and fall of nominal interest rate. Finally, comparing the scenarios between developed and developing economies, it is apparent that the qualitative natures of both set of impulse response functions are same but the magnitude of impact effect significantly different.

**5.3 Inflation Dynamics: Comparison between Data and Model**

Given the two different sets of parametric configuration, the baseline model is simulated for 1000 periods. Thereafter, the inflation series, generated from the simulation, are compared to empirical data. To inspect the match between data and model at different cycle and frequency, the simulated inflation series are filtered according to frequency domain approach discussed earlier. The proximity between data and model generated inflation is judged by comparing the level (by mean), volatility (by standard deviation) and persistence (by autocorrelation over four lags). Results are given in Table: 6 (A, B and C). It is observed that model can provide a reasonable match for the level of inflation. It can partly generate the volatility similar to data in business cycle component and low frequency. Overall, the difference in volatility between two economies is obtained as observed from data. But, in case of high frequency and medium term cycle, the model underestimates volatility for developing economy. Regarding persistence, baseline model is close to the data for the advanced group in 2nd, 3rd and 4th order but fails to depict the same for developing group.

**Table: 6A**

|  |
| --- |
| Mean / Level of Inflation: Comparison Between Data and Model |
| Frequency | Monthly Data(1970 – 2011) | Baseline Model |
| Adv | Dev | Adv | Dev |
| Medium term Cycle | 0.0021 | 0.0103 | 0.0032\* | 0.0084\* |
| High | 0.0001 | 0.0007 | 0.0003\* | 0.0007\* |
| Business Cycle | -0.0006 | -0.0031 | -0.0010\* | -0.0027\* |
| Low | 0.0026 | 0.0128 | 0.0040 | 0.0104 |

*Note: ‘\*’ are assigned to the values which lie in the 95% confidence interval of data.*

**Table: 6B**

|  |
| --- |
| Inflation Volatility: Comparison Between Data and Model |
| Frequency | Monthly Data(1970 – 2011) | Baseline Model |
| Adv | Dev | Adv | Dev |
| Medium term Cycle | 0.0074 | 0.0218 | 0.0063\*\* | 0.0172 |
| High | 0.0046 | 0.0147 | 0.0020 | 0.0084 |
| Business Cycle | 0.0037 | 0.0135 | 0.0039\* | 0.0126\* |
| Low | 0.0045 | 0.0054 | 0.0044\* | 0.0063\*\* |

*Note: ‘\*’ are assigned to the values which lie in the 95% confidence interval of data.*

*‘\*\*’ are assigned to the values which lie in the 99% confidence interval of data.*

**Table: 6C**

|  |
| --- |
| Inflation Persistence in Medium Term Cycle: Comparison of Data & Model |
| Order | Monthly Data(1970 – 2011) | Baseline Model |
| ADV | DEV | ADV | DEV |
| 1 | 0.904 | 0.935 | 0.833 | 0.618 |
| 2 | 0.708 | 0.775 | 0.692\* | 0.374 |
| 3 | 0.534 | 0.601 | 0.533\* | 0.226 |
| 4 | 0.466 | 0.48 | 0.464\* | 0.103 |

*Note: ‘\*’ are assigned to the values which lie in the 95% confidence interval of data.*

**5.4 Variance Decomposition**

From the variance decomposition, it is observed that inflation variability is largely driven by preference shock on consumption for advanced economy (85%). However, the finding is considerably different for developing economy. Preference shock dominates over others (54%), but monetary policy shock also explains one-third (34%) of inflation volatility. In contrast, productivity shocks remain insignificant. Thus, the demand side disturbances would be one of the causes for higher inflation variability in developing economies.

**5.5 Sensitivity Analysis of Inflation Volatility**

Using simulation analysis, it has been possible to recognize the structural and policy factors which would escalate the volatility in developing countries. From Table: 7 (A to D), the results of sensitivity analysis are listed. Simulating the values of various deep parameters for developing economies, it is found that food price inflation is the most volatile component in the aggregate inflation. All through the sensitivity analysis, food sector inflation remains substantially greater than non-food inflation as it is expected to be. It also drives the direction of aggregate inflation in the economy. Apart from this, it has been possible to identify some structural and policy factors which would make striking difference in inflation variability between developed and developing countries. It is noticed that inflation volatility is highly sensitive to the inflation stabilization coefficient. This implies if inflation is not targeted properly in the policy framework or if there is lack of transparency in policy implementation, volatility will go up extensively. Next, it is heterogeneous nominal rigidity in both sector crucially determine the volatility of inflation. If the prices prevailing in the sectors become less sticky, inflation will be more volatile in nature. From the parameterization of model, since price stickiness in food sector is lower than non-food sector; elasticity of food price inflation to the deviation of real marginal cost from its steady state is relatively higher than non-food sector. Therefore, any exogenous shock, impinging on the economy, can be transmitted immediately through the food sector.

**Table: 7A**

|  |  |
| --- | --- |
| Parameter | Inflation Volatility |
|  | Food  | Non-food | Aggregate |
| 1.3 | 0.0257 | 0.0029 | 0.0182 |
| 1.25 | 0.0266 | 0.003 | 0.0189 |
| 1.2 | 0.0275 | 0.0031 | 0.0195 |
| 1.15 | 0.0285 | 0.0032 | 0.0203 |
| 1.1 | 0.0296 | 0.0033 | 0.0211 |

**Table: 7B**

|  |  |
| --- | --- |
| Parameter | Inflation Volatility |
|  | Food  | Non-food | Aggregate |
| 0.5 | 0.0265 | 0.0034 | 0.019 |
| 0.4 | 0.027 | 0.0032 | 0.0193 |
| 0.3 | 0.0273 | 0.0031 | 0.0194 |
| 0.2 | 0.0275 | 0.0031 | 0.0195 |
| 0.1 | 0.0276 | 0.003 | 0.0196 |

**Table: 7C**

|  |  |
| --- | --- |
| Parameter | Inflation Volatility |
|  | Food  | Non-food | Aggregate |
| 0.9 | 0.0282 | 0.0008 | 0.0182 |
| 0.8 | 0.275 | 0.0031 | 0.0195 |
| 0.7 | 0.0297 | 0.007 | 0.0222 |
| 0.6 | 0.0328 | 0.0127 | 0.0261 |
| 0.5 | 0.0367 | 0.0197 | 0.031 |

**Table: 7D**

|  |  |
| --- | --- |
| Parameter | Inflation Volatility |
|  | food  | non-food | aggregate |
| 0.35 | 0.0323 | 0.0038 | 0.023 |
| 0.3 | 0.0293 | 0.0034 | 0.0208 |
| 0.25 | 0.0275 | 0.0031 | 0.195 |
| 0.2 | 0.0265 | 0.0029 | 0.0188 |
| 0.15 | 0.0261 | 0.0029 | 0.0185 |

Another noteworthy structural aspect is the preferential bias in labour supply between food and non-food. This one is also directly related to volatility. If the preferential bias moves from food to non-food sector, the prominence of food sector will decline in the economy. Since, food sector is transmitting the volatility of shocks and perturb the aggregate inflation via frequent price adjustment, shift of preferential bias to non-food sector will bring the entire economy in a lower regime of inflation volatility.

**6. Conclusion**

This paper substantiates the key stylized fact that inflation volatility is higher for developing economies than its advanced counterpart and attempts to find out the reasons behind it. Using two-sector New Keynesian model, it has been possible to replicate such difference in volatility of inflation between developed and developing economies as observed empirically. Further, it has been possible to identify the main source and critical factors of the greater volatility of inflation in developing economies. It is observed that demand side shocks are the fundamental forces for inflation volatility. Volatility crucially hinges upon the structural attributes of nominal rigidity and preferential bias of in labour supply. As the policy factor, it appears that lack of inflation targeting of monetary authority is a potential reason for inflation volatility. The baseline model for advanced and developing economy fits into the empirical regularities of inflation process moderately. It projects the level and volatility of inflation fairly well, but struggles to portray the underlying persistence for developing countries. To overcome this problem, in the next course of research, elements like wage rigidity, endogenous capital accumulation, adjustment cost of capital and investment would be introduced. These ingredients can generate sluggish adjustment, persistence and thereby improvise the model to meet the features of data.

**Appendix**

**A.1 Note on Christiano-Fitzgerald (2003) Band Pass Filter**

In this section, a brief note is produced regarding the methodology of Christiano-Fitzgerald (2003) Band Pass Filter following Rua and Nunes (2005). Band pass filters allow to retain the elements of a specified frequency band while eliminate all other unwanted frequencies. An ideal filter enables to isolate the fluctuations with the periodicity of and in for any generic series . Such series can be represented as:

Where, is the ideal BP filter: with the following weights of:

And;

 for

Since, the ideal BP filter can only be applicable for the infinite time series, some approximation needs to be taken to deal with a finite sample of T observations. Christiano and Fitzgerald (2003) have proposed a procedure to estimate by which is a linear function of the data under consideration. According to them;

Where, with and

Selecting the filter weights by:

Where, is the spectrum of at frequency which measures the contribution of each frequency component to the overall variance of . Now, if staionarity and symmetry are imposed on the true data generating process, then it implies: ; and an equal weight is assigned to all frequencies, i.e. . In course of estimating the cyclical component at different frequency bands, this paper considers stationarity and symmetry of the filters. Imposing stationarity has econometric advantages and symmetry ensures no phase shifting between projected cyclical components and the original series. However, these benefits are obtained only at the cost of small amount of data lose.

**A.2** **Derivation of Price Aggregator**

Minimize the aggregate expenditure subject to one unit of aggregate consumption . So, the expression of Lagrangian function will be:

From first order conditions of optimization:

= 0 = …………….. (i)

 = 0 = ……………... (ii)

= 0 …………….. (iii)

Dividing (i) by (ii), we get:

 ………………..……. (iv)

Now, substituting the value of ‘’ into (iii), we obtain:

Consider (iv) once again:

Now, the aggregate expenditure for one unit of consumption is given by:

 => Equation (19) of Price Aggregator

**A.3 Derivation of Dynamic IS Equations**

Using the market clearing conditions of food sector: and the aggregate level: ; we obtain the dynamic IS equation for Food Sector.

Using two relations, the above expression can be simplified further. These are:

 ; and

 ……….. (25a)

Where,

 ..………… (26a)

In the similar fashion, the dynamic IS equation for non-food sector can be obtain from the consumption Euler equation of the same.

Using the market clearing conditions of: and

 ………..……… (25b)

Where,

 ……………. (26b)

**A.4 Deviation of Real Marginal Cost from Steady State and Output Gap**

Here, using the market clearing conditions of and ; and rearranging the terms, we obtain:

Now, substituting the relations of:

 ; and ; we find:

Finally, replacing: ;

The inflation equation for food sector cab derived using the above relation. Let us consider the inflation equation for food sector:

Substituting in this equation, we get:

 …………………………….. (27a)

Where,

Similarly, the NKPC for non-food sector given in (27b) can be derived.

Now, consider the inflation equation for non-food sector:

Replacing in the above equation:

 ……………… (27b)

Where,

**A.5 Measure of Price Stickiness of Developing Countries**

In Table A.5.1 and A.5.2 are showing the price duration of food and non-food items categorically.

**Table: A.5.1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Food Items** | **Duration** | **Weight** | **Weighted Duration** |
| Beverages | Cocoa | 0.45 | 0.03 | 0.01 |
| Coffee | 0.26 | 0.04 | 0.01 |
| Tea | 0.62 | 0.01 | 0.01 |
| Vegetable Oils | Coconut Oil | 0.27 | 0.01 | 0.00 |
| Groundnut Oil | 0.27 | 0.00 | 0.00 |
| Palm Oil | 0.33 | 0.05 | 0.02 |
| Soybean Oil | 0.30 | 0.02 | 0.01 |
| Cereals | Maize | 0.37 | 0.16 | 0.06 |
| Rice | 0.30 | 0.12 | 0.04 |
| Wheat | 0.34 | 0.10 | 0.03 |
| Other Foods | Banana | 0.31 | 0.02 | 0.01 |
| Orange | 0.56 | 0.01 | 0.01 |
| Beef | 0.26 | 0.03 | 0.01 |
| Chicken | 0.27 | 0.02 | 0.01 |
| Sugar | 0.67 | 0.04 | 0.03 |
| Average duration of Aggregate Food Price (Un-weighted) | **0.38** |
| Average duration of Aggregate Food Price (Weighted) | **0.24** |

**Table: A.5.2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Non-food Items** | **Duration** | **Weight** | **Weighted Duration** |
| Energy Products | Petroleum | 0.84 | 0.42 | 0.35 |
| Coal | 1.72 | 0.02 | 0.04 |
| Natural Gas | 0.90 | 0.05 | 0.05 |
| Agricultural Raw Materials | Tobacco | 0.53 | 0.00 | 0.00 |
| Log | 0.56 | 0.00 | 0.00 |
| Swan wood | 0.66 | 0.00 | 0.00 |
| Plywood | 0.23 | 0.00 | 0.00 |
| Wood pulp | 0.33 | 0.00 | 0.00 |
| Cotton | 0.23 | 0.00 | 0.00 |
| Rubber | 0.16 | 0.00 | 0.00 |
| Fertilizers | Phosphate | 6.34 | 0.00 | 0.02 |
| Urea | 1.25 | 0.01 | 0.01 |
| Potasiam Cholride | 2.23 | 0.00 | 0.01 |
| Metals & Minerals | Aluminium | 0.67 | 0.04 | 0.03 |
| Copper | 0.24 | 0.06 | 0.01 |
| Iron Ore | 12.65 | 0.03 | 0.38 |
| Average duration of Aggregate Non-food Price (Un-weighted) | **0.85** |
| Average duration of Aggregate Non-food Price (Weighted) | **0.91** |

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1. **\*** Doctoral Fellow,Department of Economics, Finance and Business, Durham Business School, University of Durham, 23/26 Old Elvet, Durham DH1 3HY, UK; Email: shesadri.banerjee@durham.ac.uk . Author gratefully acknowledges the valuable guidance and comments of Prof. Parantap Basu for this research. [↑](#footnote-ref-2)
2. Critical Value of F distribution for less than type one tail test with degrees of freedom at numerator equals to 148 and denominator equals to 148 is 1.468 at 1% level of significance. [↑](#footnote-ref-3)
3. Critical Value of F distribution for less than type one tail test with degrees of freedom at numerator equals to 2048 and denominator equals to 1838 is 1.124 at 1% level of significance. [↑](#footnote-ref-4)
4. There is one study, done by Edmonds and So (1992), considered the inflation variability for developed and developing economies together. [↑](#footnote-ref-5)
5. See the works done by Rotemberg (1982), Mankiw (1985), Blanchard & Kiyotaki (1987), Ball & Romer, (1990), Woodford (2003), Gali (2008) [↑](#footnote-ref-6)
6. Note that, when $Λ=0$, the model converts into the standard model with homothetic preferences. [↑](#footnote-ref-7)
7. See Appendix A.2 for the derivation of Price Aggregator. [↑](#footnote-ref-8)
8. See Appendix A.3 for the derivation. [↑](#footnote-ref-9)
9. See the derivation in Appendix A.4. [↑](#footnote-ref-10)
10. See Appendix A.5 for weighted price duration of food and non-food items. [↑](#footnote-ref-11)