Working Paper Series WP No. 1701

Responses of Inflation and Output to Shocks in Monetary policy: A case study with Bangladesh using the DSGE model

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January, 2017

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Abstract

This paper developed a dynamic stochastic general equilibrium (DSGE) model for Bangladesh to estimate the central bank reaction function and to analyze the policy shocks on inflation and output. The models have two stochastic shocks: productivity and the other of monetary policy. The sample period covers from 1991Q1 to 2014Q2. This model captures the behavior of the three key macroeconomic variables: GDP growth, inflation, and the policy rate. The Bayesian estimation method is used to get the posterior means based on priors and the likelihood function. The conditional variance decompositions, smoothed shocks show that the DSGE model captures the policy shocks from the data well. The main lesson is that the effective approach to controlling inflation is the management of monetary policy for Bangladesh. The monetary policy shock affects output in a positive fashion. Thus, monetary policy plays a significant role in macroeconomic stability in the country.

JEL Classification: E52, E62,F41
Key words: Dynamic Stochastic General Equilibrium Model (DSGE), policy analysis, macroeconomic variables

I. Introduction

The DSGE model have become increasingly useful for policy analysis and also for the simulation of alternative scenarios'. Many central banks, in both developed and emerging market economies (EMEs) have developed their own models for the policy analysis. The advantage of modern DSGE model over traditional reduce form macroeconomic models is that they are often thought to be difficult to use, opaque, theoretically inconsistent even if they had theory it was antiquated, poorly estimated, and subject to the Lucas Critique (1976). That is dynamism of private agents behavior changes using available information will lead to adjust their behavior in economic policy announcements are absent in the existing reduced form models (Zabczyk, 2012). Keeping this in the background, an attempt has been made to develop a DSGE model for Bangladesh economy by incorporating exact country-specific features to analyzing macroeconomic variables and estimate the central bank reaction function. Almost all the central banks are using this model for policy analysis and forecasting tools. For example US Federal Reserve Bank (SIGMA), European Central Bank (NAWM), Sveriges Riksbank (RAMSES), Bank of Canada (ToTEM), Bank of England (BEQM), Central Bank of Chile (MAS), Central Reserve Bank of Peru (MEGA-D), Norges Bank (NEMO), Bank of Finland, Reserve Bank of New Zealand, Bank of Spain,Central Bank of Brazil, Bank of Thailand, Central Bank of China, State Bank of Pakistan, IMF.

Therefore, the goal of this study is to examine the effectiveness of DSGE model in analyzing major macroeconomic variables Bangladesh as because the central bank of Bangladesh can use this type of model for policy analysis . In this regard an attemp has been made to estimate the central bank reaction functions and analysis of macroeconomic variables in Bangladesh.

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Therefore, the plan of the paper is as follows: after introduction, in Section-1, Section- II, present the literature review, Section- III, the basic structure of Bangladesh economy is described followed by the basic structure of the Dynamic Stochastic General Equilibrium model in Section-IV. Section-V explains data, methodology used for estimation DSGE model. Section VI analyzes the empirical results and finally Section-VII conclude the paper.

II. Literature Review

The Dynamic Stochastic General Equilibrium (DSGE) models are now widely used for empirical research in macroeconomics as well as for quantitative policy analysis for the purpose of monetary policy analysis and forecasting at central banks around the world (see e.g., Schorfheide, 2007a, 2007b, 2011, Hara et al. 2009, Tovar, 2008 Christiano et al., 2010, Niestroj et al. (2013) estimated the extended version of canonical DSGE model to examine the impact of the quantitative easing on US economy for the sample period from 2008 to 2012. The authors extended the model by including financial frictions and liquidity premium. Negro et al. (2014), estimated time-varying weights in linear prediction pools, and use it to investigate the relative forecasting performance of dynamic stochastic general equilibrium (DSGE) models, with and without financial frictions, for output growth and inflation in the period 1992 to 2011 for the US economy. Negro et al. (2014) showed that a standard DSGE model with financial frictions available prior to the recent crisis successfully predicts a sharp contraction in economic activity along with a modest and protracted decline in inflation. Merola (2014) provides a quantitative assessment of the impact of financial frictions on the U.S. and European countries business cycle using the model developed by Smets and Wouters (2003, 2005, 2007) by extending financial accelerator mechanism from 1967 to 2012 using Bayesian methods.

Rodrigo et al. (2011) estimated a DSGE model for a small open economy that incorporates financial frictions to analyze the consequence of the global financial crisis in 2008-9 on Chilean economy. Peiris and Saxegaard (2007) using DSGE model to evaluate monetary policy tradeoffs in low-income countries such as for Mozambique in sub-Sahara Africa except South Africa. Ahmad et al. (2012) developed a closed economy DSGE model of Pakistan with informality both in the labor and product markets consistent with the micro-foundations of Pakistan's economy while Adnan and Khan (2009) estimated a small open economy DSGE model for Pakistan using Bayesian simulation approach. Hamann, Perez and Podriguez (2006) developed a DSGE model for the small open economy of Colombia. Liu (2006) designs DSGE based New Keynesian framework to describe the key features of a small open economy particularly the model focuses on the transmission mechanism of monetary policy to provide a tool for basic policy simulations.

Sadeq's (2008) paper uses a small open economy DSGE model for central Europe Countries in transition, EU-15: Czech Republic, Hungary, Poland, Slovakia, and Slovenia. Grabriel et al. (2010) developed closed economy DSGE models of the India and US economy and estimated the models by Bayesian Maximum Likelihood method using Dynare. A number of papers presented at the workshop on DSGE models organized by Bank Indonesia and the Bank for International Settlements (Bali, 2008) showed different aspects of using DSGE model. For example, Tanboon (2008) simulated DSGE model for Thailand's economy consisting four main agents, namely households, firms, banks and government and found that the interest rate and the productivity shocks have significant impacts on Thailand's capital, investment, wage and consumption basket while Santoso (2008), presented the

Indonesian model, GEMBI, emphasizing the country-specific characteristics such as data accuracy, specific but dominant economic sectors, credibility of monetary and fiscal policies, and markets.

Chow et al. (2013) using a Dynamic Stochastic General Equilibrium Model (DSGE) examined for the sample period from 1985 to 2009, whether monetary regime choice for Singapore economy matters in influencing macroeconomic variables such as GDP growth and Inflation. There are four sectors, household, production, external and Government. The paper considered seven shocks such as productivity, government spending, foreign GDP, world interest rate, export price inflation import price inflation and risk premium. The results show that exchange rate rule had a comparative advantage when the major sources of real fluctuations are from exports shocks while Taylor rule performed better when sources of shockare from domestic productivity. The exchange rate rule also dominated the Taylor rule for reducing inflation persistence.

A research task force working group on the transmission channels (RTF-TC) between the financial and real sectors of the Basel Committee on Banking Supervision of Bank for International Settlement has attempted to improve existing DSGE models to use for policy analysis by developing a stylized model of the banking sector.They found that in the presence of financial frictions, aggressive interest rate cuts are required to offset adverse financial shock which helped DSGE models to better address fundamental policy issues, such as the overall importance of financial sector shocks in explaining the business cycle and the role of monetary policy and/ or prudential regulation to avoid or mitigate financial crises.

III.1 The Structure of the Bangladesh Economy

Bangladesh gained independence from Pakistan in 1971. During the past 4 years Bangladesh grew by on average 6.2 percent mainly backed by strong domestic demand and the financial inclusion drive of the Governments. Bangladesh save more and it took 42 years for Bangladesh to reach $1088 per-capita income level in 2013 after 42 years of her independence.

At the time of independence, the agriculture sector accounted for almost 38.6 percent of GDP while in 2013, it is accounted for only 18.7 percent . The industry and service sectors accounted for 15.5 percent and 45.9 percent respectively during the same periods. In 2013, the share of industry and service sectors increased significantly and reached to 32 percent and 49.3 percent of GDP respectively in Bangladesh.

After experimenting with a socialist model of development during early 1970s, Bangladesh has gradually moved toward a market-oriented strategy of development since late 1970s. To achieve some socio-economic objectives, the monetary and banking sectors in Bangladesh has undergone a gradual transformation owing to different policy measures tried since independence. Bangladesh economy has gone under significant economic reforms since late 1980s and gained macroeconomic stability with a sustained economic growth of about 5.0 percent per annum reasonably.

To find a remedy for the distorted financial sector, a “National Commission on Money, Banking and Credit” was formed in 1984 in Bangladesh. The World Bank also provided funds to carry out a study on the financial sector. Following these initiatives, a comprehensive “Financial Sector Reform Programs (FSRP)” was put into operation in the early 1990s. The mission of the FSRP was to eliminate distortions from the financial sector.

Liberalization of interest rates and indirect control in monetary management were the main objectives of the program through privatization (allowing new private commercial banks to operate) and denationalization (selling out government banks to private entrepreneurs) of the financial institutions (as well as other real sector enterprises) started well before (in 1983) the adoption of stabilization and structural adjustment program by Bangladesh Government.[2]

Macroeconomic performance in Bangladesh shows considerable stability . Bangladesh was enjoying relatively less volatile environment in the real GDP growth with the 0.54 and 0.30 percent volatility during the periods from 1980 -2014. Bangladesh has adopted reforms measures in monetary, banking sector to increase the effectiveness of monetary policy during these periods. In particular, Bangladesh had taken a range of economic and financial sector reforms since the 1980s with acceleration in the 1990s, thus transmission of monetary policy and its effectiveness has improved considerably. Overseas employments accounts for the 10 percent of GDP in Bangladesh. The major import items are capital machinery, petroleum oil, iron, raw cotton etc. Bangladesh has current account surplus during these periods.

III.2 Monetary Policy Framework in Bangladesh

Bangladesh Bank was established according to the Bangladesh Bank order, 1972. Bangladesh bank has similar mandate of stabilizing domestic monetary value and the exchange rate of the respective countries vis-à-vis foreign currencies, promoting a high level of production, employment and real income and encouraging and promoting the full development of the productive resources of the country. According to the Bangladesh Bank order, 1972, Bangladesh Bank has authorized to manage monetary and credit system of Bangladesh with a view to stabilizing domestic monetary value and maintaining a competitive external par value of the Bangladesh Taka towards fostering growth and development of country's productive resources in the best national interest, which is substituted by the Bangladesh Bank (Amendment) Act, 2003.

In May 2003, a significant shift in the policy regime took place when Bangladesh entered into the flexible exchange rate regime. In 2002, Bangladesh gradually moved to more open market operations by introducing Repurchase (Repo) agreement and reverse repurchase agreement in 2003 to inject and absorb liquidity from the money market. Since 2006, BB has been announcing half-yearly Monetary Policy Statements (MPS) to anchor inflation expectations of economic agents and the

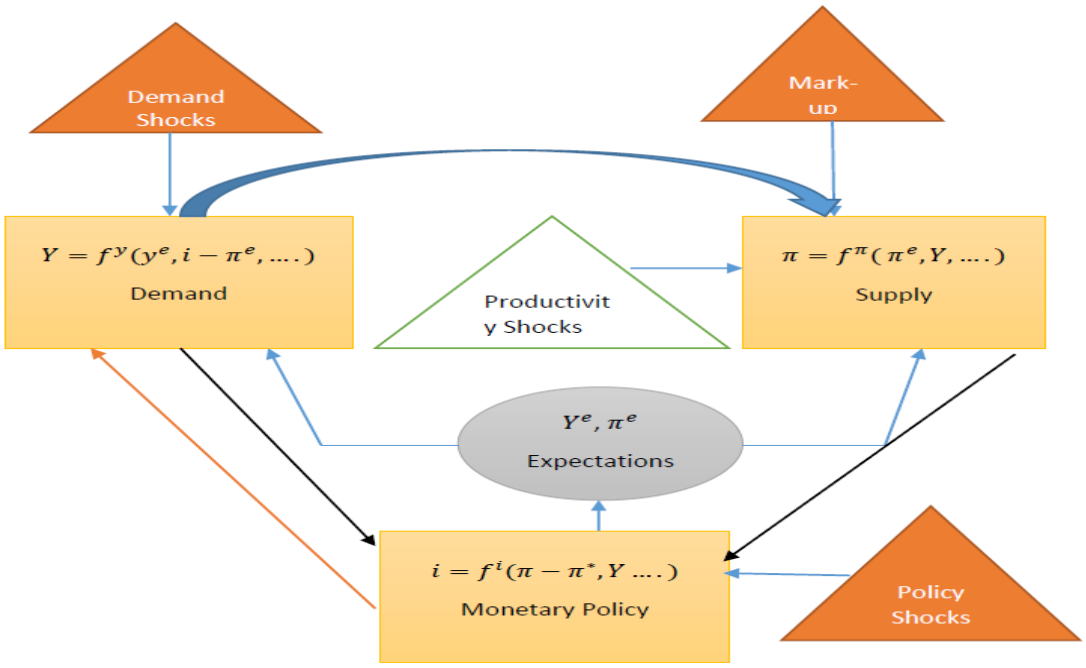
[2]*Financial Liberalization Theory of McKinnon and Shaw was the theoretical background of the Financial Sector Reform Program (FSRP)in Bangladesh. McKinnon and Shaw, in their works, argued in favor of removing distortions from the economy imposed by regulatory government policies. They proved that liberalization policy would make the financial system more efficient and effective. In line with this policy suggestion, the FSRP was designed to liberate the economy from government control, bring indirect control in monetary policy, enhance efficiency of public and private banks, and restoring order in the financial sector. The main targets of the Financial Sector Reform Program (FSRP) are outlined below: Liberalization of interest rates; Indirect monetary management; Implementation of capital adequacy requirement of commercial banks; Introduction of new policies for loan classification; Modernization of the banking sector and introduction of updated accounting system; Revision of the legal structure of financial sector; Development of capital market; Strengthening central bank's supervision; Improvement of overall management of the banking sectors with special emphasis on credit management; and Computerization of the central bank and nationalized commercial banks.*

general public. Currently, the formation of Monetary Policy Stance is based on extensive stakeholder consultations from the grassroots level up to the level of experienced professionals including past Finance Ministers /Advisers / Governors, think tanks and trade bodies. Bangladesh Bank has outlined the monetary policy stance through the Monetary Policy Statement based on an assessment of global and domestic macroeconomic condition and outlook.

IV. The Model

RAMSES (Riksbank Aggregate Macro Model for Studies of the Economy in Sweden) have been used for forecasting and policy analysis in Sweden since 2005. Following Sveriges Riksbank (RAMSES), we assume that Bangladesh macro economy is built around three interrelated blocks: a demand block, a supply block, and a monetary policy block. In the supply, demand and monetary policy blocks have economic actors from household, firms, governments and the monetary authority. The equations define these blocks derived from micro-foundations. The agents from these sectors interact in the market that clears every period, which lead to the "general equilibrium". The basic features of DSGE models are the dynamic interaction between the blocks. Expectations about the future is a crucial determinant of today's outcomes.

The Basic Structure of the Model



Source: Sveriges Riksbank (RAMSES), 2010.

The Demand Block

- The demand block, the real activity (Y) is modeled as a function of ex-ante real interest rate and the expectations of the future action.
- The central idea of this block is that when the real interest rate is high household and firms would prefer to save than consume and invest.

- People are willing to spend more when future prospects are promising, regardless of the level of interest rates.

The Supply Block

- In the supply block, the line connecting demand block to supply block show that the degree of activity emerging from the demand block, which is a critical input in the determination of inflation.
- The expectation of future inflation plays a significant role in the determination of inflation. In boom period, when the level of economic activity is high, firm increase wages to induce employees to work longer hours that in turn increases the marginal cost, putting pressure on prices and generating inflation.

Monetary Policy Block

The demand and supply blocks determine output and inflation that in turn feed into the monetary policy block. The equation describes how the central bank sets the nominal interest rate, usually as a function of inflation and real activity. The central bank raises short-term interest rates when the inflation rises, and the economy is overheating as well as lower it in the presence of economic slack. In that way, monetary policy affects the real activity and through it inflation. The policy rule closes the circle. This gives us a complete model of the relationship between three key endogenous variables: output, inflation, and the nominal interest rate.

Methodology-Bayesian

- Two building blocks - priors and likelihood functions - are tied together by Bayes' rule. We can combine the prior density and the likelihood function to get the posterior density.
- First, Priors are described by a probability density function.
- Second, the likelihood function represents the density of the observed data given the model and its parameters.
- One can assume potential priors by comparing the features and stylized facts of developed and developing economies.
- In some cases, we used the same prior's means as in previous studies but chose larger or smaller standard deviations based on country perspectives, thus allowing the data to determine the parameters location.

Dynare is a Matlab frontend to solve and simulate dynamic models. Considering the lack of knowledge of central bank's policy reaction function we used distributions as a standard open economy model for the smoothing coefficient and the forward-looking parameters and the feedback parameters. For the shock process, relatively larger prior means are chosen since Bangladesh is a small open economy and subject to large swings in the macroeconomic variables.

Data

To estimate the parameters of the DSGE model, we used the data over the period 1991.Q1-2014.Q2 (Quarterly) for Bangladesh. Quarterly data were de-seasonalized with Eviews X-11 program. For working with the model, the de-seasonalized logarithmic data were then filtered, with the Hodrick-Prescott (HP) Filter or by de-trending. HP filter real variables and de-trend nominal variables.

Central Bank Reaction Function: Taylor Rule

In economics, a Taylor rule is a monetary-policy rule that stipulates how much the central bank should change the nominal interest rate in response to changes in inflation, output, or other economic conditions. In particular, the rule stipulates that for each one-percent increase in inflation, the central bank should raise the nominal interest rate by more than one percentage point. This aspect of the rule is often called the Taylor principle.

According to Taylor's original version of the rule, the nominal interest rate should respond to divergences of actual inflation rates from target inflation rates and of actual Gross Domestic Product (GDP) from potential GDP:

$$\mathbf{i_t = \pi_t + r_t* + a_\pi(\pi_t - \pi_t*) + a_y(y_t - y^-_t)}$$

In this equation, i_t is the target short-term nominal interest rate (e.g. the federal funds rate in the US, the Bank of England base rate in the UK), π_t is the rate of inflation as measured by the GDP deflator, π_t is the desired rate of inflation, r_t is the assumed equilibrium real interest rate, y_t is the logarithm of real GDP, and y^-_t is the logarithm of potential output, as determined by a linear trend.

In this equation, both a π and a y should be positive (as a rough rule of thumb, Taylor's 1993 paper proposed setting $a_\pi = a_y = 0.5$. That is, the rule "recommends" a relatively high interest rate (a "tight" monetary policy) when inflation is above its target or when output is above its full-employment level, in order to reduce inflationary pressure. It recommends a relatively low interest rate ("easy" monetary policy) in the opposite situation, to stimulate output. Sometimes monetary policy goals may conflict, as in the case of stagflation, when inflation is above its target while output is below full employment. In such a situation, a Taylor rule specifies the relative weights given to reducing inflation versus increasing output.

The Taylor principle

By specifying $a_\pi > 0$, the Taylor rule says that an increase in inflation by one percentage point should prompt the central bank to raise the nominal interest rate by more than one percentage point (specifically, by $1 + a_\pi$, the sum of the two coefficients on π_t in the equation above). Since the real interest rate is (approximately) the nominal interest rate minus inflation, stipulating $a_\pi > 0$ implies that when inflation rises, the real interest rate should be increased. The idea that the real interest rate should be raised to cool the economy when inflation increases (requiring the nominal interest rate to increase more than inflation does) has sometimes been called the Taylor principle.

Taylor explained the rule in simple terms using three variables: inflation rate, GDP growth, and the interest rate. If inflation were to rise by 1%, the proper response would be to raise the interest rate by 1.5% (Taylor explains that it doesn't always need to be exactly 1.5%, but being larger than 1% is essential). If GDP falls by 1% relative to its growth path, then the proper response is to cut the interest rate by .5%.

Nelson (2000) estimates simple interest rate reaction function for different UK monetary policy regime from 1972 to 1997. Author carries out estimation for five different policy regimes and applies quarterly data for the regime with four or more years and monthly data for the regime less than four years in length. The paper uses OLS and IV method to carry out necessary estimation. The

outcome of the estimations shows different situation for different regimes. Estimation shows that 1972-76 period of extremely high inflation in UK is characterized by a near-zero response of nominal interest rates to the inflation rate. On the other hand the result of the study exhibits that periods of relatively restrictive monetary policy are not necessarily characterized by a greater than one-for-one long-run response of the nominal interest rate to inflation. Rather, the tightening of policy is sometimes manifested in a sharp increase in the average level of the real interest rate.

Patra and Kapur (2012) examines the performance of McCallum rule, Taylor rule and hybrid rules over the quarterly data during April 1996 - March 2011 for India to shed light on the operational feasibility of each rule in the Indian economy and the degree of commitment of policy authorities to any rules and variations therein. The paper uses both the forward looking and backward looking versions to examine the rule. Authors apply General Method of Moments (GMM) for estimating forward looking specifications of monetary policy rules when Ordinary Least square for estimating backward looking/contemporaneous specification of the policy rules. The paper encompasses real effective exchange rate in the used models in addition to output, inflation, industrial output, policy rate etc. Outcome of the paper shows that having an interest rate instrument when a nominal output growth is objective, forward looking specifications of both rules and their hybrid form outperform contemporaneous and backward looking editions.

Perera and Jayawickrema (2014) estimate alternative monetary policy reaction functions for Sri Lanka over the period of 1996Q1 - 2013Q2 with a view to characterize the monetary policy decision making process of the country applying Taylor rule. Authors applied OLS for estimation of backward looking and contemporaneous models and GMM for forward looking model. Authors incorporated exchange rate as a variable in the monetary policy reaction function. Conclusion of the paper indicates that a forward looking specification of the reaction function provides the most appropriate characterization of Sri Lankan monetary policy making among the alternative specifications. The higher focus on price stability is evident from the increased size of the coefficient on inflation gap found in the paper. The preference of central bank is also evident from the research result of the study through the higher response of monetary policy to fluctuations in output than the fluctuation in inflation.

V. Empirical Results

Table 1 show the results derived from DSGE model estimating central bank reaction functions for Bangladesh. The central bank reaction function using Taylor rule shows that current interest rate depends on lag interest rate, as well as a function of the deviation of inflation from its target rate, and an output gap measure. Table 1 shows that Taylor lag is a lag interest rate, which is assumed to be 0.50 for the developing countries. However, in case of Bangladesh the magnitude turns out to be 0.89, which implies that Bangladesh Bank use backward looking strategy while determine current short term interest rate.

The estimated coefficient of inflation (taylor_inf) and its target rate is 1.77 which is also higher than the value of 1.50 suggested by Taylor implying that Bangladesh Bank put more emphasis on inflation i.e., if inflation increase by i percentage points the short term nominal interest rate should increase by 1.77 percent . The coefficient of output gap (taylor_y) is turns out to be below its prior mean which is 0.45 implying that if the coefficient of output gap is below the number suggested by Taylor than the central bank should lower the short term nominal interest rate. The parameter

RHO_PXX, RHO_YX and psi_price are the autoregressive parameters of terms of trade, output and Calvo price which are also higher for Bangladesh. Therefore, the bottom line of this central bank reaction function is Bangladesh Bank should raise interest rate by 1.77 percent while lower interest rate if the output is lower than is potential trend and also *Bangladesh put more emphasis on stabilizing inflation, i.e., price stability.*

Table 1

Prior and Posterior estimates

Coefficient

Estimates	Priors Mean	posteriors Mean	90% HPD interval		priors Dist.	posteriors Std. Dev.
taylor_lag	0.50	0.89	0.87	0.90	beta	0.20
taylor_inf	1.50	1.77	1.49	2.04	norm	0.25
taylor_y	0.50	0.45	0.38	0.50	beta	0.20
RHO_PXX	0.50	0.94	0.92	0.95	beta	0.20
RHO_YX	0.50	0.51	0.18	0.81	beta	0.20
psi_price	0.50	0.59	0.51	0.67	beta	0.20

Notes: RHO_PXX, RHO_YX and RHO_YX, are the autoregressive parameters of terms of trade, output and Calvo price.

Standard Deviation of Shock

The standard deviation of shocks implies that which shock is more volatile for Bangladesh. Standard deviation measures the volatility of shocks. In this regard, the estimated volatility for the productivity shock is 0.11 which is much higher than its prior mean i.e., our expectations of 0.05 which implies that in Bangladesh productivity shock fluctuate more than monetary shock which is 0.02 and 0.04 of terms of trade shock. Therefore, the results implied that *Productivity shock is more volatile than monetary policy shock in Bangladesh.*

Table 2
Standard deviation of shocks

Estimates	Priors Mean	Posteriors Mean	90% HPD interval		priors Dist.	posteriors Std.Dev.
Monetary Shock	0.05	0.02	0.01	0.02	invg	4.00
Terms of trade shock	0.05	0.04	0.04	0.05	invg	2.00
Productivity shock	0.05	0.11	0.09	0.12	invg	4.00

Shocks and Observables

Three macroeconomic variables real GDP, inflation and the short-term interest rates used as observables. The model contained three stochastic shocks: namely: Monetary Policy Shocks, Productivity and Terms of Trade Shocks (M, PXX, and YX).

Conditional Variance Decompositions.

The conditional shock decomposition of GDP showed that monetary policy shock dominated the variability of GDP at all of the horizons. The other shock which also matter is productivity. The conditional shock decomposition of inflation showed that monetary policy shock (epsilon_M) dominated the variability of inflation at all of the horizons followed by the productivity shock (epsilon_YX).

Table-3:Conditional Variance Decompositions

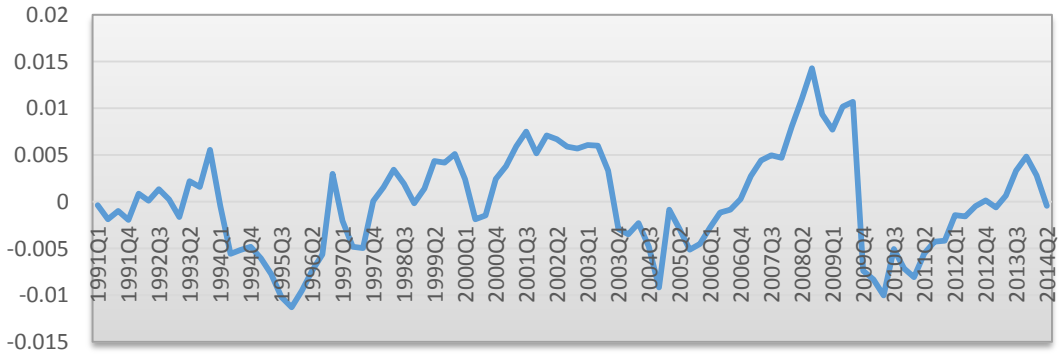
Shock/Quarter	1	2	3	4	10
GDP					
epsilon_M	0.60	0.65	0.66	0.66	0.68
epsilon_PXX	0.69	0.08	0.09	0.08	0.08
epsilon_YX	0.33	0.29	0.27	0.27	0.25
Inflation					
epsilon_M	0.20	0.68	0.70	0.70	0.71
epsilon_PXX	0.06	0.06	0.06	0.07	0.07
epsilon_YX	0.11	0.24	0.21	0.21	0.21

Source: Authors own Estimation.

Smoothed Shocks

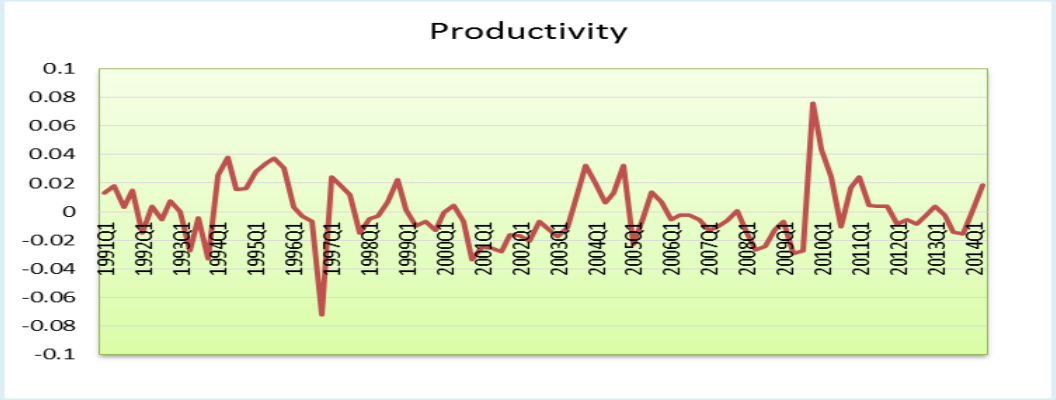
The smoothed shocks of monetary policy show that the economy of Bangladesh hit hurt by an adverse monetary policy shock during the period of 1994 to 1997 and also 2003 to 2006 during the periods of high commodity price and oil price increase and also after the global financial crisis.

Chart-2: Smoothed Shocks : Monetary Policy



The productivity shock was higher during 1994 to 1996, 2003 to 2005 and 2010.

Chart-2: Smoothed Shocks: Productivity



VI. Conclusion

The intention of this study is to estimate the central bank reaction function for Bangladesh. Using quarterly data for the sample period from 1990 to 2014, this paper found that central bank of Bangladesh put more emphasis on inflation stabilization over growth. The results also supported by the conditional variance decompositions, smoothed shocks of GDP and inflation. The DSGE model captures the policy shocks from the data well. The main lesson we derive from the study is that the to control inflation and increased GDP monetary transmission channel could be used because monetary policy shock affects both output and inflation. Therefore, monetary policy plays a significant role in the macroeconomic stability of Bangladesh.

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