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The Director
Research Department
Bank of Botswana
Private Bag 154
Gaborone

Or, e-mail to radipotsanem@bob.bw

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2011 MONETARY POLICY STATEMENT MID-TERM REVIEW

1. Introduction

1.1 The Mid-Term Review (MTR) of the 2011 Monetary Policy Statement (MPS) evaluates progress made in the first half of the year in maintaining inflation within the 3 – 6 percent medium-term objective range. The review also assesses key financial and economic developments that may influence the inflation outlook and the likely monetary policy response in the latter part of the year to maintain price stability. Publishing the Bank's inflation outlook and the prospective monetary policy stance fosters public expectations of low, sustainable and predictable inflation.

1.2 The Bank's definition of price stability is when inflation is within the medium-term objective range of 3 – 6 percent that is consistent with sustainable long-run growth of the economy. Moreover, low inflation that is close to trading partner inflation contributes to the stability of the real effective exchange rate (REER) which, in turn, promotes international price competitiveness of domestic producers and economic growth.

1.3 As anticipated at the beginning of the year, economic recovery continued in the first half of 2011, albeit with below-trend output and associated low demand pressures on inflation. Nevertheless, as earlier projected, inflation rose in the first half of 2011 from 7.4 percent in December 2010 and peaked at 8.5 percent (in February and March 2011), before falling to 7.9 percent in June.[1] The upside influence on inflation in the first half of the year included adjustment of administered prices (electricity tariffs and fuel prices) and fees for private schools, while the dissipation of the effects of last year's increase in value added tax (VAT) and the reduction in telecommunications tariffs helped to lower inflation. The Bank Rate was unchanged at 9.5 percent in the first half of 2011, following a 50 basis point reduction in December 2010, as the medium-term outlook for price developments was positive. Going forward, it is anticipated that inflation will remain above the objective range in the short term, but should fall within the 3 – 6 percent medium-term objective range in the second half of 2012.

1.4 World economic recovery is projected to continue at a moderate pace, with a likelihood of further weakness. In part, the moderation in world output expansion reflects the impact of aggressive fiscal consolidation measures across major economies. However, the degree to which the fiscal measures will be successful in reducing budget deficits and bringing sovereign debt to sustainable levels remains uncertain for several countries. Meanwhile, continuing political unrest in North Africa and the Middle East poses a risk to international oil prices and supply. World GDP growth is, therefore, projected to decelerate from 5.1 percent in 2010 to 4.3 percent in 2011 and recover to 4.5 percent in 2012, mostly underpinned by strong growth in emerging market and developing economies.

2. Monetary Policy Framework

2.1 The Bank's monetary policy objective is to attain price stability, and this is defined as inflation in the medium-term objective range of 3 – 6 percent. A low and predictable level of inflation contributes to sustainable economic growth and development by promoting savings mobilisation, productive investment and international competitiveness of domestic producers. A sustained rise in inflation is not conducive to economic growth as it discourages financial saving, generates investment uncertainties and erodes the purchasing power of incomes, thereby reducing living standards. In contrast, a prolonged period of rapidly falling inflation could signal a decline in economic performance, which could require monetary policy easing to stimulate growth.

2.2 The Bank's policy framework entails a forecast-based and forward-looking monetary policy strategy that is focused on the medium term. The medium term, defined as a three-year rolling period, is considered a reasonable time frame over which monetary policy can affect price developments. The medium-term forecast for inflation is derived from an assessment of prospective developments for various determinants of inflation, including domestic demand conditions, changes in prices of imports and exchange rates, adjustment of administered prices and consumption taxes, as well as public expectations with respect to the rate of price changes.

2.3 The Bank uses interest rates and open market operations to influence demand for goods and services (relative to supply capacity) and, ultimately, price developments in the direction consistent with price stability. In this respect, the policy response to inflationary pressures is based on an evaluation of the sources of inflation and the likely impact on future price developments. In particular, a distinction is made between factors that have a transitory impact (over a period of up to one year)[2], such as changes in administered prices and consumption taxes, and those that are likely to have an enduring influence on inflation, such as changes in demand conditions, which are subject to monetary policy influence. This approach to policy formulation facilitates appropriate and timely

1 Inflation was marginally lower at 7.8 percent in July.

2 Monetary policy does not normally respond to these factors since the medium term is the relevant time frame for monetary policy to have an effect on the level of prices.

responses to any forecast deviation of inflation from the objective range. In addition, the alternative measures of inflation, viz., headline inflation, 16 percent trimmed mean and inflation excluding administered prices, play an important role in explaining the sources of inflation.

2.4 An important benefit of achieving the inflation objective is the contribution to the stability of the REER, which supports international competitiveness of domestic industries. In the event that the inflation objective remains higher than forecast inflation of trading partner countries, the crawling band exchange rate arrangement facilitates a gradual downward adjustment of the nominal effective exchange rate (NEER) in order to maintain stability of the REER.

2.5 The Monetary Policy Committee (MPC) meets every six weeks. The Committee reviews inflation forecasts and the monetary policy stance in order to evaluate the current and prospective changes in economic developments that influence the outlook for inflation. This facilitates a timely response to anticipated economic and other events that would result in a significant and lasting deviation of inflation from the objective range.

2.6 The Bank's monetary policy framework and implementation are regularly communicated to the public through the publication of the annual Monetary Policy Statement, Mid-Term Review of the Monetary Policy Statement and Press Releases following every MPC meeting. Such communication fosters policy transparency, accountability and credibility. It also enhances the degree to which the Bank is likely to succeed in influencing expectations of price stability.

3. Inflation in the first half of 2011

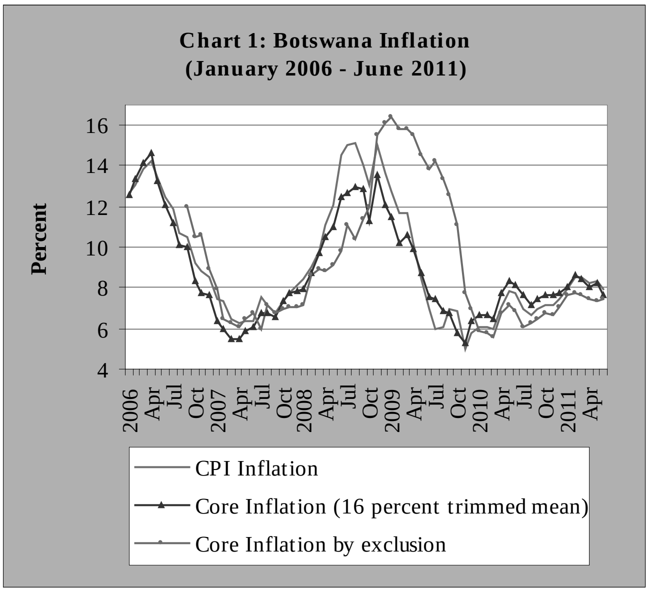
3.1 Average inflation in trading partner countries increased from 2.8 percent in December 2010 to 4.3 percent in June 2011 due to higher commodity prices. In South Africa, headline inflation, which is the target measure for the South African Reserve Bank, rose from 3.5 percent in December 2010 to 5 percent in June 2011, mostly reflecting the increase in the cost of food and upward adjustment of administered prices. This meant that inflation remained within South Africa's target range of 3 – 6 percent in the first half of 2011. For the SDR countries, comprising USA, UK, Japan and the euro zone, inflation rose from 1.8 percent to 3.2 percent in the same period (Appendix Chart A3 shows inflation rates for SDR countries).[3]

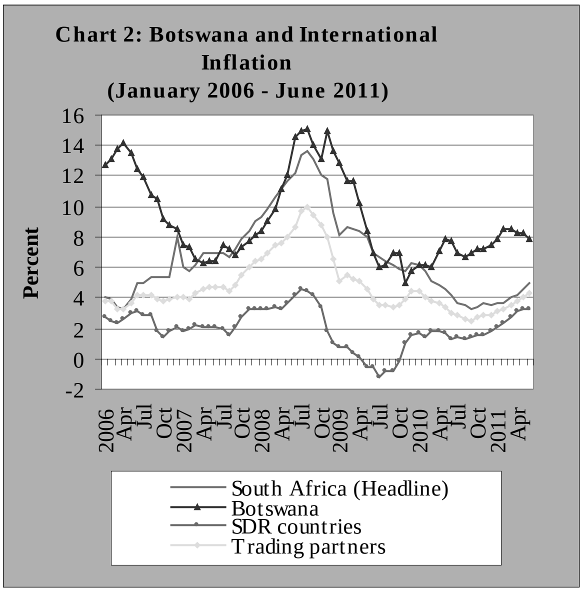
3.2 Domestic inflation averaged 8.3 percent in the first quarter of 2011 (from 7.3 percent in the last quarter of 2010) mainly due to faster annual increase in the cost of food and fuel and upward adjustment of fees for private schools. Subsequently, inflation fell marginally, to an average of 8.1 percent in the second quarter of 2011, held up by the increase in fuel prices (in April and May), which offset the downward trend resulting from the dissipation of the impact of the previous year's increase in VAT. Moreover, electricity tariffs were also increased, more or less at the same rate as in 2010, thus leading to a neutral impact on inflation. Charts 3 and 4 above show the contribution of food and fuel price developments to overall inflation. In terms of monthly developments, inflation increased from 7.4 percent in December 2010 to 8.5 percent in February and March 2011. Thereafter, inflation declined to 8.2 percent in April and 7.9 percent in June. Inflation (excluding administered prices) rose from 7.1 percent in December 2010 to 7.4 percent in June 2011, while the 16 percent trimmed mean inflation eased slightly from 7.7 percent to 7.6 percent in the sam

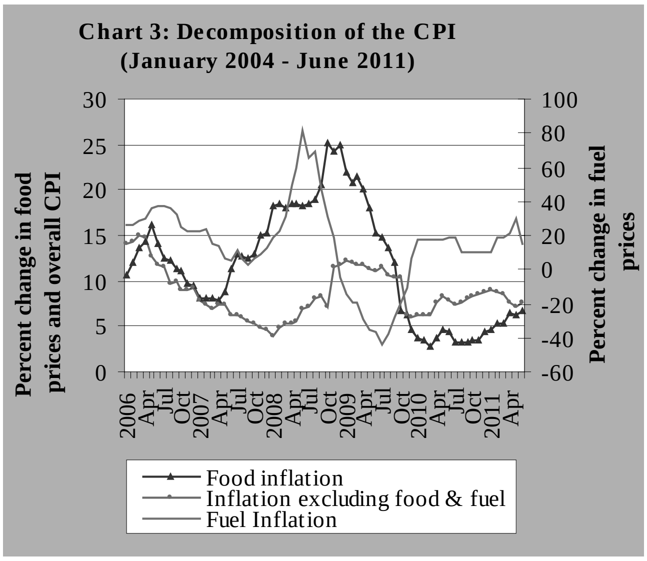
3.3 By tradeability, imported tradeables inflation rose from 9.3 percent in December 2010 to 9.6 percent in June 2011. Inflation for domestic tradeables also increased from 5 percent in December 2010 to 6.5 percent in June 2011. Overall, the all tradeables inflation rose from 7.7 percent to 8.5 percent in the same period. Meanwhile, the year-on-year increase in prices for non-tradeables fell from 6.9 percent in December 2010 to 6.4 percent in June 2011, thus reflecting the downward revision of mobile phone tariffs, while last year's increase in the cost of medical services also dropped from the inflation calculation.

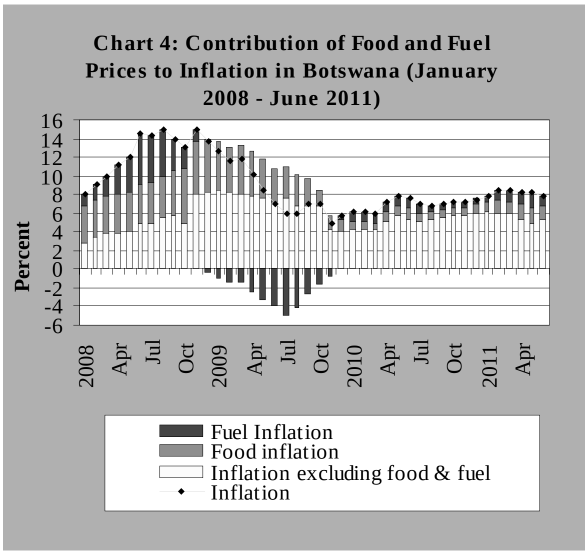
3.4 Domestic demand pressures on inflation were restrained in an environment of below-trend domestic economic activity and modest monetary expansion. Growth in disposable incomes was also sluggish, given the freeze in public service salaries and the increase in VAT. The moderate increase in money supply reflects the impact of the slower rate of increase in government expenditure and net foreign assets, compared to a sharp acceleration of 18 percent in credit. Following the annual growth rate of 7.2 percent in 2010, GDP contracted by 2.2 percent in the first quarter of 2011 (1.1 percent increase in the fourth quarter of 2010), due mostly to a seasonal fall in mining production. Overall, GDP for the twelve months to March 2011 was 4.9 percent higher than the corresponding period in 2010, with a small 0.6 percent increase for the mining sector (reflecting the effect of production planning), while non-mining GDP rose by 6.9 percent in the same period. The rapid annual growth in construction (19.4 percent), agriculture (12.9 percent), manufacturing (9.5 percent), trade (8.3 percent) and transport and communications (5.9 percent) contributed to the healthy non-mining sector expansion.

3 There was considerable variation in price developments across the constituent economies. For instance, throughout 2010 and in the first half of 2011, UK inflation was significantly higher than that of other SDR countries, but this was partially offset by deflation in Japan.









Source: Statistics Botswana (previously Central Statistics Office) and Bank of Botswana

3.5 Private sector credit growth in the six months period to June 2011 was 11.3 percent, much higher than the 5.6 percent for the corresponding period in 2010, thus reflecting recovery in economic performance. In this period, household borrowing increased from 4.3 percent in 2010 to 5.6 percent, while lending to private businesses rose by 19.4 percent, compared to 7.5 percent in 2010. In the year to June 2011, credit to the private sector increased by 18 percent, a higher growth rate than the 16.6 percent in the twelve months to June 2010. Credit growth accelerated by 13.4 percent and 23.6 percent in May and June, respectively, due to a marked increase in borrowing by businesses, but also because of the low base associated with the decrease in credit to the business sector in May 2010. However, money supply expansion was moderate at 8.6 percent in the year to May 2011, dampened by sluggish growth in both government expenditure and net foreign assets.

3.6 Total government recurrent and development spending contracted by 0.8 percent in the twelve months to March 2011, compared to a budgeted 3.7 percent reduction (announced in the 2010 Budget Speech) and 9.6 percent growth for the corresponding period in 2010. Development expenditure contracted by 12.6 percent in the fiscal year ending March 2011, while recurrent spending rose by 5.1 percent. A moderate increase of 1.4 percent in total government spending is budgeted for 2011/12, including a substantial 19.1 percent decline in development expenditure. So far, in the first three months of the fiscal year 2011/12, total recurrent and development spending was 6.5 percent higher than in the corresponding period in 2010/11. The low rate of increase in spending reflects the Government's commitment to prioritising expenditure on projects and returning to a balanced budget in 2012/13. At the same time, there are efforts towards raising revenue, including increasing some of the levies for government services and higher dividends from parastatals. While desirable, the expenditure rationalisation to eliminate the fiscal deficit will, to some extent, reduce the expansionary effect of government spending on other sectors and the broader economy.

4. Monetary Policy Implementation in the First Half of 2011

4.1 Globally, monetary policy was conducted in the context of expectations for moderate and uncertain economic recovery, as well as divergent growth rates across regions and countries. In particular, it was anticipated that economic activity would be restrained by the impact of fiscal consolidation measures in some major economies, while emerging market and developing economies would grow at a faster rate, underpinned by both domestic demand and external trade. Meanwhile, it was expected that global inflationary pressures would generally be restrained owing to low levels of capacity utilisation, high rates of unemployment and well-anchored inflation expectations in major economies. Nevertheless, there were signs of inflationary pressures in emerging market economies and upside risks to inflation associated with higher international oil and food prices.

4.2 In the circumstances, the general thrust of monetary policy in major economies was accommodative, with some central banks maintaining policy interest rates at the low levels set during the global economic crisis (Federal Reserve Bank, Bank of England and Bank of Japan)[4]. On the other hand, emerging market economies, including China, India[5] and Brazil maintained a policy tightening stance to curb inflationary pressures. Thus, capital flows were tilted towards higher yielding emerging market economies, leading to fears of continuing global imbalances and risk of competitive currency devaluations.

4.3 In Botswana, monetary policy was implemented against the background of economic recovery as buoyed by an improvement in international commodity markets and sustained robust performance of the non-mining sectors. Nevertheless, it was estimated that output would be below trend, thus implying a non-inflationary negative output gap (Appendix II). Furthermore, there were indications that domestic demand pressures would be modest, given the moderate pace of monetary expansion associated with the sluggish growth in both personal incomes and government spending.

4.4 Generally, inflation was forecast to remain above the objective range in the short term, with prospects for attaining price stability in the medium term. In the circumstances, the medium-term inflation outlook was positive, and was in line with the prognosis for the first half of 2011. The Bank Rate was, therefore, maintained at 9.5 percent in the first half of 2011. Given the unchanged monetary policy stance, there were marginal fluctuations in money market interest rates in the same period (Chart 6), mainly reflecting changes in the bidding preferences of primary counterparties at auctions[6]. As such, the yield on the 14-day Bank of Botswana Certificate (BoBC) increased slightly from 6.56 percent at the end of December 2010 to 6.57 percent in June 2011, while the 3-month BoBC yield eased from 7.15 percent[7] to 6.64 percent in the same period. The prime lending rate of commercial banks was constant at 11 percent between December 2010 and June 2011, while the 88-day deposit rate fell from 5.49 percent in December 2010 to 5.23 percent in June 2011.

4.5 In order to reduce the amount of excess liquidity in the banking system and, therefore, contain the cost of monetary operations, the primary reserve requirement was raised from 6.5 percent to 10 percent of Pula deposits at commercial banks effective July 1, 2011. Normally, an increase in the primary reserve requirement ratio implies monetary policy tightening. However, in this instance, the increase is unlikely to constrain supply of credit as, in essence, the funds mopped up through BoBCs are excess to what is required for productive lending.

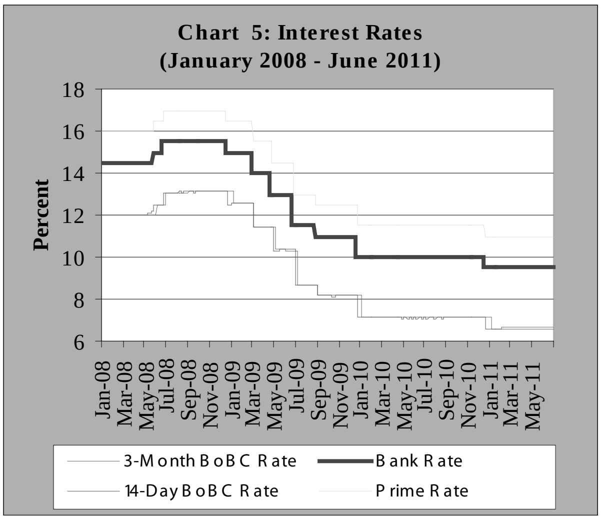
4.6 As a result of the increase in inflation between December 2010 and June 2011, real interest rates fell and were mostly negative. The 3-month BoBC real interest rate fell from -0.23 percent in December 2010 to -1.17 percent in June 2011. Similarly, the real interest rate for the 14-day BoBC fell from -0.78 percent in December 2010 to -1.23 in June 2011. At the same time, the real prime lending rate fell from 3.35 percent in December 2010 to 2.87 percent in June 2011, while the real 88-day deposit rate declined from -1.78 percent to -2.48 percent in the same period.

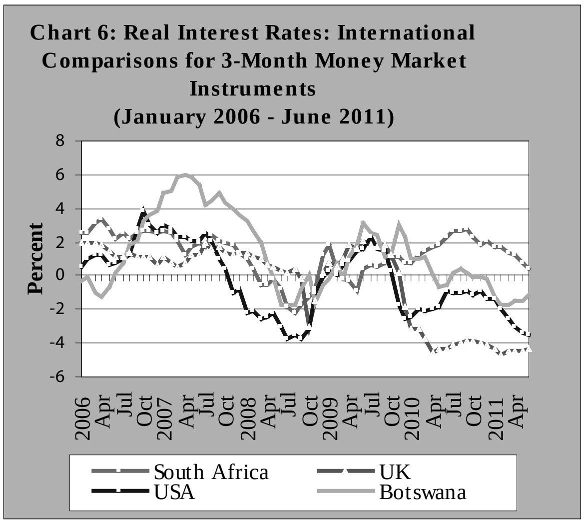
4 The European Central Bank, which had also maintained the policy interest rate unchanged from the low level set at the trough of the global recession, increased interest rates in April and July 2011, to forestall inflationary pressures; a further increase is expected later in the year.

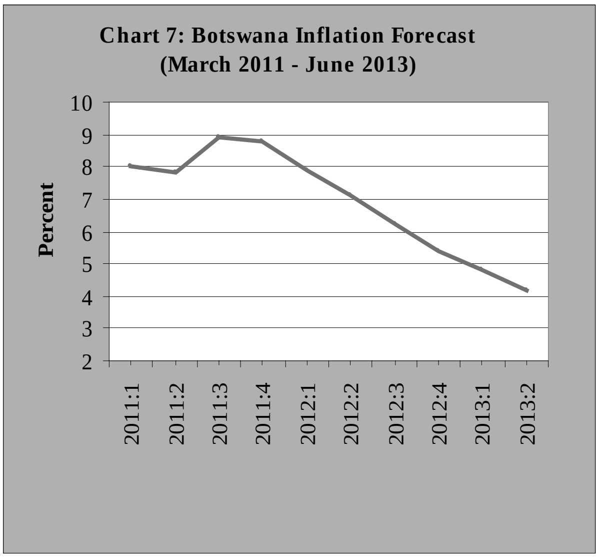
5 Inflation rates for China and India are shown in Appendix Chart A4.

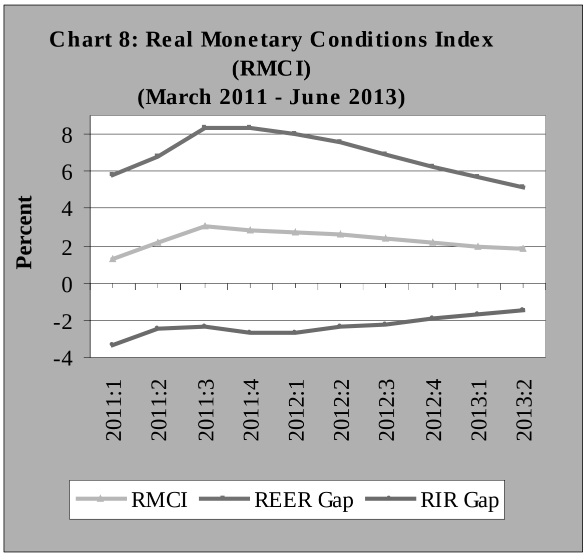
6 Quoted yields are based on the weighted average of the winning bids at auction.

7 The 3-month BoBC is auctioned once at the beginning of each month, and the rate stated here was for the result of the auction that was held immediately prior to the MPC meeting in December.









Source: Bank of Botswana

4.7 As domestic inflation was higher than the average inflation of trading partner countries, the nominal exchange rate of the Pula crawled downwards. Consequently, the nominal effective exchange rate depreciated by 1.3 percent in the six months to June 2011. Bilaterally, the Pula depreciated by 4.9 percent against the SDR (weakening by 1.4 percent against the US dollar), while it appreciated by 1.2 percent against the rand. The REER[8] of the Pula appreciated by 1.1 percent in the six months to June 2011 due to the positive inflation differential between Botswana and its trading partner countries; thus, the rate of crawl only partially offset the inflation differential.

4.8 Movements in interest rates and the Pula exchange rate are reflected in changes in the real monetary conditions index, which is a measure of the relative tightness or easiness of financing conditions in the economy. In the first half of 2011, the real interest rate gap was negative, thus implying easy financing conditions. However, this effect was more than offset by the restrictive positive real exchange rate gap. Overall, real monetary conditions were relatively tight, albeit stable throughout the first half of 2011.[9]

5. Medium-Term Inflation Outlook

5.1 The forecast for inflation entails an assessment of prospective developments in factors that affect domestic price movements, including demand-pull pressures resulting from real economic activity, imported inflation and other exogenous factors, such as changes in administered prices. The external influences on domestic prices include economic and financial developments in South Africa (Botswana's major trading partner) and global events, such as

8 The REER is calculated using Botswana's headline inflation, the weighted average inflation for SDR countries and South African headline inflation.

9 Real monetary conditions measure the relative easiness or tightness of monetary policy and gauge the effect that monetary policy has on the economy through changes in the exchange rate and interest rates. The real monetary conditions are measured by an index (RMCI) that combines, through a weighted average, the deviations of the real exchange rate and real interest rate from their trend values. Meanwhile, a positive change in the real effective exchange rate indicates an appreciation of the Pula against the basket of currencies (rand and SDR) in real terms.

changes in international commodity prices and demand in major markets.[10]

5.2 South Africa's GDP is projected to grow by 3.7 percent in 2011, compared to 2.8 percent in 2010. The main drivers of this forecast GDP expansion are improvements in the manufacturing and mining sectors and household consumption expenditure. Inflationary pressures are expected to remain subdued, but with an upward momentum. Although international food prices have levelled out, they remain a major risk to the inflation outlook, especially as South Africa's food price inflation lags global trends and, hence, a faster increase in food prices can be expected in the near term. Nevertheless, South African annual headline inflation is projected to remain within the 3 - 6 percent inflation target range for the whole of 2011.[11] In consideration of balanced risks to the inflation outlook, the South African Reserve Bank is expected to maintain the current monetary policy stance in the short term.

5.3 Global economic recovery is expected to moderate somewhat and remain uneven across countries and regions. World output is projected to expand by 4.3 percent in 2011 (compared to 5.1 percent in 2010), and to increase further by 4.5 percent in 2012. Growth is underpinned by strong performance in most emerging market and developing economies. The overall moderation in the global economic expansion reflects the impact of transitory factors in major economies, including supply-chain disruptions following the natural disaster in Japan and high commodity prices. Moreover, the continued aggressive fiscal consolidation measures intended to ensure long-term fiscal and debt sustainability in some major economies, as well as the enhanced supervision of financial sectors in major economies are likely to restrain growth in the short term. Furthermore, high rates of unemployment have a negative impact on business and consumer confidence and, thus constrain growth. Other downside risks to global economic activity arise from increasingly weaker output growth for the USA and renewed volatility of financial markets, including a decrease in the value of equities (stock markets) and an increase in yields for government debt, thus, potentially having a negative impact on economic performance.[12]

5.4 There are indications of reduced pressures on world inflation associated with moderation of commodity prices and continuing low levels of capacity utilisation and high unemployment rates in major economies. Overall, it is projected that inflationary pressures in the world economy will be restrained in the medium term, despite possible asset price bubbles in emerging market economies, including China and India. World inflation is forecast to increase from an average of 3.7 percent in 2010 to 4.5 percent in 2011. Forecast inflation in SDR countries is 2.8 percent and 2 percent for 2011 and 2012, respectively.

5.5 With regard to international commodity prices, it is projected that the international price of oil will rise by an annual rate of 34.5 percent in 2011 and fall by 1 percent in 2012, while food prices are forecast to stabilise at a higher level, but with a lower rate of price change. It is considered that the upward pressure on food prices has eased given improvement in crop harvests and lifting of the ban on export of grains by the Russia Federation. However, there are upside risks to world inflation, including uncertainty with regard to developments in international oil prices[13], given the ongoing political unrest in some oil producing countries of North Africa and the Middle East. Overall, it is expected that external price developments will have a benign influence on domestic inflation.

5.6 The stable inflation differential between Botswana and her trading partner countries implies maintenance of a modest rate of a downward crawl in 2011. However, market forecasts suggest that the rand will depreciate in the short term, with the resultant appreciation of the Pula against the South African currency exerting marginal downward influence on domestic inflation.

5.7 The recovery of the domestic economy is expected to be sustained going forward, reflecting mostly an improvement in external demand, and the continuing healthy performance of some of the non-mining sectors. Nevertheless, it is projected that output will remain below the long-term trend, with the resultant negative output gap[14] contributing to modest demand pressures on inflation in the medium term. In this

10 Forecasts for external variables are obtained mainly from the Reuters survey of forecasters.

11 This projection is derived from market consensus forecasts. However, the South African Reserve Bank forecasts that inflation will marginally breach the upper end of the target range in the fourth quarter of 2011 and first quarter of 2012, due to a lagged impact of the increase in food prices.

12 The sovereign credit rating agency, Standard and Poor's downgraded USA debt from AAA to AA+ on August 5, 2011, noting that the deficit reduction and debt ceiling package agreed by the authorities fell short of measures that are necessary to stabilise the Government's medium-term debt dynamics. In another development, Moody's Investor Service downgraded Portugal's credit rating to junk status, thus sparking renewed concerns over the sustainability of the European sovereign debt markets. There have also been concerns about sustainability of Spanish and Italian fiscal positions, in addition to the outstanding debt problems being experienced by Greece.

13 Although the international oil price (US light crude) fell from USD92 per barrel in January 2011 to USD90 per barrel in June, it fluctuated widely in the interim period. For example, the international oil price was as high as USD110 in March and USD113.69 (a 30-month high) in April, before falling to USD98 in June.

14 See a detailed description of the output gap measure in the Appendix.

context, the Business Expectations Survey for March 2011 shows that businesses are projecting a slower growth for the economy, and indicates a fall in overall business confidence from 67 percent in the September 2010 survey to 47 percent. The surveyed businesses anticipated a moderation in inflation towards the objective range.

5.8 The increase in administered prices is estimated to add 1.7 percentage points to inflation in the short term, with most of the effect dissipating from the second half of 2012. The effect of the fuel price increase in February, April and May 2011 (which contributed an estimated 1.04 percentage points to inflation) will continue into the first half of 2012. Similarly, in the absence of a further increase, the estimated 0.41 percentage points addition to inflation due to an increase in electricity tariffs will drop out of the inflation calculation in June 2012. Meanwhile, the August 2011 increase in transport fares and fuel prices are estimated to add 0.16 percentage points and 0.45 percentage points, respectively, to inflation going forward. Overall, inflation is forecast to remain above the objective range in the short term due to the impact of the increase in administered prices, a revised higher forecast for inflation in South Africa and the lagged impact of higher food prices. Expectations are that inflation will fall within the objective range in the second half of 2012 (Chart 7). The risks to the inflation outlook include any substantial increase in administered prices and government levies, as well as any increase in international oil and food prices beyond current forecasts.

6. Monetary Policy Stance

6.1 In line with the Bank's forward-looking, forecast-based framework, the Bank's monetary policy is predicated on an assessment of prospective medium-term economic performance, relative to the long-term trend (the output gap). Hence, the policy response takes into account the likely impact of economic activity and associated demand on future price developments (inflation forecast). Below-trend economic performance (negative output gap) is associated with reduced or low pressure on inflation and could signify a need to provide monetary policy stimulus to support economic growth, while economic activity that is above trend is likely to result in an increase in inflation and could require policy tightening to dampen inflation.

6.2 It is expected that economic activity will remain below trend in the medium term, influenced by moderation in global economic expansion and reduced government spending. Moreover, it is projected that demand and its impact on economic activity will be constrained by the slow growth in personal incomes, and the increase in administered prices and government levies which will have a negative impact on real disposable incomes. Against this background, it is expected that inflation will remain above the 3 – 6 percent objective range, largely due to transient factors, but it will converge to the objective range in the second half of 2012. The largely positive inflation outlook provides scope for maintaining the prevailing monetary policy stance, which should be supportive of economic recovery, in an environment where the impact of the expansionary fiscal policy is limited by the low level of government revenue.

6.3 In assessing the monetary policy stance, the Bank also considers developments in real interest rates and real exchange rates that define monetary conditions in the economy, which ultimately have an impact on domestic demand. Real monetary conditions tightened somewhat in the first half of 2011, largely due to real exchange rate developments, but this was partially offset by the maintenance of constant nominal interest rates. Looking ahead, the real exchange rate and real interest rates suggest an easing of real monetary conditions in the medium term (Chart 8). Therefore, the current state of the economy and expectations relating to the domestic and external economic outlook, along with the inflation forecast, suggest that the prevailing monetary policy stance would be consistent with the achievement of the 3 – 6 percent inflation objective in the medium term. This policy stance could, however, change in response to indications that any expectations of high inflation are becoming entrenched.

7. Summary and Conclusions

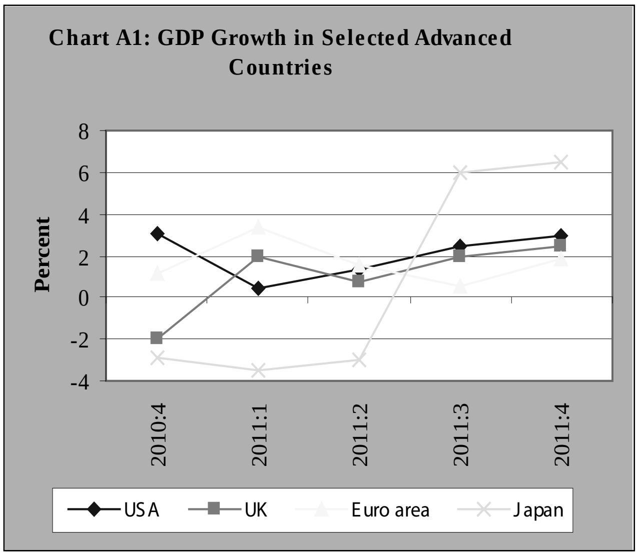
7.1 Inflation was above the objective range in the first six months of 2011, influenced mainly by the lingering impact of the increase in VAT in 2010 and the upward adjustment of electricity tariffs and fuel prices. Both the domestic demand and external inflationary pressures remained low. Given the positive medium-term outlook for price developments, the Bank Rate was unchanged between December 2010 and June 2011.

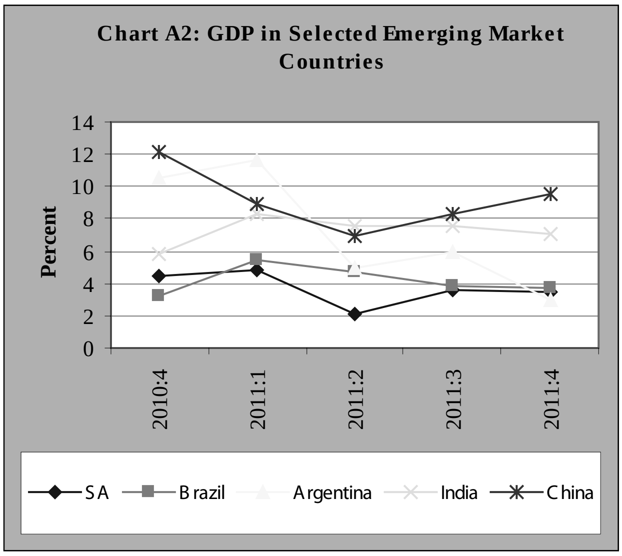
7.2 Going forward, external price pressures should remain generally benign against the background of restrained world economic activity, modest commodity price inflation and the dampening impact of low levels of capacity utilisation, high rates of unemployment and well-anchored inflation expectations in major economies. Domestically, subdued fiscal stimulus, sluggish income growth and below-trend performance of the economy will constrain demand pressures on inflation. The risks to the inflation outlook emanate from any possible large increase in administered prices and government levies, as well as higher inflation expectations engendered by the persistence of inflation above the objective range in the short term.

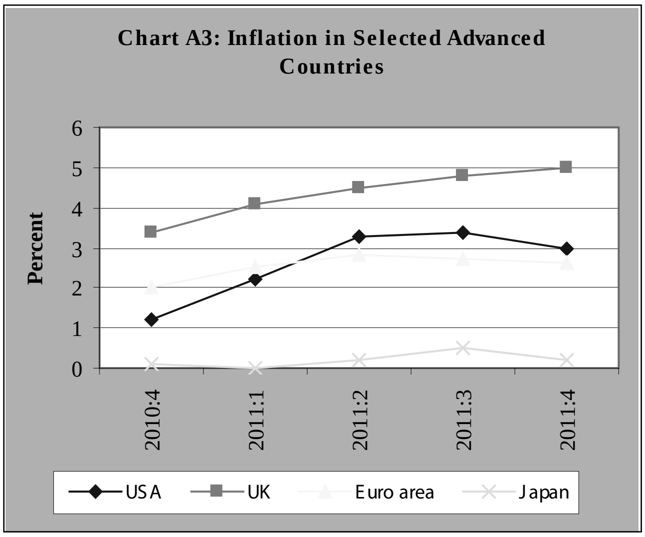
7.3 Accordingly, the prevailing monetary policy stance is consistent with the achievement of the 3 – 6 percent inflation objective in the medium term, and remains appropriate for supporting economic recovery, including sustenance of robust performance of the non-mining sectors. The Bank will continue to monitor economic and financial developments with a view to responding appropriately to ensure medium-term price stability, without undermining economic recovery and growth.

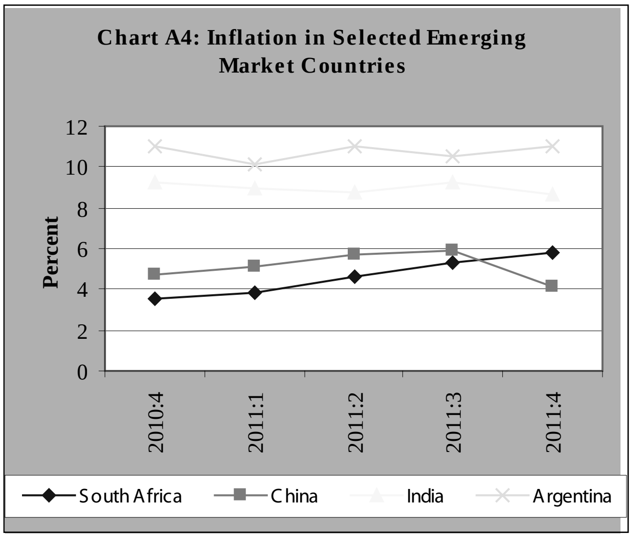
APPENDIX I

Output Growth and Inflation for Selected Countries









Source: JP Morgan Chase

Note: Data from 2011 Q2 are forecasts

APPENDIX II

The Output Gap Measure

The output gap is an important variable in the formulation and implementation of monetary policy. It is defined as the difference between the economy's actual level of total output and its potential output level (baseline/capacity level). It is, therefore, a gauge of the extent to which economic activity is strong or subdued relative to the economy's potential or capacity. Potential output represents the maximum amount of goods and services that an economy can supply on a sustainable basis with existing resources, without putting undue pressure on prices. It is noted that inflation is generally determined by both external (imported inflation) and domestic factors. The domestic factors can be categorised into supply (i.e., productivity) and demand influences.

A sustained positive output gap (actual output higher than potential) is indicative of an increase in demand, suggesting that inflationary pressures may be building up. This is because when economic activity is above potential, firms are operating at or close to full production capacity. For firms to increase production levels further, they have to undertake costly investments, which take some time to construct. Hence, in the meantime, firms tend to respond to increased demand by employing more of the variable resources (including labour and overtime), the cost of which is translated into higher prices.

Conversely, a prolonged negative output gap (actual output lower than potential) implies weak demand and, easing of inflationary pressures. In the event of weak demand, firms initially reduce the variable cost elements, resulting in a slower rate of price increases. Firms will initially not reduce plant and capital, taking the view that the fall in demand is temporary.

Thus, the deviation of actual output from potential output provides a measure of demand pressure on inflation. Given that the main objective of monetary policy is price stability, estimating the output gap is essential to the implementation of monetary policy.

It should be noted, however, that a rate of growth in actual output greater than potential rate of growth may not be sufficient to propel the economy from a position of negative to positive output gap in the short run, since such high actual growth may only serve to narrow the output gap instead of completely closing it. In particular, when moving from a deep economic trough, it usually takes a sustained period of high growth to return to potential capacity. This possible outcome is illustrated in Figure A1 and Table A1 which show the behaviour of non-mining output gap in Botswana given certain levels of growth in actual and potential output. For example, the value of output gap in the fourth quarter of 2011 is -1.4 percent[15] although actual output and potential output are expected to grow by 9.1 percent and 7.1 percent, respectively. This is because the economy was deeper in the trough in the third quarter of 2011 at -1.9 percent. The higher growth in actual output in the fourth quarter of 2011 compared to that of the third quarter only narrows the output gap from -1.9 percent to -1.4 percent.

15 Output gap is expressed as a percentage deviation of actual output level from potential output level.

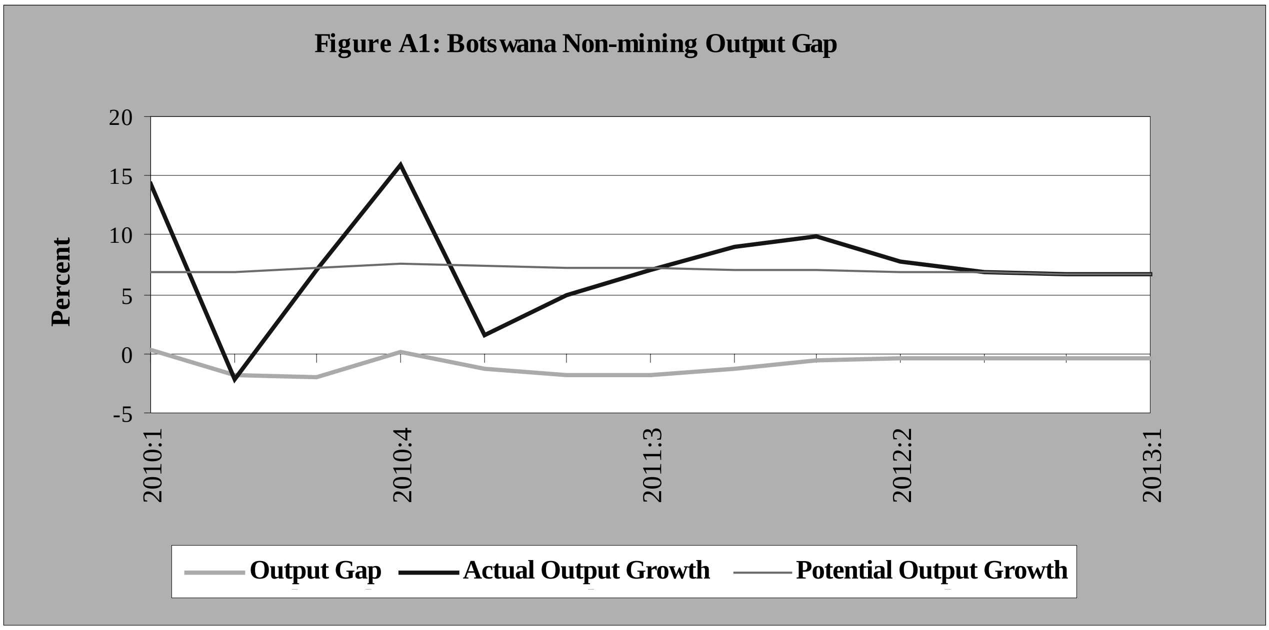


Table A1: Botswana Non-mining Output Gap

Period	Output Gap	Output Growth	Potential Output Growth
2010Q1	0.4	14.2	6.9
2010Q2	-1.9	-2.2	6.8
2010Q3	-1.9	7.1	7.2
2010Q4	0.2	16	7.5
2011Q1	-1.2	1.6	7.3
2011Q2	-1.8	4.9	7.2
2011Q3	-1.9	7.1	7.2
2011Q4	**-1.4**	**9.1**	**7.1**
2012Q1	-0.6	9.9	7
2012Q2	-0.4	7.8	6.9
2012Q3	-0.4	7	6.8
2012Q4	-0.4	6.7	6.8
2013Q1	-0.4	6.6	6.7

Note: The rate of growth figures are annualised quarter-on-quarter changes

Potential output and, therefore, the output gap are not directly observable and must be estimated. There are a number of different methods used to estimate the output gap. These include the production function method and various filtering techniques such as the Hodrick-Prescott (HP) filter and a multivariate filter based on the Kalman filtration process. In the production function method, potential output is determined by trend levels of input such as labour, capital and total factor productivity. Simplified, the filtering techniques involve averaging past actual output growth to derive the economy's trend or potential output. The Bank uses the Kalman filter process which, in addition to past output developments, incorporates other influences such as domestic policy and external developments (See Section 2 on monetary policy framework).[16]

16 Reasons for adopting the Kalman filter process include the points that data for the production function are currently inadequate, while the more basic Hodrick-Prescott filter approach would be deficient in an environment of high output variability, such as the case for Botswana.

MACROECONOMIC MODELLING AT BANK OF BOTSWANA

L. V. James, T. A. Kganetsano and B. Powder [1]

Abstract

This paper discusses, in detail, the Bank's macroeconomic modelling project which started in 2001 with Bank of England's Centre for Central Bank Studies (CCBS) providing technical assistance and from 2004 working with experts from the Czech National Bank in the context of International Monetary Fund technical assistance. The main purpose of the two collaborative efforts was to develop models for formal macroeconomic forecasting and policy analysis as a contribution to improving monetary policy formulation. The project yielded a Forecasting and Policy Analysis System (FPAS) with two complementary elements being the Near-Term Forecasting Model and the Core Model for Medium-Term Forecasting, which, in addition to expert analysis and judgement, are used to support a forward-looking framework for the formulation and implementation of monetary policy. The paper highlights the value of the FPAS in providing a framework for consistent assessment of a wide range of factors in projections for inflation, facilitating examination of alternative scenarios, as well as allowing scope for forecast review and evaluation.

1.0 Introduction

The use of macroeconomic models for economic analysis dates back many decades. Whitely (1994) indicates that the first macroeconomic model was developed by Timbergen in 1936 for the Dutch economy. He further notes that "Keynes stimulated further modelling activity by formulating the system of national accounts" and that "his work on the national accounts still provides much of the backbone to current modelling activity".

Macroeconomic models are used, amongst others, to "analyse the economy, evaluate macroeconomic policies and to make predictions about the likely future behaviour of the economy", (Whitely, 1994). More recently, Kłos and Wróbel (2005) argue that macroeconomic models are "becoming an important component of the toolkit of decision-makers". However, authorities may rely on a suite of models, rather than a single model, in order to deal with the complexities of the economy. In fact, George (1999) noted that, "In an ever-changing economy, no single model can possibly assimilate in a comprehensive way all the factors that matter for policy". It is mainly for these reasons that economists often estimate several macroeconomic models and forecasting techniques for a single economy, with a number of small models feeding into a larger one. Furthermore, macroeconomic models do not and cannot provide all the answers to all our economic problems; they just assist in the policy decision-making process. As such, off-model information is a very valuable input. This is a point also emphasised by Osakwe (2002), that, "although macroeconomic models improve our understanding of how economies function, they cannot be substitutes for sound economic analysis and judgement. Models are best seen as complements rather than substitutes for sound economic analysis".

Even though modelling in developed countries dates back quite a number of years, modelling in developing countries, especially in Africa, is relatively new and faces a number of challenges, which include lack of good quality data, underdeveloped and segmented markets often with no statistically significant correlations between certain key variables, as well as lack of resources (human) and capacity. There are also issues of structural changes/breaks in developing countries that modellers need to contend with. To this end, Kłos and Wróbel (2005) note that "on-going structural changes in agents' behavioural patterns and a shortage of data are the main obstacles to the structural modelling of a transition economy". Given the concentration of human resources, better access to data and analytical requirements for supporting member countries, much of the macroeconomic modelling work for developing countries is found at international organisations such as the International Monetary Fund (IMF) and the World Bank (WB).

Modelling has also become increasingly popular with central banks (monetary authorities). Since the 1990s, a number of central banks, mostly from developed countries, started focusing their monetary policy primarily towards the price stability goal in what is commonly known, in the literature, as direct inflation targeting (DIT). That is, instead of using indirect tools of monetary policy to target intermediate variables, such as money supply or credit that could influence the objective variable (inflation), they have opted for explicit inflation targeting. An inflation targeting regime by itself calls for an investigation of the transmission mechanism through which monetary policy influences the economy and the price level.

1 Respectively, Senior Economist (Modelling and Forecasting Unit), Research Department, Manager (Open Market Operations Unit) Financial Markets Department and Economist (Balance of Payments Section), Research Department. The views expressed in the paper are those of the authors and do not necessarily reflect those of the Bank of Botswana.

Consequently, this area of research has received a lot of attention by monetary authorities and academics alike. As noted in Coricelli et al. (1996), "a genuine and precise understanding of how fast, and to what extent, a change in the central bank's interest instrument modifies inflation lies at the heart of inflation targeting". Some of the central banks that have moved in this direction include the Bank of England, the South African Reserve Bank (SARB), the Bank of Canada, the Reserve Bank of New Zealand and the Czech National Bank.

In a DIT framework, inflation forecasting becomes a very important element of the framework for the formulation of monetary policy. It is mainly for this reason that a considerable amount of resources has been devoted to developing macroeconomic models of the monetary transmission mechanism (MTM). These models assist the monetary authorities in several ways. For example, the Bank of England (1999) lists three ways in which models assist the Monetary Policy Committee (MPC) of the Bank of England. First, the MPC uses models to forecast growth and inflation. Second, some models are used to explain the causes of important recent events, since forecasting the future requires an understanding of the past. Finally, models are helpful in addressing puzzles arising from apparent differences between recent economic behaviour and average relationships over the past. In Africa, the SARB and the Central Bank of Ghana appear to be the only central banks to have adopted DIT. As a result, the SARB has developed a suite of models that are used to forecast the economy and inflation. The Central Bank of Mozambique has also developed inflation forecasting models even though the central bank is not yet an inflation targeter.

The Bank of Botswana has also embarked on a capacity building exercise in the area of modelling and forecasting, which has, so far, led to the production of two robust and policy useful inflation forecasting models. The purpose of this paper is, therefore, to document all the modelling work so far done at the Bank of Botswana and the challenges that lie ahead. The structure of the paper is as follows: section 2 looks at the brief history of macroeconomic modelling at the Bank of Botswana, starting with the Bank's collaboration with the Bank of England. This is followed by an outline of the Bank's collaboration with the Czech National Bank under the International Monetary Fund's Technical Assistance (TA) Mission. Section 3 briefly sets out the role of the forecasting and policy analysis system in monetary formulation, while section 4 concludes.

2.0 Modelling Work at the Bank of Botswana

2.1 Collaboration with the Bank of England (BoE)

Modelling work at the Bank of Botswana started in 2001 when the Bank of Botswana solicited support from the Bank of England to initiate construction of an inflation forecasting model. According to the Background Note on Inflation Forecasting (unpublished), the project (building an inflation forecasting model) had several components. The first was to identify and quantify the various sources of inflation in Botswana. Second, the project sought to identify the various components of the transmission mechanism of monetary policy in Botswana. Third, the project would entail developing a formal forecasting framework and model that would enable the impact of alternative policy interventions to be simulated and evaluated. These steps were to be done with a view to enhancing the effectiveness of monetary policy by establishing more precisely the impact of policy measures on inflation.

The project was also intended to support the possible move towards inflation targeting, for which a formal inflation forecasting framework is an essential pre-requisite. Moreover, it was recognised that monetary policy ought to be forward-looking and required a formal forecasting and policy analysis system that, among others, helps to analyse the economy, evaluate macroeconomic policies and predict the future path of the economy, particularly the outlook for inflation. As noted by Keynes in 1923, "If we wait until a price movement is actually afoot before applying remedial measures, we may be too late". Similarly, Greenspan (1994) noted that, "The challenge of monetary policy is to interpret current data on the economy and financial markets with an eye to anticipating future inflationary forces and to countering them by taking action in advance".

2.1.1 The BoB-BoE Model

The BoB-BoE joint project identified imported inflation, administered prices and aggregate demand pressures as the main sources of inflation in Botswana.

(a) Imported Inflation

Imported inflation is the most influential source of inflation in Botswana because the country is a relatively open and small economy, with imports accounting for around forty percent of GDP and imported tradeables constituting forty-five percent of the Consumer Price Index (CPI). The influence of imported inflation also goes beyond the imported tradeables. For example, many 'domestic tradeables' are also largely imported, while services rely heavily on imports for inputs. Given that approximately 80 percent of imports originate from South Africa, that country's inflation rate has the more direct and immediate influence on price developments in Botswana. For a small country facing a large imported inflation component, the exchange rate could be a pertinent policy tool for inflation control, particularly when there is scope for discretionary revaluation of the domestic currency. Thus, prior to 1991, the Pula exchange rate in Botswana was actively used to fight imported inflation. However, there could be a conflict, where a loss of domestic industry competitiveness would require a devaluation of the exchange rate. Thus, prior to May 2005, the exchange rate policy was characterised by a series of revaluations and devaluations implemented by the authorities as and when it was considered appropriate. In the circumstances, devaluation resulted in quicker adjustment of domestic prices compared to the slower response to a revaluation. More recently, the 12 percent devaluation of the Pula in May 2005 resulted in inflation rising from 6.3 percent to a peak of 14.2 percent in April 2006.

Prior to June 2005, the adjustments of the nominal exchange rate involved slightly altering the baskets weights and/or the 'adjustment factor' of the basket mechanism. There were also periodic discrete adjustments dating back to 1977. From June 2005, Botswana adopted a crawling peg exchange rate system, where the Pula continues to be pegged to a basket of currencies consisting of the South African rand and the IMF Special Drawing Rights (SDR), a composite currency comprising the US dollar, British pound, Japanese yen and the euro. Under the crawling peg regime, the exchange rate is adjusted in small continuous steps, rather than in large discrete ones, through a forward-looking crawl with the rate of the crawl based on the differential between the Bank's inflation objective and the inflation forecasts for trading partner countries over the twelve months time horizon.

(b) Administered Prices

A significant proportion of the domestic non-tradeables goods and services have administered prices characterised by large and infrequent changes, which have a significant impact on domestic inflation. These include rentals on public housing, electricity charges, water and telecommunications tariffs, public transport fares, fuel prices and charges for public services including public health care. Goods and services with administered prices account for a significant 19.8 percent of the CPI basket.

(c) Aggregate Demand Pressures

Botswana has generally experienced rapid economic expansion, with real annual GDP growth averaging 10 percent a year during the 1970s and 1980s, which, however, subsequently decelerated to an average of around four percent a year during the 1990s. The robust expansion was mainly driven by the export sector, especially the diamond component. Periods of very rapid economic growth were always associated with large increases of export production mainly in the mining sector. For example, Gaolathe (1997) noted that "the period from 1987 to 1991 represents the period of unusually rapid economic growth in Botswana" and that "there were signs that actual output exceeded potential output and that literally every sector was buoyant". The construction sector, for example, is estimated to have grown by 40 percent in both 1987/88 and 1988/89. Gaolathe (1997) also attributes such growth to what he calls "the fortunes of the mineral sector". The main channel through which diamond exports are linked to the economy is through the government; it is only to the extent that government spends the revenues that it receives from the mineral sector that aggregate demand is affected to any great extent. Otherwise, the diamond sector operates as a relatively isolated enclave in economic terms, and fluctuations in the level of output and export earnings have little direct impact on the rest of the economy.

To the extent that rapid economic expansion leads to increased demand in excess of supply, this creates domestic inflationary pressures. Until the end of 2007, the Bank of Botswana had used growth in domestic credit and government spending as key indicators for domestic demand. The continuously high mineral export earnings and the associated accumulation of foreign exchange reserves, means that the economy can afford to extend credit to finance growth in other sectors of the economy that rely on imported inputs. However, the rate of credit expansion is considered to be one of the major factors that generate demand pressures; and to the extent that it is excessive, it can be inflationary. Meanwhile, with government spending accounting for about 40 percent of GDP, real growth rates of government spending in excess of 10 percent are common. Most of private consumption and investment tend to be driven by government spending; making government an important economic agent and engine of growth. As a result of rapid accumulation of foreign exchange reserves and government driven development in an economy with limited absorption capacity, excess liquidity has been a major characteristic of Botswana's financial system, a characteristic which complicates the central bank's efforts to fight inflation.

2.1.2 The Monetary Policy Transmission Channels

Prior to 1975, Botswana was part of a common monetary area (with Lesotho, South Africa and Swaziland) and, therefore, did not have monetary policy and exchange rate autonomy. Financial and monetary affairs of the country were controlled from South Africa, the largest union member state. However, following the discovery and mining of diamonds, foreign exchange reserves started to build up quickly, while there was need for autonomy in focusing on the country's development needs. Thus, the availability of mineral resources which generated foreign exchange reserves meant that Botswana could afford to have separate monetary and exchange rate policies from those of South Africa, which was operating under a different economic and political environment. However, during the early stages of monetary independence, monetary policy was still controlled from outside, since the Pula was fixed to the US dollar at the same rate as the rand/US dollar exchange rate, which meant that effectively, the Pula was pegged one-to-one to the South African rand. This meant that there was little or no monetary autonomy. Subsequently, from June 1980 the Pula was pegged to a basket of currencies comprising the rand and the SDR that was discretely adjusted from time to time, before adoption of a crawling peg exchange rate system at the end of May 2005. Botswana's monetary policy has also evolved from direct controls (credit ceilings, controls on interest rates, directed credit, etc.) to a market-based monetary policy (use of indirect instruments of monetary policy). More recently, from 2008 the monetary policy framework has evolved to resemble an inflation targeting regime as it incorporates key features of this framework, such as inflation forecasting and the use of inflation forecasts as the intermediate target.

As noted above, the involvement of the Bank of England was with a view to understanding the influences on domestic price developments and transmission mechanism in order to improve the efficacy of monetary policy. Having relied on credit as an intermediate target for quite some time, evidence (2008 Monetary Policy Statement) suggested that monetary aggregates, including credit, do not always provide the required signals for monetary policy. For example, the effectiveness of monetary targeting could be undermined by uncertainty as to the appropriate monetary aggregate to target and a weakening relationship of that target with domestic inflation due to financial innovation, use of technology and global accessibility of finance. For instance, empirical evidence indicates that (a) the short-run role of money as a leading indicator has been affected by the process of financial liberalisation and innovation in some countries; and the dynamic nature of this process is such that continuing effects of a similar nature cannot be ruled out in the future; (b) "rate/quantity" deregulation has made deposit pricing more flexible in some countries, which reduces the reliability of control over monetary aggregates through portfolio allocation channels; and (c) it was difficult to identify any long-run stable equilibrium relationship between money and nominal income.

In line with the developments in developed countries, this evidence seems to support the view that monetary policy should instead focus directly on the key objective, i.e., inflation. Other variables, such as money and credit, are only used as indicators of future economic developments. Since financial deregulation opens up the economy, with foreign exchange controls and constraints on holding of foreign assets removed, domestic capital markets are increasingly subjected to international capital flows. This reduces the importance of liquidity constraints in the transmission mechanism. Thus, Blundell-Wignall, A., et al (1990), suggested that "financial liberalisation appears to reduce the degree to which credit availability is a constraint on spending decisions, and, hence, the ability of the authorities to use this hitherto powerful channel of influence. Wealth and intertemporal-substitution effects are, therefore, likely to be relatively more important transmission channels for influencing consumption and housing demand in more liberalised financial environments".

The intertemporal-substitution hypothesis states that, "employment and work hours fluctuate cyclically because workers want to increase their leisure and non-market work during recessions when real wages are relatively low and reduce their leisure and non-market work during macroeconomic expansions when real wages are relatively high". This, therefore, clearly indicates that the demand for credit does not only depend on interest rates, but is also influenced by other developments in the economy. In Botswana, these other influences on credit growth include structural changes in the financial sector (e.g., increased access to credit), greater competition resulting in the introduction of new loan products, the general increase in incomes and the substantial loan amounts associated with large new investment projects (Bank of Botswana Monetary Policy Statement, 2008). Furthermore, as a developing country with relatively weak market infrastructure, some transmission channels that are important for money market operations are undermined. For example, the asset price channel could be ineffective because financial markets that are important for asset price formulation are either non-existent or underdeveloped. A proper quantification and analysis of the transmission processes and contributory factors to macroeconomic and price developments, therefore, required a formal approach to modelling and forecasting that would, in turn, be used for monetary policy formulation. The Bank, therefore, embarked on a capacity building exercise, including establishment of a policy analysis and inflation forecasting system to help guide monetary policy formulation, but not necessarily to target inflation directly, even though this exercise is a prerequisite for adopting inflation targeting. In this regard, collaboration with the Bank of England resulted in the formation of a small structural macroeconomic model for the Botswana economy[2].

The BoB-BoE collaboration model was essentially an adaptation of the Bank of England's Small Macroeconomic Models (SMMs)[3], which are typically aggregated models, with considerable theoretical content, that present a stylised representation of the whole economy. They contain few equations and are less complex, but tend to impose more structure in the form of restrictions on signs of coefficients and the equation dynamics. The SMMs can, nevertheless, be effectively used to quantify transmission channels and evaluate the impact of monetary policy. They are also useful in analysing the reaction of the economy to various exogenous shocks under alternative assumptions; in particular, to investigate the implications for output and inflation of different monetary policy rules. Further, they allow for parameters to be altered reflecting changes in behavioural assumptions.

The quarterly model for the Botswana monetary transmission mechanism, therefore, displays the two important features (often imposed) that are common to most models of the transmission mechanism:

(a) The economy converges towards a long run where prices are fully flexible in nominal terms. The long run is described by a neo-classical model with adaptations, where these adaptations arise only from rigidities in real values. These real price rigidities prevent the markets for goods and services and factors of production from fully clearing; and, hence, the long run is not necessarily compatible with full employment.

(b) In the short run, the nominal value of prices can deviate from their long-run nominal values. Nominal prices fail to adjust immediately because of New Keynesian phenomena, which assume that nominal values are slow to adjust to their long-run values. If a nominal price fails to adjust, real prices cannot be at their long-run values: an implication is that nominal shocks can have temporary effects on real variables.

2 Specifically, this model was developed with the extensive assistance of Lavan Mahadeva of the Bank of England.

3 These models are discussed in the Bank of England publication (1999), "Economic Models at the Bank of England".

The model was designed such that it focuses on the monetary sector of the economy, partly in order to reflect the policy concerns and constraints of monetary policy in Botswana. This, however, does not imply that the model is inconsistent with the standard monetary transmission models laid out in, for example, Svensson (1997) or McCallum and Nelson (1999). The model was perhaps unusual in that it focuses on explaining what shocks to the aggregate macroeconomic data would mean to monetary variables such as net foreign assets, private sector credit and reserves. It was considered to be suggestive of the underlying structure of Botswana's transmission mechanism seen in the aggregate.

2.1.3 A Description of the Model

The BoB-BoE model of the Botswana's transmission mechanism is summarised, with a detailed description of the model presented in Appendix A.

- **An Uncovered Interest Parity** equation that determines the expected nominal exchange rate depreciation on the basis of the differential between domestic and foreign interest rates.
- **A Passthrough Equation** that determines domestic prices on the basis of South African prices expressed in domestic currency terms.
- **An IS curve** which describes how domestic demand is affected by real interest rates.
- **An Export Equation** linking non-traditional exports to the real exchange rate and South African GDP (representing foreign demand).
- **An Import Equation** relating imports of goods and services to domestic demand and the exchange rate.
- **A Money (M0) Demand Equation** showing how real money balances respond to changes in GDP (domestic demand) and the interest rate.
- **A Money Multiplier Equation** describing M2 as a function of M0 and the deposit rate differential over the bank rate.
- **A Policy Rule** that stipulates how the Bank Rate (or alternatively the expected exchange rate change) is set by the monetary authority to control inflation and excess output.

2.2 BoB - International Monetary Fund (IMF) Collaboration

Subsequent technical assistance by the International Monetary Fund involving experts from the Czech National Bank resulted in establishment of a Forecasting and Policy Analysis System (FPAS) with three main pillars, namely: model building, forecast production and a structured input to monetary policy formulation. This resulted in the development of tools for near-(short) term and medium-term modelling and forecasting, data management and forecast presentation. The short-term forecasting tool for inflation – the Near-Term Inflation Forecasting Model (NTF) – was established as part of the formal FPAS in 2004. Thereafter, focus shifted to building a Medium-Term Forecasting (Core) Model, contributing to entrenchment, in 2008, of the Bank's forward-looking and medium horizon forecast based monetary policy framework.

2.2.1 The Current Structure and Key features of the Near-Term Inflation Forecasting Model (NTF)

The Bank's FPAS has two complementary elements, namely: the Near-Term Forecasting Model and the Core Model for Medium-Term Forecasting, which, in addition to expert analysis and judgement, are used to support monetary policy formulation. Both models are based on the findings of initial research on the policy and price transmission process (see Appendix B, showing Botswana's monetary policy transmission mechanism). The NTF model was designed to capture the imported components of domestic inflation, as well as the developments in the rand/Pula nominal exchange rate (ZAR/BWP). The analysis of the transmission mechanism had indicated that the exchange rate channel had a substantial influence on domestic inflation through the Pula-denominated prices of imports. It is essential to note that the NTF system does not include other transmission links, such as domestic demand. Furthermore, the NTF model structure does not include explicit monetary policy analysis. Nevertheless, the model is a key part of the broader inflation forecasting system; and it is used to provide initial conditions for the Core-Model, which is designed to capture the medium to long-term dynamics of the economy.

The NTF has been used to generate near-term inflation forecasts over a forecast horizon of one year, i.e., four quarters out of sample. The key influences to inflation captured in the NTF system include developments with respect to South Africa's inflation, as Botswana's major trading partner, the rand/Pula exchange rate and inflation persistence (represented by past inflation a quarter earlier). Prospective developments with respect to these factors, therefore, determine the forecast path for inflation over a year out of sample. The results of the NTF are anchored to provide the initial forecast horizon of the Core Model. This is meant to enhance forecast accuracy of the latter in the short-term, since the former is believed to be superior in terms of ability to capture the short-term dynamics of the data.

Both the NTF Model and the Medium-Term Model embody the same design philosophy, whereby the dynamic adjustment occurs around a well-defined equilibrium path or steady state solution. Therefore, steady state solutions for four critical variables are exogenously imposed on the NTF model. These are changes in the nominal ZAR/BWP exchange rate, the real ZAR/BWP exchange rate, and the South African and domestic inflation rates. The basic principle is to recognise the fact that since there are nominal rigidities in the economy, monetary policy can only affect real variables in the short run, while long-run trends in real variables are largely outside its scope (Handa, 2000). This principle is consistent with the vertical long-run Phillips curve theory and it is referred to as the super neutrality condition.[4] In addition, the steady state solution paths ensure consistency between the inflation objective, the exchange rate policy and the fundamentals of the economy, such as the trend appreciation of the real exchange rate, which is outside the scope of monetary policy.

The NTF model is also designed in such a way that the impact of other factors outside the model (additional factors and/or expert information), such as the impact of adjustments to regulated prices or consumption taxes on price developments, could be evaluated. Such effects are imposed on the model as add factors. Any other development expected to impact on inflation, but not directly captured by the model, is dealt with in a similar manner. In short, the NTF forecast is augmented with informed judgement based on other tools, such as spreadsheet modelling and forecasting of other inflation determinants not directly modelled. Furthermore, given that the NTF model has exogenous variables, it follows that projections of such variables are necessary over the forecast period in order for the model to perform well. The exogenous variables are the nominal ZAR/BWP exchange rate and South African headline inflation.[5]

The functional specification of the NTF model is as given in the equation below

$$\Pi_t = -\alpha_1(\Pi_{t-1} + E_{t-1} - \Pi^*_{t-1} - Z^{tnd}_{t-1}) + \alpha_2\Pi_{t-1} + \alpha_3 E_t + \alpha_4 E_{t-1} + \alpha_5\Pi^*_t$$
$$+ \alpha_6\Pi^*_{t-1} + \Pi^{*ss}_t - \alpha_7\Pi^{ss}_t + (\alpha_8 + \alpha_9)E^{ss}_t + (\alpha_{10} + \alpha_{11})\Pi^{*ss}_t$$
$$+ \alpha_{12}D_1 + \alpha_{13}D_2 + \alpha_{14} \qquad (1)$$

4 The super neutrality of money is said to exist if continuous changes in the money supply do not have any real effects on the economy.

5 Market consensus forecasts for South African headline inflation are obtained from Reuters, while the nominal ZAR/BWP exchange rate is derived from forecasts of the US dollar cross rates namely; Euro/USD, JPY/USD, GBP/USD and ZAR/USD sourced from Bloomberg as well as the crawl of the nominal effective exchange rate (NEER).

where;

Π_{t-1} and Π_t represent past and current levels of domestic inflation; E_t and E_{t-1}, are the nominal exchange rates, both contemporaneous and lagged;

$\Pi^*_t + \Pi^*_{t-1}$, are South African headline inflation, both contemporaneous and lagged; as well as the past real exchange rate trend (Z^{tnd}_{t-1}) while α_1 - α_{14} represent estimated parameters. The parameter (α_1) is essentially an error correction coefficient which reduces to zero in the long run, but assumes a non-zero value in the short-term.

One other key feature of the NTF model is that it is built around a number of assumptions regarding equilibrium values of certain variables in the model. The assumptions relate to the long-run values of four variables; namely, the changes in the nominal ZAR/BWP exchange rate (E^{ss}_t) and real exchange rate ($\Pi^{ss}_t + E^{ss}_t + \Pi^{*ss}_t$), as well as South African (Π^{*ss}_t) and domestic (Π^{ss}_t) inflation rates. D_1 and D_2 represent dummies to cater for the structural break in the inflation series created by the introduction of Value Added Tax (VAT) in 2002.

2.2.2 The Structure and key features of the Medium-Term Inflation Forecasting Model (MTF)

The MTF was designed for medium-term forecasting of inflation and other key macroeconomic variables. It is a structural representation that captures key economic relationships (the transmission process) in the Botswana economy. The model allows for consistent projections of up to twelve quarters ahead for key macroeconomic variables such as output, inflation, interest rates and exchange rates. The model consists of four basic behavioural equations, including: Aggregate demand (IS curve); Aggregate supply (Phillips curve); Uncovered Interest Rate Parity (UIP); and the Monetary Policy Rule (Taylor Rule).

Aggregate Demand

$$\hat{y}^n_t = a_1\hat{y}^n_{t-1} + a_2 rmci_t + a_3\hat{y}^{SA}_{t-1} + a_4\hat{y}^m_{t-1} + \varepsilon_t \quad (1a)$$

$$prem_t = \Delta\bar{z}_{t+1} + \bar{r}_t - \bar{r}^*_t - m_1\hat{y}^m_t \quad (1b)$$

Equation (1a) is an aggregate demand (IS curve) construction, where $\hat{y}^n_t$ is the non-mining output gap[6], $rmci_t$ is the real monetary conditions index[7], $\hat{y}^{SA}_{t-1}$ is the lagged South African output gap and $\hat{y}^m_{t-1}$ is the lagged mining output gap[8]. The coefficient a_4 is given (i.e., by way of calibration) a very low value to account for the relatively weak spillover from the mining sector to the non-mining sector observed in the historical data, as well as to prevent spillovers of the huge volatility in the mining output to the rest of the variables. ε_t is the shock to aggregate demand[9].

Equation (1b) is a version of the uncovered interest rate parity (UIP) that binds together the domestic trend real interest rate $\bar{r}_t$, the foreign trend real interest rate $\bar{r}^*_t$, the mining output gap and the trend change in the real exchange rate, $\Delta\bar{z}_t$, in order to determine the country risk premium, $prem_t$. Any increase in mining activity above the trend (i.e., when mining output gap becomes positive) reduces the risk premium to a level below the one implied by the rest of fundamental trends, a development that causes the real exchange rate to appreciate and/or the real interest rate to decline and *vice versa*.

The coefficient m_1 is calibrated as being relatively low in value to align it with evidence from the historical data and to prevent sharp movements in the risk premium and the exchange rate that could be caused by the huge volatility in the mining output.

The mining output gap is itself modelled in the context of the world business cycle that is approximated by a combination of the US and Euro area output. Equation (1c) describes the mechanism:

$$\hat{y}^m_t = m_2\hat{y}^m_{t-1} + m_3\hat{y}^*_t + v_t \quad (1c)$$

where $\hat{y}^*_t$ is the world output gap. The world output enters the model as an exogenous variable and its forecasts are determined outside the model. All the gaps, i.e., the mining and world output gaps, are estimated using the Kalman filter while v_t is the shock to the mining output.

6 The output gap refers to the difference between long-term trend output, as an indicator of productive capacity, and actual output.

7 Defined as deviations of the weighted long-term real interest rate and the weighted real exchange rate from their trend levels.

8 The mining sector was found to affect the non-mining sector, although the effect is minimal, with a lag and it was found to affect the country risk premium contemporaneously.

9 This type of shock can come from such things as tax cuts or increases, loosening or tightening of the money supply and increases or decreases in government spending.

Aggregate Supply

The "Phillips curve block" consists of five equations:

$$\pi_t^{core} = b_1 E_t \pi_{t+1} + (1-b_1)\pi_{t-1}^{core} + b_2\hat{\varphi}_t + \varepsilon_t \quad (2a)$$

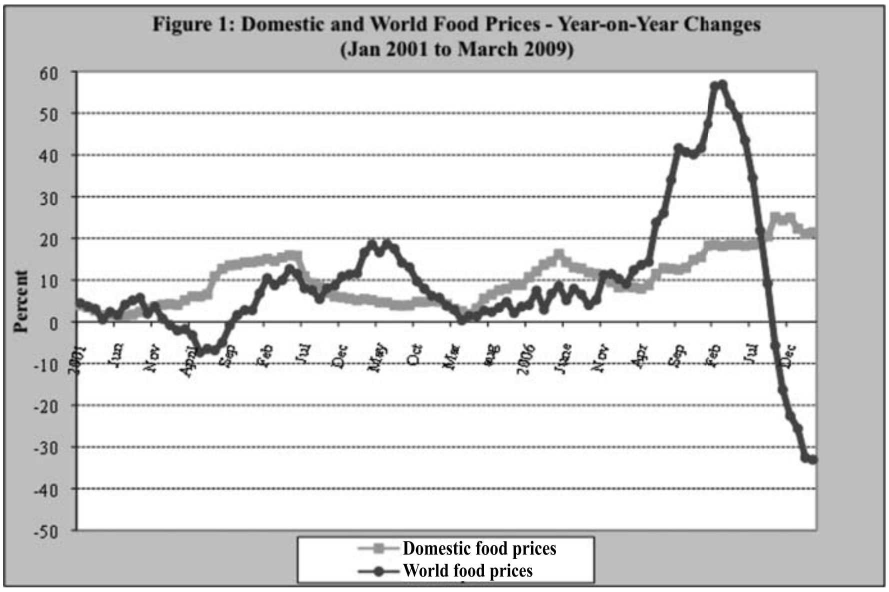
$$\hat{\varphi}_t = b_3 \hat{z}_t^{EF} + (1-b_3)\hat{y}_t^n \quad (2b)$$

$$\pi_t^{food} = b_4 \pi_{t-1}^{food} + (1-b_4)E_t\pi_t + b_5\hat{\psi}_t + \eta_t \quad (2c)$$

$$\pi_t^{oil} = b_5\pi_{t-1}^{oil} + (1-b_5)(\Delta p_t^{oil} - \Delta s_t^{USD} + \Delta \bar{z}_t^{USD}) + \nu_t \quad (2d)$$

$$\pi_t = (1 - w^{food} - w^{oil})\pi_t^{core} + w^{food}\pi_t^{food} + w^{oil}\pi_t^{oil} \quad (2e)$$

Equation (2a) represents the standard forward-looking Phillips curve for core inflation (π_t^{core}), where core inflation is defined as headline inflation excluding food and oil components. π_t^{core} depends on inflation expectations ($E_t\pi_{t+1}$), past core inflation (π_{t-1}^{core}) and the current value of the real marginal costs ($\hat{\varphi}_t$). The real marginal costs (see equation (2b) represent costs incurred by domestic producers (approximated by the output gap in the non-mining sector, $\hat{y}_t^n$), as well as importers (approximated by the real effective exchange rate gap, $\hat{z}_t^{EF}$). Cost push inflation is determined by imported inflation represented by import costs (i.e., from South Africa) while the output gap represents costs arising from domestic demand pressures. Coefficient b_3 approximates the weight of imported goods.



Equation (2c) captures food prices inflation (π_t^{food}). It is a forward-looking Phillips curve, constructed specifically for food prices. According to the equation, food inflation depends on inflation expectations ($E_t\pi_{t+1}$), lagged food inflation (π_{t-1}^{food}) and current real marginal costs ($\hat{\psi}_t$) faced by food retailers. The real marginal cost is defined differently from the equation for core inflation. The real marginal cost for food retailers is calculated using the world food price index in US dollars, the nominal exchange rate against the US dollar and the domestic food price index. It was found that domestic prices of food are correlated to the relative world and domestic prices of food adjusted for the nominal exchange rate. The link between the domestic and world food prices is supported by the historical data as shown in figure 1 below, although domestic food prices are less volatile.

The evolution of domestic prices of oil related products[10] is represented by equation (2d). The pass-through from world oil prices to domestic prices of oil related products is done in such a way that domestic prices of oil related products inflation depend on its past value and changes in the world oil prices (Δp_t^{oil}), as well as the nominal exchange rate of the Pula against the US dollar (Δs_t^{USD}). Despite its simplicity, this relationship fits the historical data well. Figure 2 shows the cross-correlation between domestic prices of oil related products and world oil prices. On the 'y' axis there are values of the correlation coefficients for all 'time shifts' between the domestic prices of oil related products and world oil prices, while the 'time shifts' are on the 'x' axis. A 'time shift' of zero means, for instance, that the correlation is contemporaneous (i.e., the effect of developments in one variable is felt in the same quarter), while a 'time shift' of -1 means that the second variable is lagged for one period (a quarter in particular), etc. It is evident from figure 2 that domestic prices of oil related products are positively correlated to developments in the world oil prices. The correlation coefficient is high in the contemporaneous and the previous quarter, indicating that the pass-through is very fast. Figure 3 also shows the co-movement between the two series, particularly after 2006. Finally, equation (2e) sums core, food and oil price changes to determine headline inflation (π_t), based on the weights taken from the CPI basket.

Uncovered Interest Rate Parity (UIP)

The UIP condition relates the behaviour of domestic and foreign interest rates, and the nominal exchange rate. Where a central bank intervenes in the foreign exchange market, to model the exchange rate consistently, the exchange rate target should be calculated as a sum of the inflation differential and trend appreciation. The

10 These are proxied by the 'operation of personal transport' sub-group of the CPI basket, which however also includes some unrelated items and excludes others that are oil related such as paraffin.

Figure 2: CPI Oil and World Oil Prices (Pula)

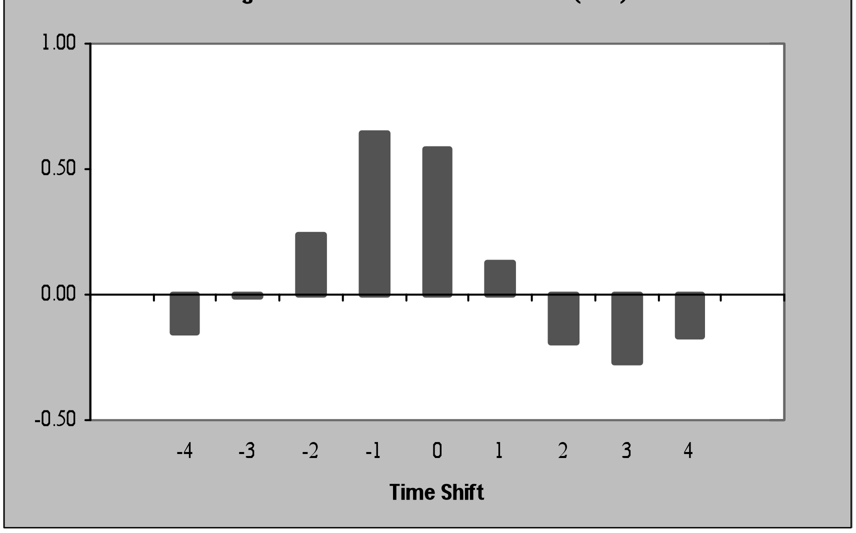
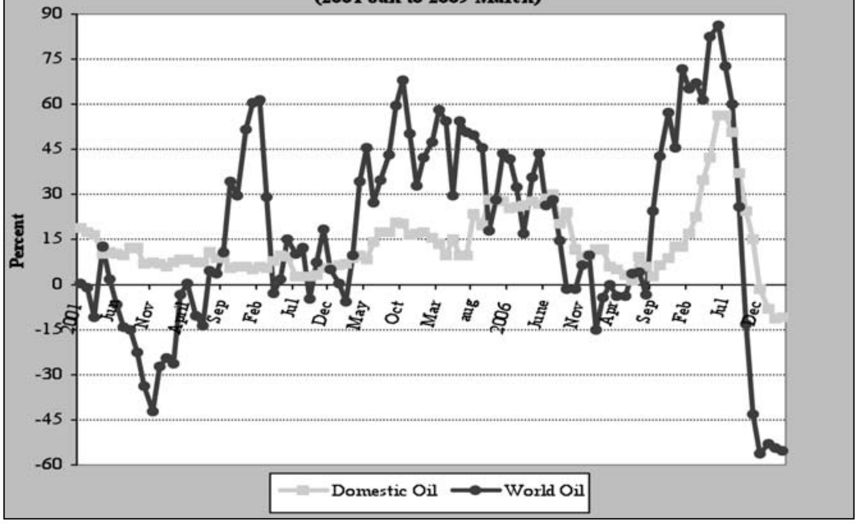


Figure 3: Domestic and World Oil Prices - Year on Year Changes (2001 Jan to 2009 March)



UIP then becomes a weighted average of the exchange rate target and the simple UIP, constructed as follows:

$$S^{ef}_t = \beta S^{ef\,tar} + (1-\beta)*(E\_S^{ef} + (i - i^{ef} - prem)/4 + \varepsilon_t) \qquad (3)$$

Where S^{ef} is the nominal effective exchange rate; $S^{ef\,tar}$ is the target for the nominal effective exchange rate; E_S^{ef} the expected nominal effective exchange rate; i is the domestic nominal interest rate; i^{ef} is the effective nominal interest rate; *prem* is a risk premium and ε is an exchange rate shock (i.e., currency devaluation or revaluation). The coefficient β indicates the extent to which the monetary authority manages the exchange rate. Its value ranges from zero to one. Zero means fully managed, whereas one means fully floating.

Policy Rule

The model is closed by a policy reaction function of the Taylor rule type. The three-month BoBC rate is used in the model as the instrument of monetary policy. According to the reaction function, the Bank is assumed to respond to deviations of inflation four quarters ahead from its target and to the current output gap. The last period policy stance may also affect the current policy stance:

$$i_t = d_1(i_{t-1}) + 1-d_1 (i^{tnd} + d_2 \Pi_{t+4} - \Pi^{tar}_{t+4}) + d_3 y_t^n + \delta_t \qquad (4)$$

Where i is the domestic short-term nominal interest rate; Π is year-on-year inflation; Π^{tar} is targeted year-on-year inflation; yt^n is non-mining output gap and δt is a policy shock. The variable i^{tnd} is the trend in the nominal short-term interest rate, also known as the policy neutral rate. It is calculated as the sum of the trend real interest rate, (r^{tnd}), and the target in the year-on-year inflation,(Π^{tar}), as follows:

$$i^{tnd} = r^{tnd} + \Pi^{tar}_{t+3} \qquad (5)$$

The Taylor rule is used to produce a projected path for monetary policy. The projected interest rate path responds to projected movements in other macroeconomic variables within the model. Projections that incorporate a presumed policy response to projected inflation are increasingly being preferred to those generated under the assumption of a constant rate of interest, i.e., the rate of interest prevailing at the time the projections were prepared. One of the problems associated with constant interest assumption is that it can give rise to potential internal inconsistencies. To illustrate this, consider a situation where an assumption of constant interest and exchange rates resulted in a projection with inflation deviating outside the target range over the forecast period. This could raise a number of problems. First, it is not internally consistent to assume that a central bank committed to keeping inflation within some target would allow such a deviation from target to persist. In practice, the central bank would move to alter the interest rate in order to bring inflation back to target. Second, if the constant nominal interest rate assumption was maintained, and the inflation rate was projected to change, this would result in a change in real interest rates and thus reinforce the initial inflation movement and lead to potentially unstable paths for the projected nominal variables. Third, it is not consistent to base a projection on a constant interest rate path when other variables included in the projection already include an implicit expectation of future policy responses. These internal inconsistencies can be avoided by using an endogenous interest rate path.

3. The Role of the Bank's FPAS in Monetary Policy Formulation

The Medium-Term Forecasting Model has an in-built policy analysis capability which makes it useful for both forecasting and policy analysis. The importance of inflation forecasting derives from the fact that forecasts systematically guide the response of monetary policy. The inflation forecast is considered the intermediate policy target, since, in practice, the policy stance is adjusted whenever there is evidence that future inflation might differ persistently from the target path. Therefore, a forward-looking monetary policy regime requires a rigorous modelling of the economy and forecasting capability that incorporates technical data, sound and consistent analysis and policy makers' intuitive and analytical judgements. In essence, the central bank's inflation forecast should make use of all available information on the outlook for inflation.

To enable credible modelling and forecasting, it is critical that the structure of the economy must be reasonably stable so that it is more readily modelled to provide a forecast of acceptable accuracy. This implies that there should be sufficient historical data to establish reliable relationships; and that there should be reasonable confidence that these relationships will remain stable under the envisaged regime. In order to broaden the set of information, countries typically use inputs from several different models, while at the same time, it is also recognised that models can never replace judgement by the policymakers and that discretion will always play a role in determining policy. The Bank uses, in addition to judgement, the NTF, which has so far performed well in capturing the short-term dynamics of Botswana price developments in order to enhance the accuracy of the MTF model. The ability of the NTF to capture short-term developments in inflation is a result of its design which captures the two most important factors in the determination of inflation in Botswana; these being the rand/Pula exchange rate and South African (i.e., imported) inflation. Models, nevertheless, are considered to be a tangible representation of the monetary policy framework and the accepted view of the policy transmission process; hence, they facilitate a disciplined, coherent and consistent policy analysis.

4. Conclusion

Complete structure of the Forecasting and Policy Analysis System is now in place, facilitating changes/improvements to the monetary policy framework announced during the launch of the 2008 Monetary Policy Statement, including abandoning the annual inflation objective in favour of a rolling three-year medium-term inflation objective of 3 – 6 percent, as well as the use of the more inclusive and representative medium-term inflation forecast as the medium-term target, in place of the less inclusive annual rate of credit growth.

As a signal for monetary policy (one that is forecast-based), the Bank focuses on the discrepancy between the inflation objective and the inflation forecast over the medium term. This involves generating a response to the projected trend of inflation that is either significantly higher or lower than the price stability objective. Apart from the harmful effects of high inflation, the price stability objective takes account of the fact that significantly low levels of inflation could be indicative of subdued economic activity, which may require policy easing to stimulate growth. The inflation forecast incorporates the impact of several relevant economic factors; and it also quantifies the extent to which each of these factors affects inflation and the time lag it takes for the impact to take effect. Among others, it is premised on the assessment that the main influences on inflation in Botswana include the gap between the demand for goods and services and the capacity of the economy to supply these goods and services; the level of interest rates; exchange rate developments; foreign inflation; changes in administered prices; and inflation expectations.

In addition, the FPAS continues to aid in providing an organisational framework for assessing all the relevant information for ensuring consistency in generating projections and for considering alternative assumptions and scenarios, therefore, contributing to a more forward-looking monetary policy. However, the development of models and forecasting capability should be viewed as a continuous process involving continuing refinement, infusion of new techniques and development of complementary tools.

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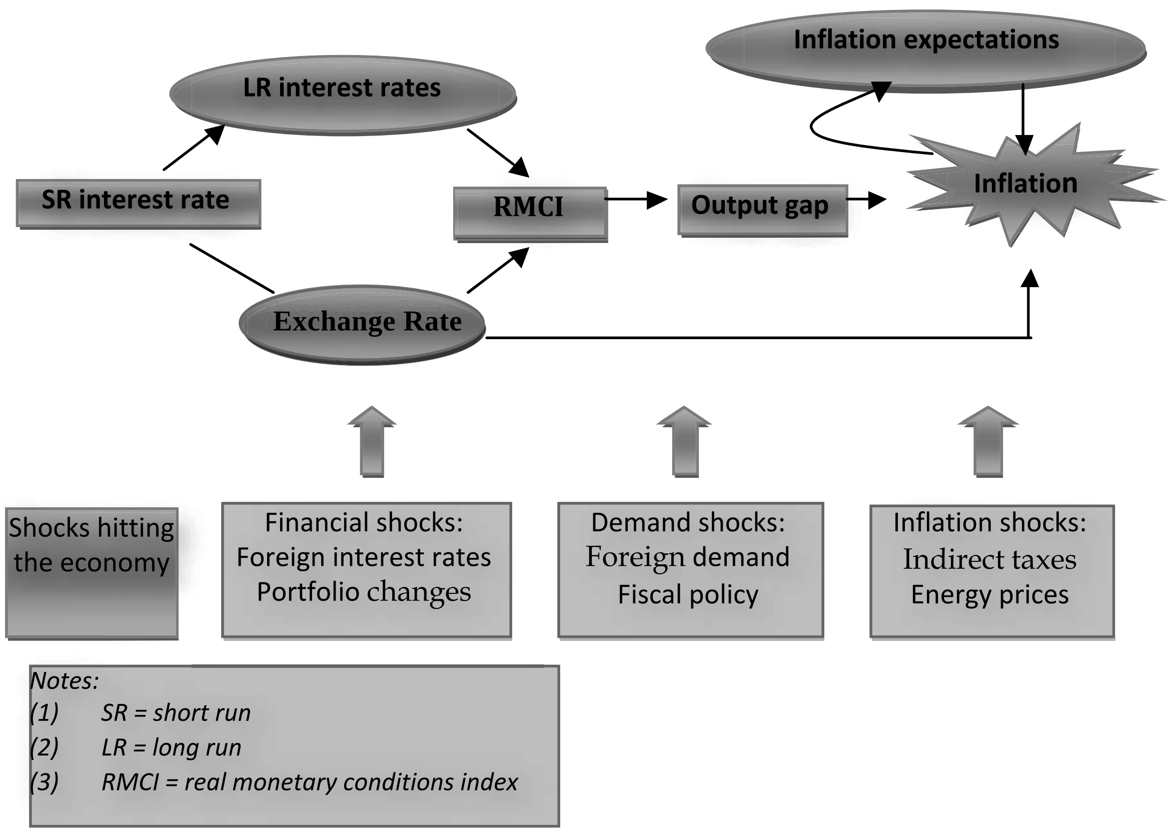
APPENDIX A

A description of the variables in the BoB-CCBS model. All variables are in logs, apart from the inflation rates and the interest rates that are measured in quarterly terms from 0 to 1. The full model description is as follows:

dd	consumption plus investment (real)
llr	the expected real lending rate (one year ahead)
clprlev	ratio of nominal private sector credit to nominal GDP
yp	potential GDP
g	real government spending
y	real GDP
m	aggregate real imports
x	aggregate real exports
ntx	non-traditional exports
dp	the quaterly rate of CPI inflation
p	the CPI price level
ds	change in stocks
px	the price of non-traditional exports in rand
ptx	the price of traditional exports in dollars
psa	the South African core price level
eeu	the nominal US/Pula exchange rate
esa	the nominal SA/Pula exchange rate
yf	South African real GDP
resa	the real exchange rate with respect to SA
openness	A variable to capture the opening of Botswana trade (proxied by exports/domestic demand)
reus	the real exchange rate with respect to the US
rius	the quarterly US real interest rate (ex-ante)
pus	the level of US prices
infus	US quarterly inflation
infsa	SA quarterly inflation
m0	base money
i	the Bank Rate (quarterly)
depr	the deposit rate (quarterly)
bobcr	nominal interest rate on Bank of Botswana Certificates, a variable to indicate financial development in Botswana (proxied by a time trend)
risa	the SA real interest rate
nfalev	the ratio of net foreign assets in dollars to domestic nominal GDP (converted to dollars at the current exchange rate)
dr	the rate of increase of the amount of reserves in dollars
clpbclev	the ratio of nominal public credit to domestic nominal GDP
unclasslev	the ratio of NOI to domestic nominal GDP

APPENDIX B: *Botswana's Monetary Policy Transmission Mechanism*[11]



Demand, output gap and real monetary conditions: All things equal, an increase in the Bank Rate results in an increase in other market interest rates and adjustment of the exchange rate; to the extent it is flexible. These developments change the real monetary conditions and, consequently, the desire for borrowing, which affects aggregate demand. The response of firms to the lower demand determines the margin of the output gap and the rate of increase of prices.

Foreign price increases: Other things remaining the same, local vendors would tend to pass on to consumers price increases of foreign-sourced goods and services.

Exchange rate developments: A change in the exchange rate will affect the import price of foreign-sourced goods and services. The exchange rate, on the other hand, can be affected by capital flows (cross-border financial transactions) that respond to the variation in interest rate differentials. This channel is, however, weak in Botswana given that the exchange rate is not fully flexible and, therefore, does not respond to changes in interest rates. Nevertheless, a change in the Pula exchange rate from any source will be transmitted through this channel.

11 Botswana's Monetary Policy Transmission Mechanism as extracted from the 2008 Bank of Botswana Annual Report.

Other price shocks: For Botswana, these would include an increase in administered prices (mostly the cost of utilities and government services and others, such as fuel prices and transport fares). To the extent that these are artificially held below market levels for a long time, subsequent adjustments tend to be much larger than the general price trends and the inflation objective.

Expectations: Among other considerations, suppliers of goods and services and workers base their decisions on price increases and wage adjustments on what they expect inflation to be. Expectations can be both backward and forward looking. Those with backward looking expectations see inflation persisting at past levels and will be slow to respond to changes in policy actions that affect inflation. On the other hand, setting the inflation objective and entrenching the credibility of the policy framework can have a significant influence in encouraging forward looking expectations, which take account of the current and prospective conditions in determining expectations of future inflation.

While there are significant foreign influences and other occasional shocks to domestic inflation (as shown at the bottom of Appendix B), the monetary policy framework is premised on an understanding that the rate of domestic price increases reflects, in the main, local demand conditions and policy environment. Monetary policy, therefore, has an impact on expectations and other second-round effects. First, the extent to which local vendors pass on foreign price increases to consumers will depend on local conditions with respect to competitiveness and demand for their goods and services. In turn, demand is influenced by the monetary policy stance and its effect on real monetary conditions. Second, a well articulated and credible policy influences expectations as a source of inflation; thus, generally, price increases and demand for wage adjustments would be related to the monetary policy stance and the extent to which the public believes the inflation objective to be achievable on a sustained basis. Third, a widely accepted price stability objective can influence the rate of increase in administered prices to be consistent with the inflation objective. In the circumstances, there is scope for policy coordination and a measured approach to such cost increases.

ESTIMATING THE SACRIFICE RATIO: EVIDENCE FROM THE BOTSWANA DATA

Thato Mokoti [1]

Abstract

The paper estimates the sacrifice ratio for Botswana, a tool that can be used to inform and guide policymakers in formulating policies that reduce the trade-off between the control on inflation and output expansion. The study uses the structural vector auto regression (VAR) model in estimating the sacrifice for total real GDP and real non-mining GDP, over the period 1993Q3-2008Q4. The results, derived solely from data generation process and the method applied, indicate that a disinflation policy in Botswana results in more cumulative output losses for total real GDP than for real non-mining GDP. It is, however, important to caution that given the short data series and variability that is not associated with domestic policy changes, it is difficult to draw plausible conclusions (from this study) about the effects of monetary policy on output and inflation. In this regard, it was also not possible, using the method in this study, to single out monetary policy shocks from other aggregate demand shocks. The limitation of this approach in assessing the impact of policy suggests a need to explore other approaches to evaluating policy that are more suited to accommodating data constraints such as prevailing in Botswana.

1. Introduction

It is commonly believed that sustained low levels of inflation may give rise to long-run benefits to the society in terms of increasing the level of potential output. However, there is also a strong belief that the reaction of monetary authorities to keep inflation under control involves short-run costs in terms of loss of output, better known as the sacrifice ratio. The sacrifice ratio can, therefore, be defined as the cumulative output losses as a percentage of real gross domestic product (GDP), that an economy must endure in order to reduce average inflation on a permanent basis by one percentage point (Kinful, 2007). The real cost of monetary policy tightening in terms of foregone output in the short run is attributed to the persistence of inflation. Inflation persistence may arise due to three possibilities. First, it may occur due to the overlap and lack of coordination of wage and price contracts in an economy since wages and prices adjust at different times. Second, since people's inflation expectations are based on some sort of an adaptive mechanism; as a result, they may adjust only slowly overtime. Third, if the public is not fully convinced that the monetary authority is committed and capable of reducing inflation, then inflation will exhibit some inertia.

The literature citation on the sacrifice ratio and its quantitative measure guide the design of a disinflation policy and its consequences on output. For this reason, the sacrifice ratio is a guide in determining the optimal speed of disinflation due to restrictive monetary policy action (Filardo, 1998).

While some attempts have been made on the estimation of the sacrifice ratio, the estimation has been confined mostly to industrialised countries. For developing countries, particularly African countries, estimation of the sacrifice ratio is rarely attempted, except the work for Ghana by Kinful (2007). Since successful conduct of monetary policy requires not only specifying a set of objectives, which generally include inflation and employment, the trade-off between the objective of price stability and economic growth in Botswana is similarly germane. This study, therefore, estimates the sacrifice ratio for Botswana as a contribution to information that would be available to policymakers in formulating policies. In general, knowledge of the sacrifice ratio helps minimise the trade-off between the control on inflation and output expansion; hence, a measured response to controlling inflation could be adopted in order to minimise short-run costs in foregone output growth.

However, Botswana's economy is driven mainly by the mining industry, especially diamond production, the output of which is exported. Diamond output accounts for about 40 percent of GDP, 50 percent of government revenues and 70 percent of merchandised exports.[2] Since monetary policy affects domestic demand, the demand for diamonds cannot be influenced by monetary policy changes in Botswana; but depends on the trading and marketing arrangement between Debswana and De Beers Company, as well as world demand. For this reason, the analysis of the effects of monetary policy on output in Botswana need to take into account its two components – that which is determined by factors outside the influence of Botswana's monetary authorities and the other which can be impacted by the monetary policy. This study, therefore, derives the sacrifice ratio for both the whole economy and, alternatively, for non-mining output. The following Section summarises the structural vector autoregression (SVAR) model specification adopted for this study, while the data and time series properties are described in Section 3. The results of the SVAR estimates are presented in Section 4 and estimates of the sacrifice ratio reported in Section 5, followed by the conclusion in Section 6.

1 Economist (Modelling and Forecasting Unit), Research Department. The views expressed in the paper are those of the author and do not necessarily reflect those of the Bank of Botswana.

2 The figures are averages calculated over the period 1993Q3-2008Q4.

2. Methodology

In estimating the sacrifice ratio for Botswana, this study follows closely the SVAR approach pioneered by Cecchitti and Rich (2001), and later used by Durand et al (2008). An SVAR model is a dynamic simultaneous equations model with restrictions imposed based on economic theory. The use of this method in this study is mostly justified by the fact that other approaches of deriving the sacrifice ratio do not adequately control for the impact of non-monetary factors on the behaviour of output and inflation. For example, the approach developed by Ball (1994) assumes that each disinflation episode is a result of monetary policy actions; and, therefore, ignores the impact of supply shocks as well as other demand shocks such as those arising from substantial changes in money demand and fiscal policy. To avoid this omission, the sacrifice ratio for Botswana is estimated from the SVAR framework based on the long-run identifying restriction popularised by Blanchard and Quah (1989).[3] The advantage of a long-run restriction, as opposed to one that is contemporaneous, is that it avoids any judgement about short-run rigidities. Instead, the restrictions are based on general mainstream assumptions about the economy in the long run.

Due to sample size limitation[4] of real GDP in Botswana, the estimation of the sacrifice ratio in this study is constrained to a two-variable system in order to allow for enough degrees of freedom for the VAR model used. However, there is a weakness in use of a two-variable system since it fails to identify separate components of aggregate demand shock. As a result, the estimated monetary policy shock would not only include policy shifts, but also other aggregate demand shocks such as fiscal, investment and consumption shocks.

Unlike Durand et al (2008), who estimated the sacrifice ratio for twelve European Monetary Union (EMU) countries based on a bivariate VAR system consisting of total real GDP and the inflation rate, this study goes further. First, a two variable system consisting of total real GDP and inflation is estimated. Then, in order to reflect Botswana's situation, a VAR system based on real non-mining GDP and inflation is estimated separately. Since the sacrifice ratios obtained from this method are highly sensitive[5] to the identification restrictions and the size (number of variables) of the model, an almost similar SVAR model is used in deriving the estimates of the sacrifice ratio for total real GDP and real non-mining GDP.

The economy is assumed to be described by a bivariate SVAR model of the following form:

$$\begin{aligned} \Delta y_t &= \sum_{i=1}^{n} b_{11}^{i} \Delta y_{t-i} + b_{12}^{0} \Delta \pi_t + \sum_{i=1}^{n} b_{12}^{i} \Delta \pi_{t-i} + \varepsilon_t^{y} \\ \Delta \pi_t &= b_{21}^{0} \Delta y_t + \sum_{i=1}^{n} b_{21}^{i} \Delta y_{t-i} + \sum_{i=1}^{n} b_{22}^{i} \Delta \pi_{t-i} + \varepsilon_t^{\pi} \end{aligned} \qquad t = 1,\ldots,T \qquad (1)$$

Where

y_t is log of real output[6] at time t.

π_t is the inflation rate between the current quarter and the same quarter in the previous year.[7]

$\varepsilon_t = \left[\varepsilon_t^{y}, \varepsilon_t^{\pi}\right]'$ is a vector of mean zero structural disturbances that can be considered as innovations pertaining to an aggregate supply $\left(\varepsilon_t^{y}\right)$ and aggregate demand $\left(\varepsilon_t^{\pi}\right)$.

Following Durand et al (2008), the denominator of the sacrifice ratio equation (equation 2) is then the cumulative final effect of a monetary policy shock ε_t^{π} implemented on at time t on the inflation rate level at time $t+\tau$, while the numerator is the cumulative output loss between time t and $t+\tau$ following the same shock ε_t^{π} .The numerator is not just the cumulative effect of monetary policy shock on output level at $t+\tau$ but the sum of its effects from t to $t+\tau$. Taken together, the relative impact of monetary policy on output and inflation, and hence the sacrifice ratio, over the time horizon τ, can be calculated as follows:

$$S(\tau) = \frac{\sum_{j=0}^{\tau} \left(\partial y_{t+j} / \partial \varepsilon_t^{\pi}\right)}{\left(\partial \pi_{t+\tau} / \partial \varepsilon_t^{\pi}\right)} = \frac{\left(\sum_{i=0}^{0} a_{12}^{i}\right) + \left(\sum_{i=0}^{1} a_{12}^{i}\right) + \ldots + \left(\sum_{i=0}^{\tau} a_{12}^{i}\right)}{\left(\sum_{i=0}^{\tau} a_{22}^{i}\right)} = \frac{\sum_{i=0}^{\tau}\left(\sum_{j=0}^{i} a_{12}^{i}\right)}{\sum_{i=0}^{\tau} a_{22}^{i}} \qquad (2)$$

Where a's are estimates of parameters from the impulse response functions.

The description above is in line with the definition of the sacrifice ratio as the cumulative output loss associated with a one percentage point permanent reduction in inflation. Since estimation of the sacrifice ratio requires selection of horizons for the long-run restriction on aggregate demand shocks and to calculate the dynamic response of output and inflation to monetary policy

3 The long-run identifying restriction is that aggregate demand shock (in this case assumed to be a monetary policy shock) has no permanent effect on the level of real GDP.

4 Quarterly real GDP data for Botswana is only available from the third quarter of 1993, or 62 observations.

5 The estimated effects of shocks can differ significantly as a result of slight changes in identification restrictions. Furthermore, the inaccuracy of the estimates from this method increases with the complexity of the model used.

6 Since this study estimates the sacrifice ratio for total real GDP and non-mining real output, therefore y_t in this case refers to these two definitions of real output.

7 The model includes the change (or first difference) of inflation to allow shocks to have a permanent effect on the level of inflation.

shocks, the estimates of the sacrifice ratio are based on the dynamic response of output and inflation occurring five years (20 quarters) after a disinflation policy.

3. Data Description and Time Series Properties of Data

3.1 Data Description

This study uses quarterly data for the period 1993:3-2008:4. The variables used (Figure 1 in the Appendix) are total real GDP for the economy (ltgdp), real non-mining GDP (lngdp), the inflation rate (inf) and the rand/Pula nominal exchange rate in levels (lex). The GDP data are sourced from the Statistics Botswana (formerly Central Statistics Office) while all the remaining data are sourced from Bank of Botswana (BoB) publications. All the series, apart from the inflation rate, have been converted into logarithms. The inflation rate is defined as the annual growth rate of the headline consumer price index (HCPI). The series for quarterly HCPI and rand/Pula exchange rate were derived by taking an average of the three months of a quarter. Furthermore, the two series for real GDP are measured in constant 1993/94, prices while the base period for HCPI is September 2006. Due to the high volatility and effects of recurring seasonal influences[8] in total real GDP, the series has been seasonally adjusted using the X-12 seasonal adjustment method.

The rand/Pula nominal exchange rate has been included as an exogenous variable in order to capture the influence of external environment on inflation and output. Three dummy variables have also been used namely: dumvat, dumdev and dumoil. On July 1, 2002, the Government of Botswana introduced 10 percent value added tax (VAT), covering a wider range of goods and services, replacing the 10 percent sales tax, which had a narrower coverage. As a result, inflation rose significantly during the third quarter of 2002. Furthermore, from May 2005, the crawling band exchange rate mechanism for determining the value of the Pula exchange rate was introduced. This framework enables continuous adjustments of the Pula exchange rate based on the inflation differential between Botswana and trading partners in order to maintain stability of the real effective exchange rate and, which, in turn, balances price competitiveness of the export sector. The implementation of the crawling band was preceded by a 12 percent devaluation of the Pula, as a one-off adjustment to reverse the accumulated real appreciation of the currency. Therefore, dumdev is introduced to capture the effect of the 12 percent devaluation on inflation, while dumoil picks up the effect of the global rise in oil prices as well as surging food prices during the second quarter of 2008.

3.2 Unit Root Test Results

The graphical plots of series for variables (Appendix, Figure 1) show most data series to be non stationary, except for inflation and the nominal exchange rate, for which stationarity is not clear. It is observed that none of the series fluctuate around the zero mean, an indication of a stationary series. However, Table 1 presents unit root tests results based on the Augmented Dickey-Fuller (ADF) and Ng-Perron tests for the whole sample period. The reason for the use of the Ng-Perron test along with the ADF test is that traditional methods of unit root test (ADF and Phillips-Perron tests), are known to suffer from severe finite sample power and size problem. Both the ADF and Phillips-Perron tests have low power against the alternative hypothesis that the series is stationary with a high autoregressive root (DeJong et al, 1992). The two tests are also known to have severe size distortion when the time series has a large negative moving average root (Schwert, 1989). In contrast, the Ng-Perron test is able to apply the generalised least squares (GLS) estimator. This approach improves the power of the test when there is a large autoregressive root and reduces the tendency of over-rejecting the null hypothesis when there is a large negative moving average in differenced series. For these reasons, the Ng-Perron test is preferred in this study. Meanwhile, despite the fact that when plotting the variables, the output series tend to display some trending behaviour, the unit root test is applied with both trend and without trend. The procedure allows for assessment of whether trends in the series are deterministic or stochastic. Furthermore, both the ADF and the Ng-Perron test statistics are evaluated using critical values at the 5 percent significance level.

The ADF test applied on the level of total real GDP in Botswana, taking into account the trending behaviour of output, suggests that the series is integrated of order zero i.e., I(0). When the test is specified without trend, the ADF test suggests that total real GDP is I(1). However, when the Ng-Perron test is carried out on the level of real GDP data with trend, the null hypothesis of unit root is not rejected. When the trend component is not taken into account, the Ng-Perron test still suggests that the total real GDP series is non-stationary. Based on the power of the Ng-Perron test and the fact that total real GDP in Botswana has a trending behaviour, the conclusion reached is that real output is I(1). Therefore, given the assumption that an aggregate supply shock has a permanent effect on output, the finding that total real GDP is I(1) is in line with the specification of

8 Mining sector is the dominant factor on Botswana's output. As a result, movements in total real GDP series follow movements in mining output. Due to the declining pattern of mining output every first quarter, this pattern is mimicked by the total output series.

the model in equation 1, since I(0) variables do not have a permanent component.

Meanwhile, the null hypothesis for the existence of a unit root on the level of real non-mining GDP is rejected when the ADF test is specified with a trend, suggesting that non-mining output is I(0). However, when an ADF test is applied without trend, the null hypothesis of a unit root is not rejected and the test results suggest that non-mining real GDP is I(1). When applying the Ng-Perron test on non-mining output with a trend component accounted for, the series is also found to be I(1). When the Ng-Perron test is applied without a trend, the null hypothesis of a unit root on non-mining output is not rejected at both the level and first difference of output. Therefore, based on Ng-Perron test and also given that the series for real non-mining output has a trend, the conclusion reached is that real non-mining GDP in Botswana is also I(1). This finding is also in line with the long-run identifying restriction specified for the structural VAR model in this study.

Table 1: Unit Root Test Results using ADF and Ng-Perron Tests

	ADF Test			
	With Trend		Without Trend	
Variables	Level	1st Difference	Level	1st Difference
LTGDP	-3.679045*	-8.959988*	-1.205788	-8.916643*
LNGDP	-6.252612*	-10.54784*	-0.149206	-10.64674*
INF	-4.002451*	-6.921267*	-4.157083*	-5.943567*
LEX	-1.378305	-5.643614*	-3.461474*	-1.841420
	Ng-Perron Test			
	With Trend		Without Trend	
Variables	Level	1st Difference	Level	1st Difference
LTGDP	-15.9838	-1.86563	0.78339	-0.83621
LNGDP	-28.3375*	-120.705	1.83953	-0.44742
INF	-26.1625*	-429.508*	-0.13823	-24.0917*
LEX	-3.74422	-29.3643*	-3.39387	-31.1486*

* Denotes the rejection of the null hypothesis of the unit root at the 5 percent level of significance.

When testing for the unit root for the level of inflation series, the ADF test specified with a trend suggests that the inflation rate in Botswana is I(0). When the ADF test is applied without specifying the trend, the null hypothesis of existence of unit root in inflation series is still rejected, suggesting that the inflation rate in Botswana is I(0). The Ng-Perron test specified with trend also provides evidence that the inflation series is I(0). However, when the Ng-Perron is specified without a trend in the inflation series, the test suggests that inflation in Botswana is I(1). Therefore, given the power of the Ng-Perron test, as well as the fact that the inflation series does not depict any particular trend, the conclusion reached is that inflation in Botswana is I(1). This finding is also in line with the definition of the sacrifice ratio used in this study, which assumes that the deviations in the inflation rate from its initial level due to a monetary policy shock should be permanent. The finding that the inflation rate is I(1) is also in line with the specification of the structural VAR model. For the exogenous variable, the ADF test specified with trend suggests that the nominal exchange rate series is I(1), while the test carried without trend shows that the series is I(0). Meanwhile, the two tests carried out using the Ng-Perron test both suggest that the nominal exchange rate series in Botswana is I(1); hence, the conclusion is that the series is I(1).

3.3 Lag Length Determination

The results from determining the appropriate lag lengths for the two VAR systems[9] estimated in this study are shown in Table 2. The specification of the optimal lag length for each of the VAR models is determined using the Schwarz Information Criterion (SIC) and the Akaike Information Criterion (AIC) in E-views. The lag length has to be sufficient enough to generate a vector of white noise innovations; but not too high to consume all the degrees of freedom. Therefore, the results suggest that for the VAR system consisting of total real GDP and inflation, both the SIC and the AIC indicate that the short-run dynamics of the model is described by the lag length of four or simply VAR(4). Furthermore, both the SIC and the AIC show that the VAR system consisting of real non-mining GDP is also described by VAR(4). This result appears to be consistent with the time it normally takes for monetary policy to ultimately affect both output and prices.

Table 2: Lag Length Selection Results for the Reduced Form VAR Models

	DLTGDP, DINF		DLNGDP, DINF	
Lag	AIC	SIC	AIC	SIC
0	-0.472096	-0.110426	-0.012874	0.131794
1	-0.725276	-0.218938	-0.169782	0.119554
2	-0.781205	-0.130199	-0.271554	0.162450
3	-0.918140	-0.122466	-0.586998	-0.008326
4	-1.29819*	-0.35785*	-0.818959*	-0.095619*
5	-1.172541	-0.087531	-0.757668	0.110340

* Indicates lag order selected by the criterion

9 The estimated VAR system consisting of total real GDP and inflation also includes the rand/Pula nominal exchange rate, dumoil, dumvat and dumdev as exogenous variables. However, the VAR system consisting of real non-mining GDP and inflation only includes the rand/Pula nominal exchange rate as an exogenous variable. Since all variables in this case are I(1), first differences of the series are used in estimating the two VAR models.

3.4 Cointegration Results

Since a conclusion from carrying out the unit root tests is that all the two output series and the inflation rate are I(1), and there also exist stochastic and deterministic trends in some of the series, a cointegration test using the Johansen approach was undertaken. If there is cointegrating relationship between variables, an error correction representation of the data can be specified to avoid the problem of spurious regression. Table 3 illustrates the results from the Johansen approach carried out on E-views using the Trace and Maximum Eigenvalue test statistics.

Table 3: Johansen Cointegration Test Results

		Trace Test		Maximum Eigen-value Test	
	Hypothesised no. of ce's[10]	Trace Statistic	0.05 critical value	Max-Eigen Statistic	0.05 critical value
LTGDP,INF	None	15.75680	25.87211	12.01638	19.38704
	At most 1	3.740421	12.51798	3.740421	12.51798
LNGDP,INF	None	21.51971	25.87211	13.13085	19.38704
	At most 1	8.388869	12.51798	8.388869	12.51798

To reject the null hypothesis of no cointegration relationship, the Trace and the Maximum Eigenvalue test statistics must be greater than the 5 percent critical values reported for each. The Trace test indicates that there is no cointegration between total real GDP and inflation rate in Botswana. This finding is also confirmed by the Maximum Eigenvalue test. The results from Table 3 also suggest that there is no long-run relationship between non-mining output and inflation in Botswana. This finding supports the long-run identifying restriction specified in the structural VAR model that monetary policy shocks have no effect on real output in the long run.

3.5 Diagnostic Tests for the Reduced Form VAR Models

Meanwhile, with a lag length of four selected for both the two reduced form VAR models used in this study, none of the residuals from the estimated equations exhibit any serial correlation at 5 percent significance level as depicted by the Lagrange Multiplier test results in Table 4. That is, the null hypothesis of no serial correlation for all the lags selected by the AIC and SIC for the two models is not rejected.

10 This denotes hypothesised number of cointegrating relationships/vectors.

Table 4: Serial Correlation Test Results using Lagrange Multiplier

	DLTGDP, DINF		DLNGDP, DINF	
Lag	LM Stats	Prob	LM Stats	Prob
1	8.087053	0.0884	2.856556	0.5821
2	4.426535	0.3513	4.670528	0.3228
3	2.073116	0.7223	2.755459	0.5995
4	1.972983	0.7407	9.368652	0.0525

Table 5: Specification Test Results based on the Ramsey RESET test

			Probability
DLTGDP	F-Stats	0.255506	0.615806
	Log Likelihood	0.337691	0.561165
DINF	F-Stats	1.833580	0.094828
	Log Likelihood	2.649773	0.133555
DLNGDP	F-Stats	0.445425	0.507850
	Log Likelihood	0.549284	0.458610
DINF	F-Stats	2.602216	0.113555
	Log Likelihood	3.136581	0.076554

All roots of the estimated models lie within the unit root circle, which suggests that the models pass the stability test. Furthermore, both the F-statistic and the Log likelihood ratio from the Ramsey RESET test in Table 5 indicate that the two models used in this study are correctly specified.

4. Estimation Results from the SVAR Model

Table 6 presents results from the estimated structural VAR models. The results indicate that all the two estimated systems are just identified.[11] The estimated long-run impact coefficients are also statistically significant in all the two models. Although the coefficients of the short-run impact matrix are not reported in Table 6, they consistently have the same signs as the coefficients for the long-run impact matrix.

Table 6: Estimation Results from Structural VAR Models

	DLTGDP, DINF			
	Coefficient	Std Error	z-Statistic	Probability
a(1)	0.014897	0.001395	10.67708	0.0000
a(2)	-0.183138	0.085874	-2.132648	0.0330
a(3)	0.635267	0.059498	10.67708	0.0000
Log likelihood	49.48992			
	DLNGDP, DINF			
	Coefficient	Std Error	z-Statistic	Probability
a(1)	0.013340	0.001249	10.67708	0.0000
a(2)	-0.332485	0.113812	-2.921358	0.0035
a(3)	0.826472	0.077406	10.67708	0.0000
Log likelihood	33.45897			

11 Just identified means that the number of parameters from the SVAR in equation 1 equals the number of parameters recovered from the estimated reduced form VAR.

Since estimation of the sacrifice ratio requires the selection of horizons for the long-run restriction on aggregate demand shocks (in this case monetary policy shocks) and to calculate the dynamic response of output and inflation to monetary policy shocks, the estimates derived in this study are based on impulse responses of output and inflation occurring five years after a shift in monetary policy.

Figure 2 in the Appendix reports the impulse response functions[12] of the VAR system consisting of total real GDP and inflation rate to supply and demand shocks. As expected, a supply shock that increases aggregate supply has an initial positive impact on total output level. The results also indicate that the cumulative effect of the supply shock on total real GDP is positive and permanent in the long run, reinforcing the traditional view that supply disturbances exert a permanent impact on output path. The effect of a supply shock on total real GDP is also significant[13] over the entire forecast horizon. On the other hand, Figure 2 indicates that following a supply shock, inflation remains almost unchanged before declining to reach its minimum point after three quarters. Although the effect of a supply shock on inflation is statistically insignificant over the entire forecast horizon, the effect is permanent and negative, a finding consistent with theory. As for demand disturbances, in this case taken as monetary policy shocks, Figure 2 indicates that such disturbances have an initial positive impact on total output level; and also later, resulting in output oscillating around its trend level before it eventually converges to trend. This finding seems to indicate a persistent effect of a monetary policy shock on total output in Botswana. However, the response of output to such a shock is statistically insignificant over the entire forecast horizon, an indication that monetary policy shock has little or no enduring impact on total output. The response of total output to a change in monetary policy in the short run is not surprising since the economy is dependent on exports of diamonds. Therefore, a large part of total real GDP is determined by factors outside the influence of Botswana's monetary authorities. However, the results indicate that a monetary policy shock meant to reduce aggregate demand, increases inflation.[14] The cumulative impulse response function indicates that the effect of a monetary policy shock is significantly positive and permanent.

Figure 3 in the Appendix reports the impulse responses of the VAR system constructed from real non-mining GDP and inflation. The results indicate that the impact of supply disturbances leads to an increase in the level of non-mining output. Non-mining output level then falls to reach its minimum yet positive level after two quarters, and thereafter, fluctuates above the trend level into the long run. The cumulative response of non-mining output to a supply shock is significantly positive and permanent for all quarters, except between the first and third quarter. Furthermore, a supply shock that increases aggregate supply reduces inflation on impact. Meanwhile, a supply shock dampens inflation until the third quarter before inflation starts to oscillate below the long-run equilibrium level. The results, therefore, indicate that a supply shock associated with non-mining output permanently reduces inflation, although the response is statistically insignificant. Figure 3 also indicates that the impact of a monetary policy shock results in an increase in non-mining output, raising output further to a peak in the first quarter, before it declines until the third quarter. Thereafter, it oscillates around the trend level for several quarters until it converges on the trend in the long run. Unlike total real GDP, the effect of a monetary policy shock on non-mining output is significantly positive between the ninth and tenth quarters, an indication that monetary policy in Botswana, to a certain extent, can influence real non-mining activity. Furthermore, the results also indicate that demand shocks have an insignificant persistent effect on non-mining output in Botswana. The results also indicate that a monetary policy shock initially raises the inflation rate. However, inflation peaks after the second quarter and then declines to reach its minimum yet positive level in the seventh quarter, an indication that inflation in Botswana responds to policy shocks with a lag. The cumulative impulse response function shows that the effect of a monetary policy shock on inflation is significantly positive for all but one quarter, and permanent.

In addition to the impulse response functions, the variance decompositions for all the estimated SVAR models are reported. In a time series, a variable sequence may fluctuate over time partly due to its own shocks and in part due to shocks from other variables in the system. Given the long-run identifying restriction used in the two models, variance decomposition in this case helps to measure the relative importance of supply and demand shocks underlying output fluctuations, as well as variations in inflation over different time horizons. Unlike the traditional belief that aggregate demand shocks play an important role as a source of output fluctuations over very short horizons, Table A1

12 JMulTi was used to produce impulse response functions based on the Studentized Hall Bootstrap Confidence Interval involving 100 replications and a time horizon set at 20 quarters.

13 The significance of the response function is given by the standard error bands, i.e., in the case where both the top and bottom error bands lie in the same region, either positive or negative, then the response is statistically significant.

14 Such behaviour is normally blamed on the misspecification of the VAR model. Since the VAR models used in this study are correctly specified, this finding can be explained by the idea that prices tend to rise following a monetary policy tightening, since an increase in interest rates raises production costs.

in the Appendix illustrates how important supply shocks are to Botswana's total real GDP in both the short run and long run, leaving demand shocks with a limited role to play. However, the results indicate the persistent effect of demand shocks on total real GDP, indicating the lack of a costless disinflation policy. Furthermore, Table A1 shows that monetary policy shocks play a larger role than supply shocks in explaining variations in inflation in both the short and long run.

Finally, Table A2 in the Appendix presents results from the variance decomposition of a VAR system based on non-mining output and inflation. Although there are indications of monetary policy influence on non-mining output in both the short run and long run, the results show that supply shocks account for more of the variations in non-mining output than demand shocks. Furthermore, the influence of supply shocks is more pronounced for non-mining output than for total real GDP. Therefore, demand shocks are less persistent for non-mining output as compared to total real GDP. Similar to the results presented in Tables A1, Table A2 shows that demand shocks in Botswana are the main source of variations in inflation in Botswana in both the short and long run.

5. Results from Computation of the Sacrifice Ratio

The estimates of the sacrifice ratio for Botswana derived using equation 2 in Section 2 with time horizon set at twenty quarters are presented in Table 7. Since the estimates are all positive, the data indicates the existence of the short-run trade-off between inflation and output in Botswana. It is observed on the basis of these data and methodology that, in Botswana, a one percentage point permanent reduction in the annual inflation rate leads to a 0.72 percent cumulative output loss for the whole economy over a five year horizon. Further analysis of the sacrifice ratio in Botswana indicates that a one percentage point permanent reduction in inflation results in a 0.57 percent cumulative output loss from the non-mining sector.

Table 7: Sacrifice Ratio for Botswana

	Sacrifice Ratio
Total Output	0.72
Non-Mining Output	0.57

The results seem puzzling since the expectation was that the sacrifice ratio for non-mining output would be greater than that for total output for the economy. The expectation was based on the fact that a large part of Botswana's total output is determined by factors outside the control of Botswana's monetary authorities. As a result, monetary policy would have relatively less impact on total output compared to the potential effect on non-mining output. Furthermore, the expectation of a higher value of the sacrifice ratio for non-mining output than for total output was based on fact that the responses of non-mining output to demand shocks are statistically significant for certain quarters, unlike responses for total output which are statistically insignificant for the whole estimate horizon. Moreover, since monetary policy influences domestic demand pressures, the sacrifice ratio for non-mining output was expected to be more pronounced, since it should mainly impact on domestic consumption. However, as highlighted earlier, the use of a two-variable system fails to identify separate components of aggregate demand shock. As a result, the estimated monetary policy shock for total output would not only include policy shifts, but also other domestic and external demand shocks, hence, a higher sacrifice ratio for total output compared to non-mining output.

6. Conclusion

This study adopted a specific methodology and used Botswana data to estimate the sacrifice ratio. In general, determination of the sacrifice ratio informs the extent of trade-off between the objective of price stability and economic expansion and acts as a guide to policy formulation. Given that mining output contributes significantly to overall GDP in Botswana, it was also essential to estimate the sacrifice ratio for non-mining output separately. Due to data limitation, this study was constrained to a two-variable system, making it impossible to separate monetary policy shocks from other domestic and external demand shocks. As a result, it is not surprising to find more short-run costs of a disinflation policy in Botswana being borne by the total output.

Furthermore, the results from the methodology applied indicate that most of the fluctuations in output in Botswana in both the short and long run are accounted for by supply shocks. In other words, supply shocks account for relatively more of the output fluctuations in Botswana, compared to the monetary policy influence. This finding is in line with the random walk theory of GDP that changes in aggregate demand are much less important than changes in aggregate supply in explaining shifts in output. Therefore, given the estimates obtained, it can be concluded that a disinflation policy in Botswana does not entail huge losses in output.

Over the period under review, Botswana's annual inflation rate averaged 9.1 percent, higher than the 3 - 6 percent objective range set by monetary authority. It is expected that higher inflation may reduce the extent of nominal rigidities because it encourages frequent contract negotiations, resulting in a low sacrifice ratio as indicated in the case of Botswana. Furthermore, due to the high revenues accruing from diamond sales, the Government of Botswana, as the main employer, has been experiencing surpluses for most of the period under review. As a result, there have been increases in salaries of government employees almost every year, which is then replicated across the rest of the economy. This, therefore, makes nominal wages in Botswana more flexible, hence, potentially contributing to the low value of the sacrifice ratio.

However, the results indicate that price changes in Botswana are driven more by demand shocks as opposed to supply shocks. The results also indicate that a monetary policy shock in Botswana results in a permanent shift in inflation from its level. Furthermore, there is evidence of a price puzzle in Botswana. The price puzzle could be explained by the notion that prices could rise faster in the wake of a monetary policy tightening because an increase in interest rates gives rise to higher production costs, which are then reflected in higher inflation rates. The results also indicate that inflation starts falling after a few quarters following a monetary policy shock, an indication that monetary policy in Botswana affects the economy with a lag.

Finally, as a cautionary note, there is need to highlight that, in order to draw more plausible conclusions about the effects of monetary policy on output and inflation, there is need for longer time series. Due to lack of a longer time series for real output in Botswana, it was not possible, using the method in this study, to single out monetary policy shocks from other aggregate demand shocks. Therefore, with the availability of a longer time series, future research should go beyond a two-variable system in order to improve the quality and policy value of estimates of the sacrifice ratio for Botswana. Future studies should also explore other approaches to evaluating policies that are more suited to accommodating data constraints such as prevailing in Botswana.

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APPENDIX

Figure 1: Times Series Plots of Variables used in the Study

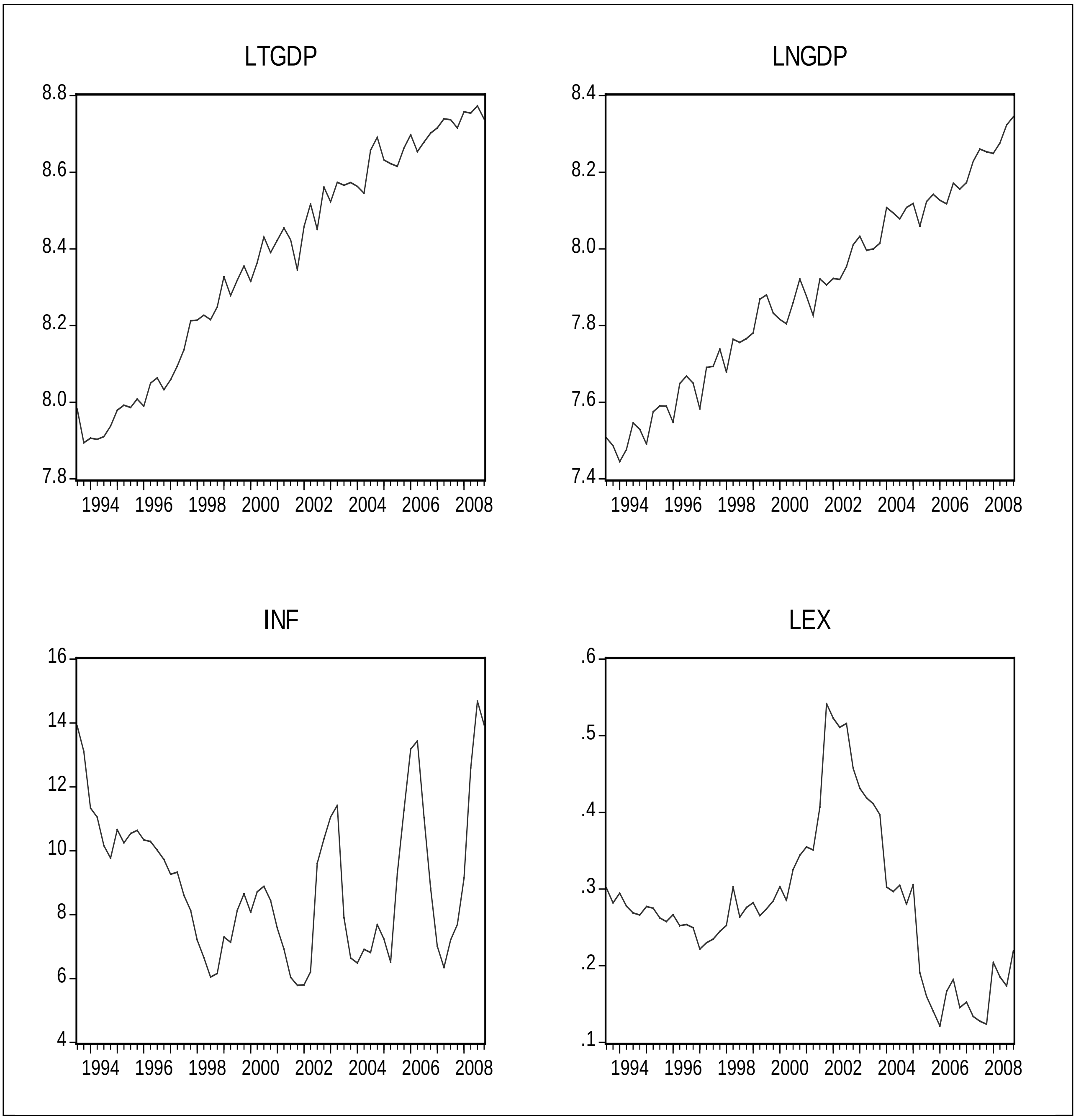
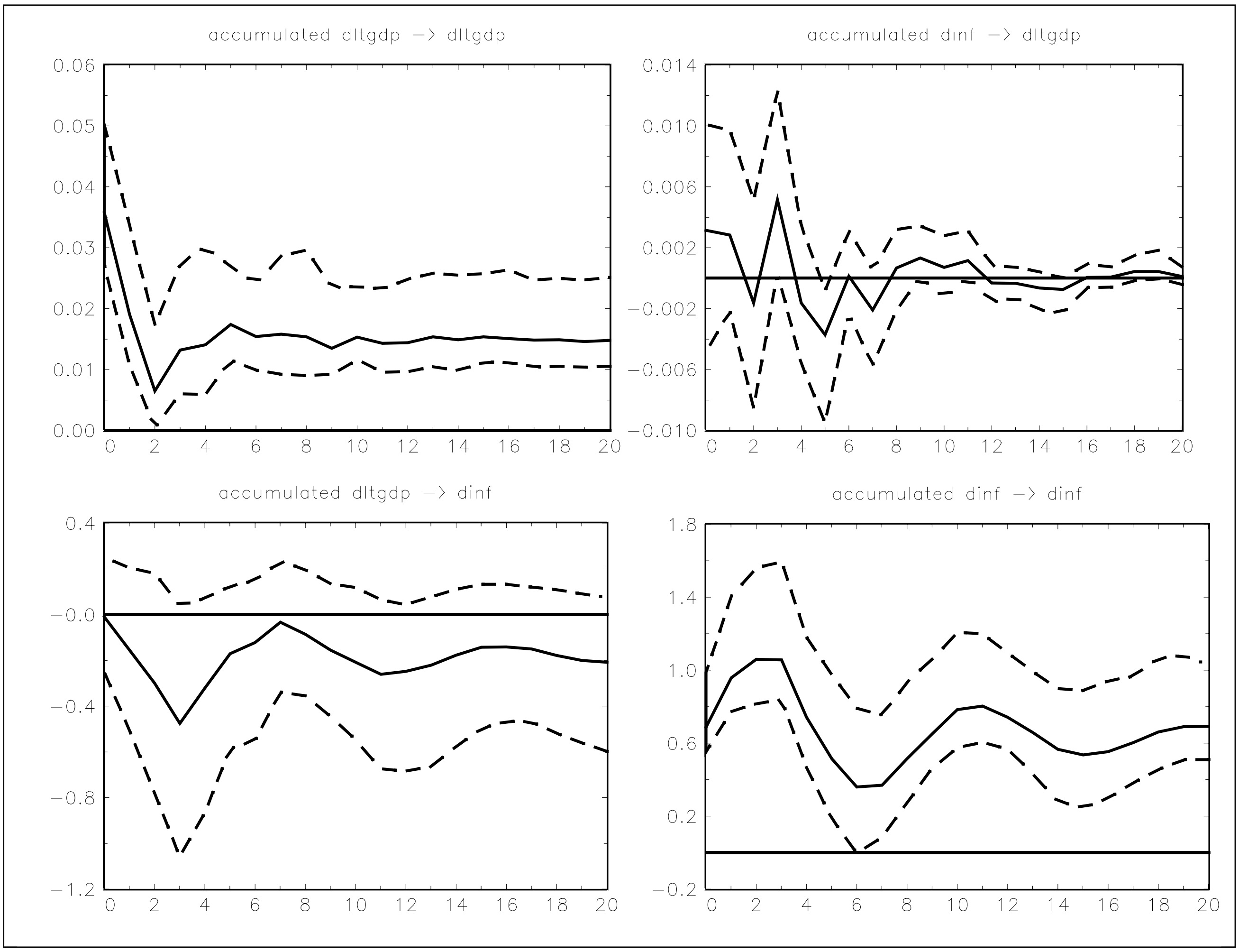
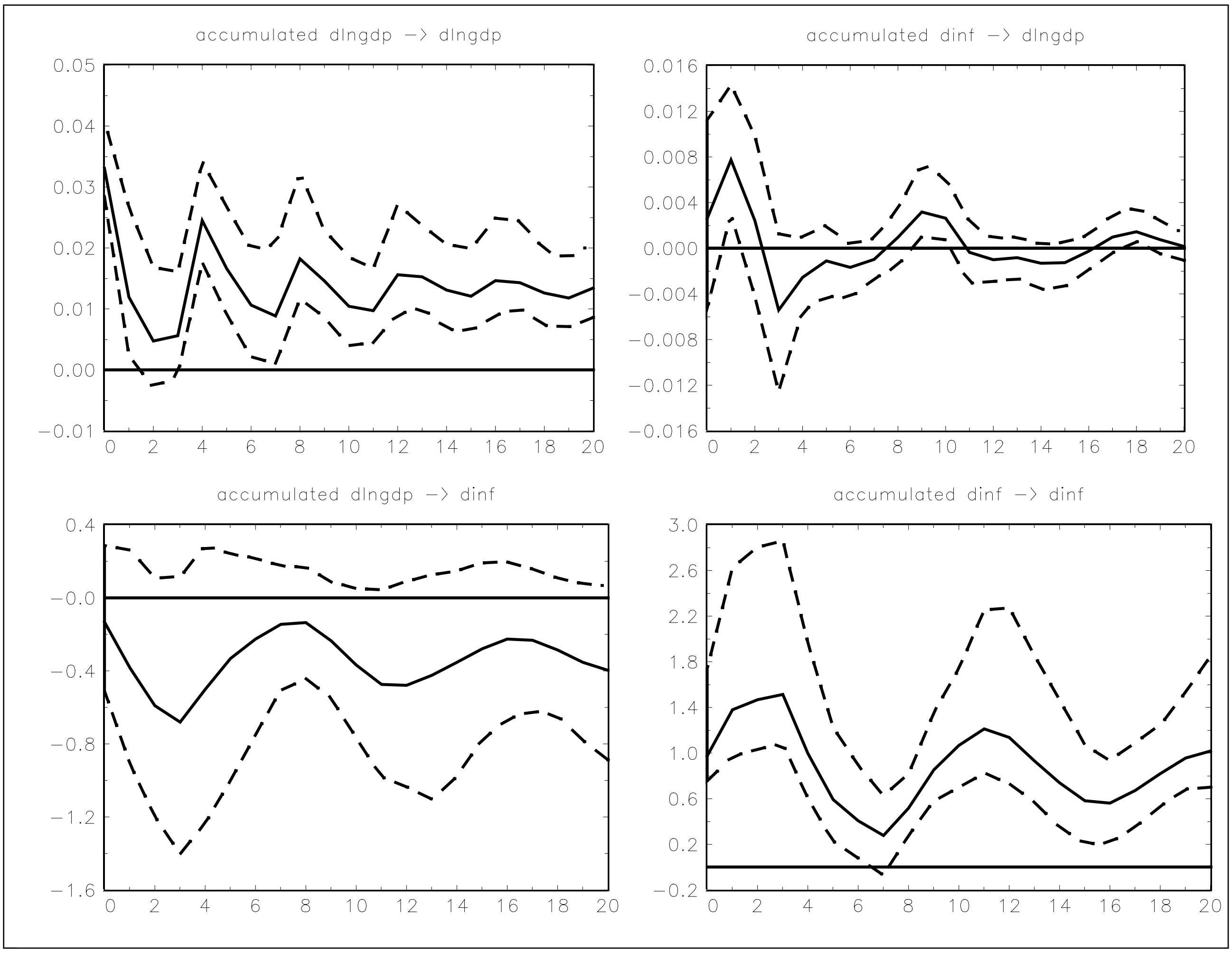


Figure 2: Cumulative Impulse Responses of Total Real GDP and Inflation to Aggregate Demand and Aggregate Supply Shocks



Note: The graphs should be interpreted with caution as follows: accumulated dltgdp → dltgdp indicates the cumulative response of total real GDP to supply shock, accumulated dinf → dltgdp indicates the cumulative response of total real GDP to an aggregate demand shock, accumulated dltgdp → dinf indicates the cumulative response of inflation to supply shock while accumulated dinf → dinf indicates the cumulative response of inflation to an aggregate demand shock. An aggregate demand shock in this study is assumed to be a monetary policy shock.

Figure 3: Cumulative Impulse Responses of Non-Mining Real GDP and Inflation to Aggregate Demand and Aggregate Supply Shocks



Note: The graphs should be interpreted with caution as follows: accumulated dlngdp → dlngdp indicates the cumulative response of non-mining real GDP to supply shock, accumulated dinf → dlngdp indicates the cumulative response of non-mining real GDP to an aggregate demand shock, accumulated dlngdp → dinf indicates the cumulative response of inflation to supply shock while accumulated dinf → dinf indicates the cumulative response of inflation to an aggregate demand shock. An aggregate demand shock in this study is assumed to be a monetary policy shock.

Table A1: Variance Decomposition of Total Real GDP and Inflation

	Proportion of Forecast Error in			
	DLTGDP		DINF	
	Accounted for by		Accounted for by	
Forecast Horizon	AS Shock	AD Shock	AS Shock	AD Shock
1	0.99	0.01	0.00	1.00
2	0.99	0.01	0.04	0.96
3	0.98	0.02	0.07	0.93
4	0.96	0.04	0.12	0.88
5	0.94	0.06	0.13	0.87
6	0.93	0.07	0.14	0.86
7	0.93	0.07	0.14	0.86
8	0.92	0.08	0.15	0.85
9	0.92	0.08	0.15	0.85
10	0.92	0.08	0.15	0.85
11	0.92	0.08	0.15	0.85
12	0.92	0.08	0.15	0.85
13	0.92	0.08	0.15	0.85
14	0.92	0.08	0.15	0.85
15	0.92	0.08	0.15	0.85
16	0.92	0.08	0.15	0.85
17	0.92	0.08	0.15	0.85
18	0.92	0.08	0.15	0.85
19	0.92	0.08	0.15	0.85
20	0.92	0.08	0.15	0.85

Table A2: Variance Decomposition of Non-Mining Real GDP and Inflation

	Proportion of Forecast Error in			
	DLNGDP		DINF	
	Accounted for by		Accounted for by	
Forecast Horizon	AS Shock	AD Shock	AS Shock	AD Shock
1	0.99	0.01	0.02	0.98
2	0.98	0.02	0.07	0.93
3	0.96	0.04	0.10	0.90
4	0.93	0.07	0.10	0.90
5	0.94	0.06	0.10	0.90
6	0.94	0.06	0.11	0.89
7	0.94	0.06	0.11	0.89
8	0.94	0.06	0.12	0.88
9	0.94	0.06	0.11	0.89
10	0.94	0.06	0.11	0.89
11	0.94	0.06	0.12	0.88
12	0.93	0.07	0.12	0.88
13	0.94	0.06	0.12	0.88
14	0.94	0.06	0.12	0.88
15	0.94	0.06	0.12	0.88
16	0.94	0.06	0.12	0.88
17	0.93	0.07	0.12	0.88
18	0.93	0.07	0.12	0.88
19	0.93	0.07	0.12	0.88
20	0.93	0.07	0.12	0.88

LONG MEMORY, STRUCTURAL CHANGE AND VOLATILITY FORECASTING: EVIDENCE FROM EMERGING EQUITY INDICES

Pako Thupayagale [1]

Abstract

This paper examines evidence of volatility persistence and long memory in the light of structural change in the volatility series. In particular, this study shows that long memory dynamics may be overestimated if regime shifts are not accounted for in the standard GARCH model. This research endogenously identifies episodes of structural change through breakpoint tests and a moving average application suggest that the unconditional variance exhibits substantial time-variation. Indeed, this is shown to be the source of the spurious finding of long memory. Furthermore, a modification of the GARCH model to allow for mean variation is introduced and its forecast performance is evaluated against the GARCH and FIGARCH models using both symmetric and asymmetric loss functions. This innovation is shown to generate improved volatility forecasting performance, but only over long horizons, and for some equity indices. The major exception relates to the case of Botswana where the standard GARCH model dominates forecast performance.

1. Introduction

Portfolio equity inflows to emerging markets have grown significantly in size as investors targeting higher return and diversification benefits have directed capital into these markets. These developments have also seen considerable attention devoted to analysis of the various risk return attributes of these markets. In particular, recent empirical literature has focused on the characterisation of the volatility profile of emerging market stock returns. Indeed, developments in stock return volatility are being followed closely (in real-time) by a host of economic agents, including traders, investors, speculators and policymakers. Accurate estimation of volatility plays an important role in many applications in finance, including valuation of derivatives (e.g., as option pricing), optimal portfolio selection (e.g., diversification strategies) and risk management (e.g., value-at-risk modelling). These applications have motivated an extensive empirical literature on volatility modelling. In particular, the modelling of conditional volatility in high-frequency financial time series has facilitated the modelling and forecasting of volatility in financial markets. The main representatives of this class of models include the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models (Engle, 1982; Bollerslev, 1986) and long memory processes such as the Fractionally Integrated GARCH (FIGARCH) model (Baillie *et al*, 1996). These models distinguish between the conditional and unconditional (or long run) variance processes such that the former is assumed to fluctuate while the latter is fixed.

This conceptual approach asserts that, although volatility is persistent (i.e., shocks to current volatility remain important for long periods into the future), it ultimately reverts to a constant long-term average volatility. However, this conventional assumption has recently been challenged. For example, Lamoureux and Lastrapes (1990), Mikosch and Stărică (2004a) and Malik *et al* (2005) demonstrate that failure to accommodate structural change in the volatility series leads to overstated estimates of persistence in variance in the GARCH framework. Furthermore, Mikosch and Stărică (2004b) show that evidence of volatility persistence could be an artefact of structural change in the data; in particular, nonstationarity of the unconditional variance. In total, the extant literature provides significant evidence to substantiate the hypothesis that GARCH measures of volatility persistence are subject to model misspecification arising from the failure to take account of structural change in the data being analysed (e.g., McMillan and Ruiz, 2009, and references therein).

Similarly, in the case of long memory estimates, a growing body of econometric research suggests that evidence of long memory may be a spurious experimental result. For instance, Lobato and Savin (1998), Diebold and Inoue (2001), Granger and Hyung (2004) and McMillan and Ruiz (2009) report evidence showing that structural breaks within the volatility series can lead to apparent evidence of long memory, unless such breaks are explicitly incorporated into the modelling framework. In sum, these strands of the modelling literature show that the existence of either structural change (or regime switches) or an unstable unconditional mean variance will present evidence of long memory when analysed using models which assume a constant unconditional mean variance, such as the standard GARCH. Also, Gourieroux and Jasiak (2001) show how stochastic processes with infrequent regime switching may precipitate a long memory effect in the autocorrelation function, thereby, giving the appearance of long memory behaviour. Therefore, in both the time and frequency domain, structural change may bias upward the finding of long memory.

1 Chief Dealer, Financial Markets Department. The views expressed in the paper are those of the author and do not necessarily reflect those of the Bank of Botswana.

This paper has three objectives. First, evidence of long memory volatility within a selection of leading emerging market equity indices is investigated. Second, this study examines the existence of both structural breaks and time-variation in the unconditional variance and tests whether these attributes exaggerate the appearance of long memory in volatility. Third, to investigate the existence of a time-varying unconditional variance, so as to test if the extraction of this long-run component can be exploited for purposes of generating improved volatility forecasts over short and long horizons and on the basis of both symmetric and asymmetric loss functions. Indeed, as is well-known, accurate volatility forecasts are important in a range of applications, from the design of trading strategies to tactical asset allocation decisions.

2. Evidence of Long Memory

The data analysed in this study are obtained from Bloomberg and consist of the daily equity returns of Botswana and five other emerging economies: Brazil, Russia, India, China and South Africa (henceforth BRICS). In addition, this study includes the US as a benchmark comparator. The equity return, r_t, is defined as $\left(p_t - p_{t-1}\right) \times 100$, where p_t is the log of the equity price at time t. All the time series include data up to December 31, 2009; but the commencement dates of the respective time series differs (owing to the uneven availability of data). Table 1 provides further details of the data used in this study.

In order to identify the long memory properties of stock return volatility in the BRICS, three procedures are performed. First, a standard GARCH (1,1) model is estimated for each index series; then, the sample autocorrelation function (of absolute returns) is examined for evidence of long memory; finally, the fractionally integration parameter is estimated through application of spectral regression techniques.

GARCH(1,1) Estimates

The GARCH (1,1) specification comprises a returns (or mean) and a variance equation. In particular, the returns generating process can be described by:

$$R_t = \mu + cR_{t-1} + \varepsilon_t \quad \text{where} \quad \varepsilon_t | \Phi_{t-1} \sim N\left(0, h_t\right) \qquad (1)$$

where R_t denotes the returns process, which may include autoregressive and moving average components and ε_t is the error term which is assumed to be normally distributed with zero mean and variance h_t, given the information set Φ_{t-1}. The conditional variance is modelled as

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \qquad (2)$$

For h_t to be well-defined, ω, α and β are constrained to be non-negative. In addition, the unconditional variance is given by $\sigma^2 = \omega / 1 - \alpha - \beta$ and requires that α+β < 1, to be finite and positive. Furthermore, GARCH models enable the measurement of persistence in variance through the summation of α and β. To provide another perspective on the estimate of volatility persistence, the half-life decay given by λ=log(0.5)/log(α+β) is also presented.

The GARCH (1,1) model estimates are reported in Table 2. For the most part, the results indicate that volatility in these markets is very persistent and is also concentrated in a narrow range from 0.985 in India to 0.994 in Brazil. Furthermore, volatility persistence is over 0.99 for Russia, South Africa and the US, which underscores the highly persistent nature of shocks to volatility and indeed the similarity in magnitude of persistence in variance between emerging and advanced economies. The major exception relates to the case of Botswana and China, where the sum of α and β is greater than unity, which means that volatility is explosive, such that a shock to volatility in one period will result in even greater volatility in the next period. Meanwhile, the half-life decay ranges from 133 days in Brazil to 49 days in India. For Russia and South Africa, shocks to volatility will taper off with a half life of about 91 and 98 days, respectively. In comparison, for the US it takes about 131 days for a shock to volatility to dissipate to half its initial size. In the case where volatility is explosive, as in the case of Botswana and China, the half life cannot be interpreted since these volatility series are non-stationary (or non-mean reverting). In sum, the results presented in Table 2 suggest robust evidence in favour of the existence of long memory volatility for most emerging markets. The exceptions of Botswana and China perhaps reflect the illiquidity characterising these markets. This illiquidity, in turn, appears to reflect structural considerations in these economies. In Botswana, illiquidity is most likely explained by a ‘buy-and-hold’ investment strategy on the part of major investors; while in China, the illiquidity may reflect the existence of exchange controls, which may curtail trading activity.

ACF and Fractional Integration

In the time domain, long memory is often associated with an autocorrelation function (ACF) that exhibits a slow hyperbolic rate of decay that reflects the persistent, but ultimately mean-reverting nature of shocks to volatility. Accordingly, the sample ACF of the BRICS is investigated, in order to ascertain if, indeed, this decay structure is evident. The ACF for the absolute index returns for up to 100 lags for each respective time series are presented in Figure 1, along with the 5 percent critical value based upon $2/\sqrt{(T)}$.

The graphical evidence presented in Figure 1 shows that the ACFs of most of these emerging markets are consistent with evidence of long memory insofar as the sample ACF of $|r_t|$ decays very slowly and remains significant even at long lags. The main exception relates to the case of India. In particular, the ACF fluctuates around the critical threshold from lag 80. While the GARCH model suggested that volatility in China was explosive, the ACF suggests that volatility in this market is persistent, but ultimately mean reverting. In the main, however, the evidence presented in these graphs suggests the existence of long memory in the stock return volatility of the BRICS. In the case of Botswana, however, the ACF also behaves erratically. Indeed, after lag 45, the ACF fluctuates around the critical threshold in a manner inconsistent with long memory dynamics.

From here this paper turns to a more formal estimation of the long memory (or fractional integration) parameter. In particular, a long memory process can be characterised by the behaviour of its spectrum $f(\vartheta_j)$ estimated at the harmonic frequencies ϑ_j near the zero frequency, such that a stationary process is defined as having long memory when:

$$f(\vartheta) \approx \kappa|\vartheta|^{-2d} \text{ as } \vartheta \to 0 \quad (3)$$

Where $\kappa > 0$ and $d \in (0, 0.5)$ is the long memory parameter. To estimate *d*, the log-periodogram regression estimator is widely used. This semi-parametric procedure was proposed by Geweke and Porter-Hudak (1983), and is based on the periodogram using the Parzen window. The estimator of the parameter of the fractional integration, *d*, is based on the following least squares regression:

$$\{\log(I_j) : j = 1,...,m\} = \gamma_0 + \gamma_1[\log|1 - \exp(-i\vartheta_j)|] + e_j \quad (4)$$

where $\hat{d} = -(\hat{\gamma}_1/2)$ provides the estimated long memory parameter for the absolute stock returns, which are presented in the final column of Table 2. The estimates of the long memory parameter, *d*, vary from 0.41 in Brazil to 0.60 in the US, and are all statistically significant. For Botswana, Russia, South Africa and the US, stock return volatility is non-stationary, since $d > 0.5$. Evidence of long memory in volatility for these economies is doubtful as a true long memory process is such that $d \in (0, 0.5)$. In total therefore, the existence of a long memory component in emerging market equity return volatility appears ambiguous. However, in their totality, the preponderance of markets appear to indicate the existence of a long memory dynamic in their volatility structure. The major exception relates to Botswana, where measures of volatility persistence, the ACF and the estimate of the long memory parameter do not suggest evidence of a long memory dynamic in the stock return volatility of the domestic companies index (DCI).

3. Evidence of Structural Change and Time-Varying Unconditional Variance

It is widely documented that measures of volatility persistence and long memory are overestimated if issues of structural change are ignored (e.g., Malik *et al*, 2005; McMillan and Ruiz, 2009). Accordingly, this section analyses the possibility that the emerging markets under analysis may have been subject to structural change deriving from major economic events and policy changes (which, in turn, may generate inaccurate evidence regarding the magnitude of volatility measures). To test for structural change in the volatility series, this paper implements the methodology of Bai and Perron, (1998, 2003a,b, henceforth BP) for finding multiple structural breaks in time series data. This method essentially searches for break points endogenously, unlike many other methods where break points are based on *a priori* assumptions. More technically, the BP methodology tests the hypothesis that there are no break points in the data against an alternative hypothesis that there are up to π (specified) break points (i.e., π+1 regimes) in the data.[2] In addition, this paper adopts a minimum distance of one trading year (i.e., 250 days) between break points and allows for up to five break points, which prevents congestion of break points and more appropriately captures structural change in the data. This procedure is adopted so that break points occur infrequently – hence, reflecting structural change – rather than a

2 That is, consider the model with m breaks (m+1 regimes):

$$y_t = x_t'\beta + z_t'\delta + \varepsilon_t$$

For j=1,…,m+1, where m is the number of breaks , yt is the dependent variable, x_t and z_t are vectors of covariates, β and δ_j are the corresponding vectors of coefficients, and ε_t is the disturbance term. Break points T_i, i = 1, …,m, are determined so as to minimise the sum of square residuals. Furthermore, this model allows joint estimation of the regression coefficients through the term $x_t'\beta$ along with identification of structural changes by the term $z_t'\delta_j$.

large number of break points which could potentially transform the time series properties of the data from a level shift into an integrated process.

The results of the break point tests are plotted in Figure 2. These figures show that the mean of the volatility process is time-varying and marked by the existence of distinct regimes. Botswana, China, Russia and the US reveal three break points (i.e., four distinct regimes); India and South Africa reveal five distinct regimes; while Brazil is characterised by six regimes. The break points identified by the BP method tend to generally coincide with episodes of major domestic economic reform and financial crisis. In this regard, the experience of South Africa is instructive.

The first regime represents the period after economic sanctions were lifted and the financial rand was abolished. In this environment, volatility was heightened amid uncertainties linked to the future direction of economic policy; especially with respect to structural reform in capital markets. The second period represents a general decrease in volatility and encompasses the period from late 1996 to 1997. This period coincided with the implementation of major financial reforms and the entry of foreign investors into the Johannesburg Stock Exchange (JSE). From 1998 to 2002, a succession of emerging market crises – the Asian, Brazilian and Russian – erupted. For example, during the financial crises in Brazil and Russia in 1998, the JSE all-share index fell by 30 percent in the month of August 1998 alone. From around 2002 to 2006, volatility on the JSE decreased – in tandem with the rest of the world – amid an environment of excess liquidity in international capital markets, which appears to have driven the mispricing of risk in global financial markets. The final regime – from 2007 to 2009 – coincides with a period of heightened volatility stemming from the most recent international financial crisis. In particular, the sub-prime mortgage crisis that began in the US (in the second-half of 2007) triggered a global financial crisis which was marked by steep declines in equity indices in the advanced economies (and indeed many emerging markets, including the BRICS). For instance, from the end of August 2008 to the middle of November 2008, South Africa's Top 40 index fell from 25,922 to 15,905 – a decline of almost 63 percent.

Indeed, this was a global phenomena, as falling stock markets and rising volatility, as evidenced by, among others, the spike in equity volatility (as measured by the Chicago Board Options Exchange (CBOE) and Standard and Poor's (S&P's) 500 volatility index), which rose from a local trough of 19 on August 22, 2008 to an all-time high of 81 on November 20, 2008.[3] Indeed, for the US, the application of the break point test shows that volatility was highest between 2008 and 2009. Furthermore, for most of the other BRICS markets, the mean level of volatility is also elevated during the period encompassing 2008-09, as highlighted by the BP test. The major exception is in the case of China, where the mean level of volatility is stable from about 1997 to the end of the review period (i.e., December 2009). The Chinese government lifted price controls in the stock market in 1992/3, indeed from then to 1997, major reforms geared at liberalising the economy and enhancing export orientated production were implemented. These structural reforms had the combined effect of raising the level of volatility in the stock market. The onset of the Asian financial crisis in 1997 led to the implementation of measures to mitigate contagion from the crisis. In particular, the results of this policy are shown by the stable level of volatility from 1997 to 2009. The effect of financial crises is also clearly reflected in the cases of Brazil and Russia. For instance, the Asian financial crisis between 1997 and 2001 led to heightened volatility across Asia and was, indeed, transmitted globally and provided a trigger for the Russian financial crisis, which had further global reverberations. Focusing on Brazil, break point tests show that periods of highest volatility coincide with the period of macroeconomic instability preceding the introduction of the Real stabilisation plan in 1994. Thereafter, the mean level of volatility remains high, but falls until 2000. In particular, in 1998-1999, Brazil experienced a banking and currency crisis which heightened volatility. Similarly, in Russia, break point tests also identify the Russian financial crisis of 1998 as period of heightened volatility. For the US, the mean level of stock return volatility is stable from 1990 to 1998. Volatility rises from 1998 to 2004, a period encompassing the bursting of the internet bubble and a variety of accounting and corporate governance scandals which impacted adversely on market sentiment. Thereafter, the mean level of volatility falls, only to spike as the subprime mortgage crisis broke. In the case of Botswana, the two most salient volatility spikes occurred towards the end of 2003 and 2007. In 2003, volatility rose most likely because of portfolio equity outflows linked to offshore investments by pension funds (a trend initiated by the establishment of the Botswana Public Officers Pension Fund). Meanwhile, at the end of 2007, market sentiment appears to have been affected by fears that the US-triggered financial crisis would slow domestic economic growth. In

3 The Chicago Board Options Exchange (CBOE) Standard and Poor's 500 Volatility Index reflects a market estimate of future volatility based on the weighted average of the implied volatilities for a wide range of strikes.

sum, the break points methodology identifies periods of differing volatility. Moreover, these periods or regimes can be intuitively associated with periods of financial stress (e.g., financial crises), policy reforms or macroeconomic instability.

The break point tests performed above imply abrupt shifts in the level of volatility. However, Mikosch and Stărică (2004b) argue that the evidence of structural change may be more subtle than the sudden changes in variance suggested by the break point tests. In particular, they analyse US equity volatility and find substantial evidence of time-variation in the unconditional (or long run) variance $\left(\sigma^2\right)$. Their results indicate that the standard assumption of a constant unconditional mean variance process is not realistic; and, consequently evidence of volatility persistence and long memory may be an artefact of time-variation in the unconditional variance process. Accordingly, to further examine structural change within the volatility series, this study examines time-variation in the unconditional mean of the volatility process. In particular, this paper utilises a procedure used by McMillan and Ruiz (2009), which allows for the derivation of the unconditional variance through recursive estimation of the GARCH (1,1) model. The time-varying nature of the unconditional volatility process is illustrated in Figure 3. The results indicate that the unconditional mean of the variance process is not constant as is traditionally assumed. Indeed, the unconditional mean variance process for the equity indices examined display large fluctuations and abrupt changes, suggesting that this process is also characterised by structural changes, reflecting a variety of factors – among others – major international events (e.g., financial crisis) or domestic macroeconomic developments (e.g., policy changes). For instance, in Brazil and Russia, the unconditional variance rises abruptly from 1998 and fluctuates erratically at this high level until about 2001. This period encompasses financial crises (in particular the Asian financial crisis and its transmission to other emerging markets), which may help explain why the sudden spike in volatility is very salient. Similarly, in the US, the fluctuations in the unconditional volatility track the regime shifts identified by the break point tests. In contrast, in Botswana, the unconditional variance appears to evolve in an arbitrary fashion, perhaps reflecting the shallowness (in terms of the low turnover ratio) of stocks listed on the domestic equity market.

It is important to examine whether extracting the time-variation in the unconditional mean variance process affects the long memory properties of the volatility series. The results of this analysis show that after filtering time-variation in the unconditional volatility from the model, the autocorrelation function for absolute returns decays more quickly. For instance, Figure 4 shows that the ACFs for Brazil, Russia and South Africa decay between lag 20 and 30; while previously, the ACF were statistically significant at all lags. Indeed, a similar result holds for China and the US. For India, the unadjusted ACF becomes insignificant at lag 80. But when temporal dependence in the unconditional volatility is incorporated, the ACF decays just after lag 30 and is mostly statistically insignificant thereafter. In contrast, for Botswana, the adjusted ACF does not quickly decay in a manner similar to the other emerging markets; rather it decays in a manner not suggestive of mean-reversion or long memory in volatility. Furthermore, this result shows that incorporation of structural change in the unconditional variance is superfluous in terms of identifying its impact on the long memory properties of equity data in Botswana.

Further evidence of the impact of neglected breaks is provided by the reduction in the size of the fractional integration parameter. For example, the size of the long memory parameter, *d*, falls from 0.41 and 0.54 to 0.11 and 0.17, for Brazil and Russia, respectively. Meanwhile, for China and the US, the long memory estimate declines from 0.48 and 0.60 to 0.34 and 0.30, respectively. The results of India and South Africa are prominent in that *d* falls substantially, in the case of India, *d*, falls from 0.47 to 0.01; while *d* falls from 0.56 to 0.03 in the context of South African equity volatility. These large declines in the magnitude of the long memory parameter emphasise the sensitivity of this estimate to structural change and the wide discrepancy that exists between measures of 'true' and 'reported' volatility. Meanwhile, in the context of Botswana, the long memory parameter falls rather dramatically. In particular, *d* declines from 0.57 to -0.09. In other words, stock return volatility in Botswana follows a short memory process once regime shifts have been accounted for. This essentially means that shocks to volatility decay geometrically and not hyperbolically. More simpler still, shocks to volatility in Botswana dissipate very quickly relative to all the emerging markets considered, such that notions of long memory in the case of the local market do not represent an appropriate description of the volatility properties of equity return volatility. More generally, these results highlight the importance of accounting for structural changes, in particular, time variation in the unconditional variance, in the modelling framework in order to arrive at more accurate volatility estimates.

Time-Varying Mean Adjusted GARCH Model

The empirical results of the previous section suggest that the assumption of a constant unconditional variance embodied in the GARCH model is not consistent with underlying stochastic behaviour. Accordingly, this assumption is relaxed, in order to examine if its long-run properties may be used to deliver accurate volatility forecasts. To this end, following Mikosch and Stărică (2004b) and McMillan and Ruiz (2009), this paper estimates a periodically updated (or adjusted) GARCH model that is able to reflect time-variation in the unconditional variance process. Specifically, this procedure involves the modification of GARCH model in equation (2) such that the constant term is substituted by a moving average of absolute returns:

$$h_t = \omega \frac{1}{\eta} \sum_{w=1}^{130} \left| r_{t-1-w} \right| + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \qquad (5)$$

where η is the window length (130) of the moving average.[4] The results of this model are reported in Table 4. The results of the moving average GARCH model are to be contrasted with those of the standard GARCH model presented in Table 2. In particular, for each of the series, the parameter α (which captures the impact of information flow) is larger for the adjusted model, while the parameter β (which captures past volatility) is smaller. In total, the extent of volatility persistence (given by $\alpha+\beta$) is lower than in the previous analysis reported in Table 2. However, in Botswana, while the magnitude of volatility persistence decreases (from 1.17 to 1.05), the underlying profile of stock return volatility remains explosive (or non-stationary). Furthermore, this lower persistence translates into a substantially lower half-life of decay, λ, for each of the series. For example, excluding China, half-lives in days ranged from 49 to 133; while in the modified GARCH, they range from 26 to 66 days, a marked reduction. The case of China is interesting, since in the standard GARCH model volatility persistence was found to be explosive (i.e., $\alpha+\beta>1$). In contrast, after accounting for time-variation in the unconditional variance, volatility is found to be highly persistent (i.e., $\alpha+\beta<1$).

While the modified GARCH model may appear to more accurately capture the volatility properties of the data, it is important to assess if the inclusion of a time-varying unconditional mean variance provides superior forecast performance relative to the GARCH and FIGARCH models. This is relevant since, as is well-known, accurate volatility forecasts are necessary in range of applications from portfolio management to risk measurement.

4 The choice of a window length of half a trading year (i.e., 130 observations) is motivated by the observation that portfolio managers typically rebalance their portfolios on a semi-annual basis.

4. Forecast Evaluation

In order to evaluate the forecasting performance of the three models considered in this study – i.e., the GARCH, adjusted GARCH and FIGARCH – the respective data sets are simply split in half and then each model is estimated for all series covering the first part of the sample and then these estimates are used to forecast volatility over the sample period covered by the second half of the data. In this manner this study is thus able to evaluate out-of-sample forecast accuracy.

Furthermore, following previous empirical work, this study also presents standardised values for all forecast error statistics using the forecast error statistic for the GARCH (1,1) benchmark for each series. This has the benefit of allowing for greater performance comparability among the competing models.

Symmetric Forecast Evaluation

Two symmetric measures are used to evaluate forecast accuracy, namely, the mean absolute error (MAE) and the root mean square error (RMSE). They are defined below:

$$MAE = \frac{1}{\tau} \sum_{t=T+1}^{T+\tau} \left| h_t^f - r_t^2 \right| \qquad (5)$$

$$RMSE = \sqrt{\frac{1}{\tau} \sum_{t=T+1}^{T+\tau} \left(h_t^f - r_t^2 \right)^2} \qquad (6)$$

where τ is the number of forecast data points and r_t^2 is the proxy for volatility and h_t^f denotes the appropriate volatility forecast. Both the MAE and RMSE assume the underlying loss function to be symmetric. Furthermore, under these evaluation criteria, the model which minimises the loss function is preferred.

Asymmetric Forecast Evaluation

Standard error statistics assume the underlying loss function to be symmetric. However, from a trading and risk management perspective, it is often the case that market participants will not attach equal importance to both over- and under-predictions of stock-return volatility of similar magnitude. For instance, a positive relationship exists between the volatility of (underlying) stock prices and call option prices. As a consequence, an under-prediction of equity price volatility implies a downward biased estimate of the call option price. This under-estimate of the price is more likely to be unfavourable to a seller than a buyer, and vice-versa. Following previous research (e.g., Brailsford and Faff, 1996; and McMillan *et al*, 2000) this study also considers error statistics designed to account for potential asymmetry in the loss function. That is, mean mixed error statistics which penalise under-predictions more considerably, i.e., MME(*U*), and the MME(*O*), which weighs over-predictions more heavily, respectively:

$$MME(U) = \frac{1}{\tau}\left[\sum_{i=1}^{O}\left|h_t^f - r_t^2\right| + \sum_{i=1}^{U}\sqrt{\left|h_t^f - r_t^2\right|}\right] \quad (7)$$

$$MME(O) = \frac{1}{\tau}\left[\sum_{i=1}^{O}\sqrt{\left|h_t^f - r_t^2\right|} + \sum_{i=1}^{U}\left|h_t^f - r_t^2\right|\right] \quad (8)$$

where *O* denotes the number of over-predictions and *U* the number of under-predictions among the out-of-sample forecasts.

Out-of-Sample Forecast Evaluation

Table 4 presents the actual and relative forecast error statistics for each model across the four evaluation measures, at the daily level. In particular, the first two columns of Table 4 reports the forecast MAE and RMSE statistics, and in parentheses are their respective standardised values (derived using the error statistic from the GARCH series). An examination of the forecast MAE and RMSE statistics shows that the results (in terms of the best performing model) indicate that, at the daily frequency, when a symmetric loss function is specified, the GARCH model dominates performance. For instance, in the case of Brazil, the GARCH model is 20 percent and 18 percent more accurate than the adjusted GARCH and the FIGARCH models, respectively. Similarly, in the case of China, the GARCH process provides more accurate forecasts than the alternative models. Indeed, for India, South Africa and the US, the GARCH model dominates forecast performance when both MAE and RMSE are used as evaluation criteria. When the MAE and RMSE are assessed at the daily level, the results suggest that the applicability of long memory models or the adjusted GARCH model is limited. In contrast, when an asymmetric loss function is specified, there exists wide variability in the performance of the various models being compared. This shows that the various model rankings are sensitive to the error statistic used to evaluate the accuracy of the forecasts. In the case of Botswana, the GARCH model provides superior forecast performance when symmetric loss functions are considered. Meanwhile, on the basis of MME(*U*) and MME(*O*), the FIGARCH and adjusted GARCH models are preferred, respectively.

Table 5 replicates the previous analysis, although in this case the data are aggregated over a monthly horizon. In particular, when monthly volatility forecasts are analysed, the results obtained present evidence in favour of the outperformance of models embodying either a long memory component (i.e., FIGARCH) or an incorporation of structural change (i.e., the adjusted GARCH) under both the forecast MAE and RMSE statistics. Using the forecast MAE statistic as a criterion, the results suggest that the adjusted GARCH delivers superior forecast performance in the case of Brazil, India and South Africa. Indeed, for both India and South Africa, the adjusted GARCH provides the most accurate forecasts on the basis of both the MAE and RMSE forecast statistics. In both cases, this outperformance is very slight given that the results of the forecasts are very close. For example, the adjusted GARCH is 9 percent more accurate than the GARCH and 2 percent more accurate than the FIGARCH in the case of India when the MAE is used as a criterion. For South Africa, the adjusted GARCH is 16 percent more accurate than the GARCH and 10 percent more accurate than the FIGARCH when the RMSE is used as a criterion. Meanwhile, under an asymmetric loss function, the results show that model performance is very mixed. However, there nonetheless exists evidence – albeit sporadic – of the superiority of the adjusted GARCH and FIGARCH. However, in the case of Botswana, the GARCH model delivers better forecast accuracy on the basis of the forecast MAE and forecast RMSE statistics. This result further underscores the short memory properties of Botswana's volatility profile and differentiates it from other economies – both emerging and advanced.

5. Conclusion

This paper contributes to the econometric literature by considering the impact of structural change on volatility behaviour. This endeavour has been motivated by recognition of the importance of accurate volatility estimates and forecasts in a wide range of applications, including portfolio and risk management and the limited empirical evidence available to date for Botswana and the BRICS. This study examines evidence of volatility persistence and long memory in light of structural change in the data – specifically, time – variation in the unconditional mean of the volatility series. The results obtained suggest that measures of both volatility persistence and long memory are overstated when structural change is not accounted for. Furthermore, this research has compared and evaluated the performance of the standard GARCH and FIGARCH models, along with a modification of the GARCH model to allow for time-variation in the unconditional mean variance (i.e., the adjusted GARCH), in terms of their ability to forecast volatility in an out-of-sample setting. The results obtained suggest that the adjusted GARCH generates improved volatility forecasting performance over a selection of markets, but only over longer horizons (i.e., monthly frequency). At the daily level, the assumption of a constant unconditional variance does appear to negatively impact on the accuracy of volatility forecasts as the GARCH model dominates performance. However, in the case of Botswana, the GARCH model dominates forecast performance over all horizons, in contrast to the other markets evaluated. This, in turn, suggests that investors, regulators and risk managers must focus on this model when calculating value-at-risk measures or other financial market indicators (e.g., hedge ratios) that require volatility forecasts. In total, accurate volatility estimates and forecasts have become a basic input for shaping trading strategies and managing risks. As such, these findings may have potential value for market participants in portfolio management and augment the empirical evidence with respect to emerging markets.

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Table 1. Stock Market Data			
Country	Index	Start data	Sample size
Botswana	Domestic Companies Index (DCI)	05/05/2002	1997
Brazil	Sao Paolo Stock Exchange (BOVESPA)	03/01/1995	4948
Russia	All-share composite (MICEX)	22/09/1997	3064
India	Bombay Stock Exchange Sensitive (SENSEX)	03/01/1990	4865
China	Shanghai Stock Exchange Composite (SECI)	02/01/1991	4658
South Africa	FTSE/JSE Top 40	30/06/1995	3626
US	Standard and Poor's 500 (S&P 500)	02/01/1990	5043
Note: FTSE/JSE is the Financial Times Stock Exchange/Johannesburg Stock Exchange.			

Table 2. GARCH and Fractional Integration Estimates						
	GARCH(1,1)					GPH
	Ω	α	β	α+β	τ	**d**
Botswana	0.088 (29.83)	0.692 (30.62)	0.478 (47.70)	1.170 (0.33)	n/a	0.57 (5.14)
Brazil	0.081 (7.16)	0.114 (18.67)	0.880 (147.32)	0.994 (0.01)	133.39	0.41 (4.82)
Russia	0.149 (10.13)	0.153 (21.46)	0.992 (127.12)	0.992 (0.01)	91.13	0.54 (6.28)
India	0.065 (8.32)	0.119 (17.06)	0.865 (126.79)	0.985 (0.08)	48.54	0.47 (6.69)
China	0.065 (17.31)	0.285 (76.56)	0.784 (281.39)	1.070 (0.23)	n/a	0.48 (5.58)
South Africa	0.026 (5.91)	0.113 (16.80)	0.880 (142.66)	0.993 (0.01)	97.76	0.56 (6.02)
US	0.007 (6.77)	0.061 (14.22)	0.932 (196.69)	0.994 (0.00)	131.35	0.60 (7.31)
Notes: Equation specification and discussion in Section 2. Numbers in parentheses are *z*-statistics, except under column ϱ where entries are *p*-values from a Wald test that ϱ=1. Half-lives, τ, are calculated as log(0.5)/log(ϱ). N/A indicates that the half-life cannot be computed since α+β>1.						

Table 3. Adjusted GARCH and Fractional Integration Estimates						
	GARCH(1,1)					GPH
	Ω	α	β	α+β	τ	**d**
Botswana	0.023 (24.19)	0.270 (25.65)	0.780 (127.06)	1.050 (0.22)	n/a	-0.09 (0.87)
Brazil	0.033 (9.13)	0.121 (27.84)	0.861 (314.55)	0.983 (0.04)	40.31	0.11 (7.63)
Russia	0.023 (6.28)	0.162 (16.41)	0.813 (111.63)	0.976 (0.00)	28.98	0.17 (5.18)
India	0.021 (8.81)	0.101 (23.27)	0.872 (257.88)	0.973 (0.03)	25.93	0.01 (3.88)
China	0.002 (3.99)	0.102 (37.75)	0.892 (391.22)	0.995 (0.00)	159.48	0.34 (4.22)
South Africa	0.009 (13.23)	0.129 (27.64)	0.853 (251.52)	0.983 (0.00)	41.06	0.03 (6.12)
US	0.002 (6.56)	0.068 (17.65)	0.921 (286.54)	0.989 (0.00)	65.97	0.30 (3.58)
Notes: Equation specification and discussion in Section 2. Numbers in parentheses are *z*-statistics, except under column ϱ where entries are *p*-values from a Wald test that ϱ=1. Half-lives, τ, are calculated as log(0.5)/log(ϱ).						

Table 4. Forecast Performance at Daily Frequency

		Forecast Error Statistic			
		Symmetric Loss Function		Asymmetric Loss Function	
	Model	MAE	RMSE	MME(*U*)	MME(*O*)
Botswana	GARCH	7.68e-05 (1.00)*	8.62e-05 (1.00)*	0.0037 (1.00)	0.0714 (1.00)
	Adj-GARCH	8.95e-05 (1.17)	9.31e-05 (1.08)	0.0082 (2.22)	0.0056 (0.08)*
	FIGARCH	7.41e-05 (1.04)	8.93e-05 (1.04)	0.0031 (0.84)*	0.0208 (0.29)
Brazil	GARCH	1.53e-04 (1.00)*	5.82e-04 (1.00)	0.0213 (1.00)*	0.0295 (1.00)
	Adj-GARCH	1.84e-04 (1.20)	6.95e-04 (1.19)	0.0309 (1.82)	0.0204 (0.69)*
	FIGARCH	1.81e-04 (1.18)	5.16e-04 (0.88)*	0.0436 (2.05)	0.0272 (0.92)
Russia	GARCH	4.58e-05 (1.00)	3.29e-04 (1.00)*	0.0616 (1.00)	0.0042 (1.00)*
	Adj-GARCH	2.26e-05 (0.49)*	3.88e-04 (1.18)	0.0266 (0.43)	0.0098 (2.33)
	FIGARCH	6.11e-04 (1.33)	5.17e-04 (1.57)	0.0092 (0.15)*	0.0077 (1.83)
India	GARCH	6.05e-05 (1.00)	6.24e-04 (1.00)*	0.0029 (1.00)*	0.0117 (1.00)
	Adj-GARCH	6.58e-05 (1.09)*	6.39e-04 (1.02)	0.0126 (4.34)	0.0093 (0.79)
	FIGARCH	7.07e-05 (1.17)	6.95e-04 (1.11)	0.0052 (1.81)	0.0085 (0.73)*
China	GARCH	2.54e-05 (1.00)*	6.06e-04 (1.00)	0.0771 (1.00)	0.0134 (1.00)
	Adj-GARCH	3.12e-05 (1.23)	8.27e-04 (1.36)	0.0149 (0.19)*	0.0474 (3.54)
	FIGARCH	3.39e-05 (1.33)	4.58e-04 (0.76)*	0.0801 (1.04)	0.0121 (0.90)*
South Africa	GARCH	2.88e-04 (1.00)*	3.51e-04 (1.00)*	0.0626 (1.00)	0.0292 (1.00)
	Adj-GARCH	5.13e-04 (1.78)	6.35e-04 (1.81)	0.0395 (0.63)	0.0068 (0.23)*
	FIGARCH	5.22e-04 (1.81)	7.68e-04 (2.19)	0.0348 (0.56)*	0.0097 (0.33)
US	GARCH	5.46e-05 (1.00)*	6.15e-05 (1.00)*	0.0924 (1.00)	0.0561 (1.00)
	Adj-GARCH	6.43e-05 (1.18)	7.83e-05 (1.27)	0.0061 (0.06)*	0.0088 (0.16)
	FIGARCH	5.88e-05 (1.08)	7.30e-05 (1.19)	0.0083 (0.09)	0.0039 (0.07)*

Notes: MAE is mean absolute error; RMSE is root mean square error; MME is mixed mean error with (*O*) denoting an over-prediction of volatility while (*U*) denotes an under-prediction of volatility. The asterisks '*' indicates the preferred model.

Table 5. Forecast Performance at Monthly Frequency

		Forecast Error Statistic			
		Symmetric Loss Function		Asymmetric Loss Function	
	Model	MAE	RMSE	MME(*U*)	MME(*O*)
Botswana	GARCH	3.38e-03 (1.00)*	5.70e-03 (1.00)*	0.0409 (1.00)	0.0748 (1.00)
	Adj-GARCH	5.74e-03 (1.70)	9.85e-03 (1.73)	0.5112 (12.5)	0.0037 (0.05)*
	FIGARCH	6.01e-03 (1.78)	7.27e-03 (1.28)	0.0236 (0.58)*	0.1240 (1.66)
Brazil	GARCH	3.82e-03 (1.00)	4.57e-03 (1.00)	2.36e-04 (1.00)*	6.72e-03 (1.00)
	Adj-GARCH	2.71e-03 (0.71)*	3.88e-03 (0.85)	5.15e-04 (2.18)	4.43e-04 (0.07)*
	FIGARCH	2.96e-03 (0.76)	3.17e-03 (0.81)*	4.52e-03 (19.2)	1.14e-03 (0.17)
Russia	GARCH	5.61e-04 (1.00)	7.37e-04 (1.00)	2.81e-04 (1.00)*	9.24e-03 (1.00)
	Adj-GARCH	2.92e-04 (0.52)	5.17e-04 (0.71)	1.91e-02 (68.0)	3.16e-04 (0.03)*
	FIGARCH	1.28e-04 (0.29)*	3.44e-04 (0.47)*	5.72e-04 (2.04)	8.03e-04 (0.09)
India	GARCH	3.59e-03 (1.00)	3.91e-03 (1.00)	2.13e-02 (1.00)	1.76e-02 (1.00)
	Adj-GARCH	3.26e-03 (0.91)*	3.72e-03 (0.95)*	2.92e-02 (1.37)	5.81e-03 (0.33)*
	FIGARCH	3.34e-03 (0.93)	3.95e-03 (1.01)	8.72e-03 (0.41)*	4.76e-02 (2.70)
China	GARCH	1.12e-04 (1.00)*	2.86e-04 (1.00)	6.91e-04 (1.00)	4.36e-05 (1.00)
	Adj-GARCH	1.25e-04 (1.12)	2.32e-04 (0.81)	2.33e-04 (0.34)*	3.12e-05 (0.72)
	FIGARCH	1.84e-05 (1.64)	1.64e-04 (0.57)*	5.47e-03 (7.92)	2.88e-05 (0.66)*
South Africa	GARCH	3.11e-03 (1.00)	5.78e-03 (1.00)	1.31e-04 (1.00)*	9.22e-03 (1.00)
	Adj-GARCH	2.56e-03 (0.82)*	4.83e-03 (0.84)*	6.72e-04 (5.13)	5.98e-04 (0.07)
	FIGARCH	2.64e-03 (0.85)	5.44e-03 (0.94)	4.80e-04 (3.66)	4.35e-04 (0.05)*
US	GARCH	4.39e-03 (1.00)	4.68e-03 (1.00)	7.26e-04 (1.00)	1.91e-03 (1.00)*
	Adj-GARCH	3.76e-03 (0.86)	3.98e-03 (0.85)	1.24e-04 (0.17)*	6.28e-03 (3.29)
	FIGARCH	3.28e-03 (0.75)*	3.52e-03 (0.75)*	3.52e-03(4.85)	2.73e-03 (1.43)

Notes: MAE is mean absolute error; RMSE is root mean square error; MME is mixed mean error with (*O*) denoting an over-prediction of volatility while (*U*) denotes an under-prediction of volatility. The asterisks '*' indicates the preferred model.

Figure 1: Autocorrelation Function For Absolute Stock Returns

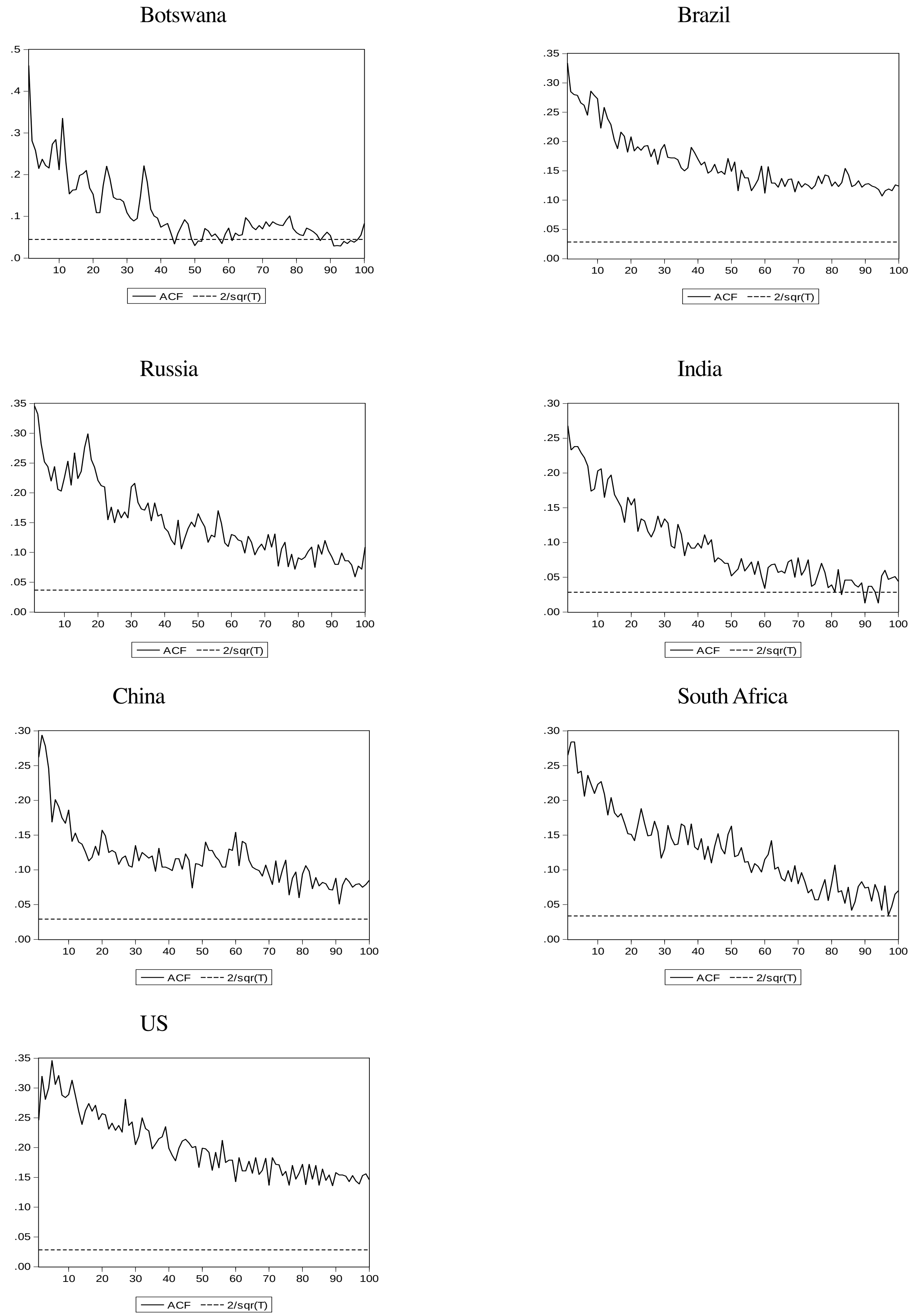


Figure 2: Absolute Returns Mean Break Points

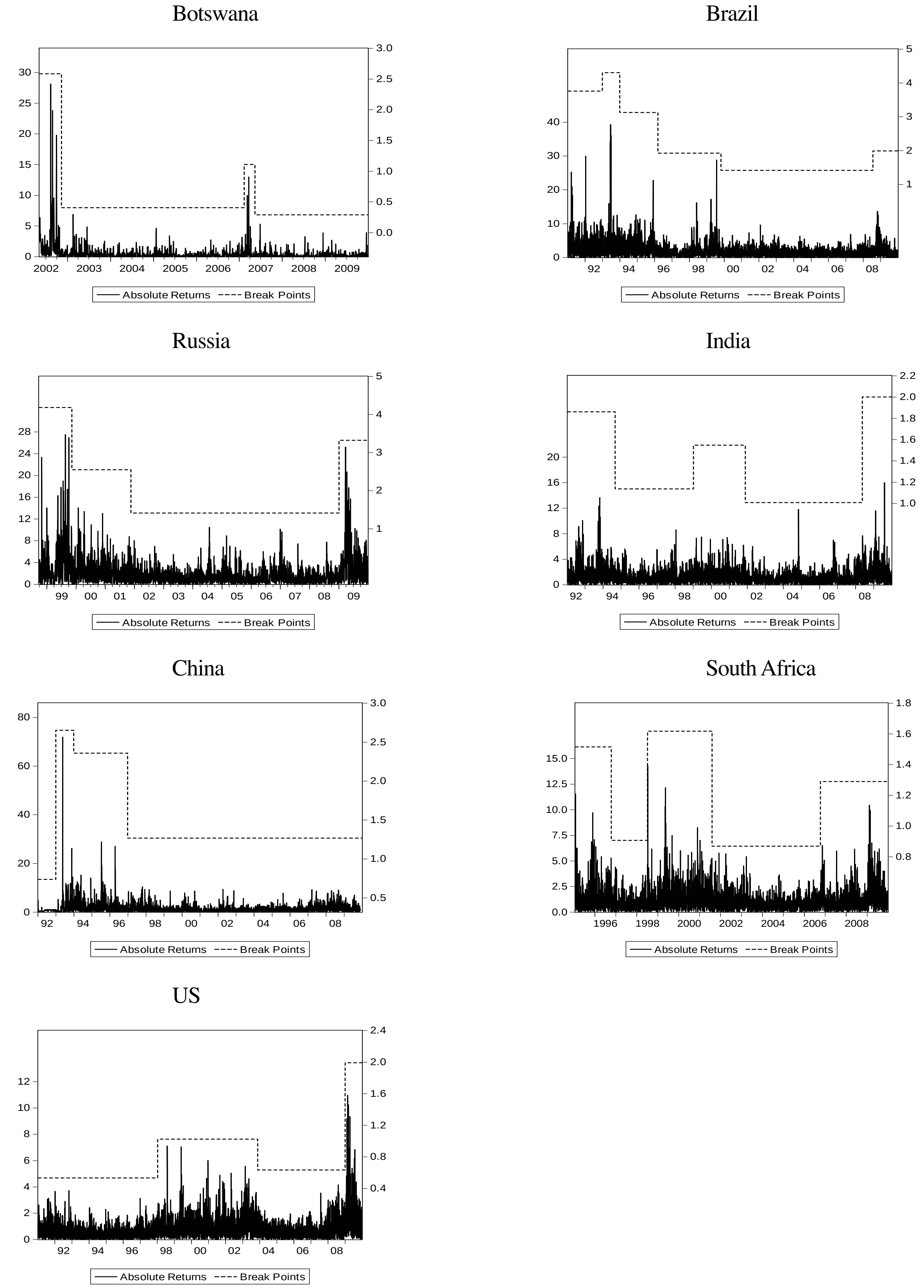


Figure 3: Time-Varying Unconditional Variance

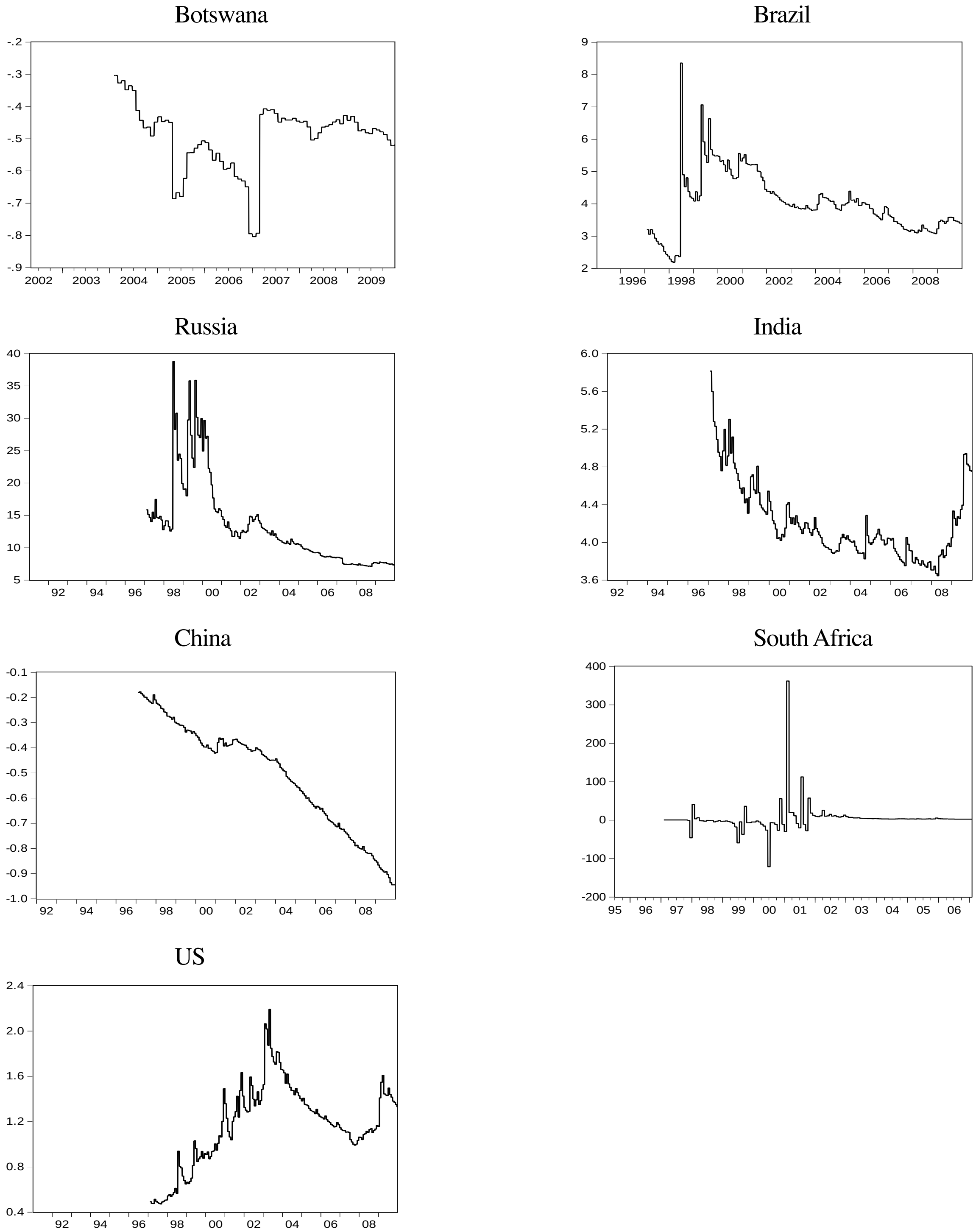
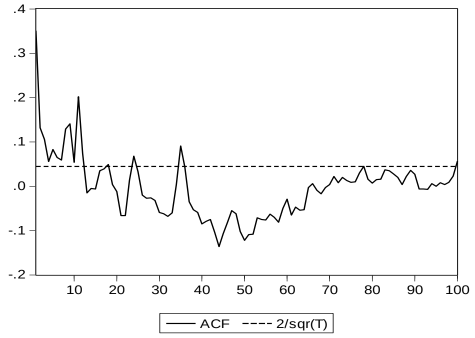
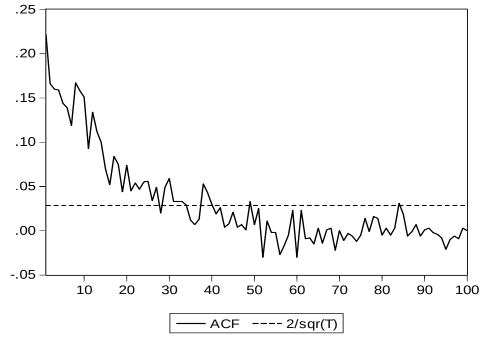


Figure 4: ACF for Adjusted Absolute Returns

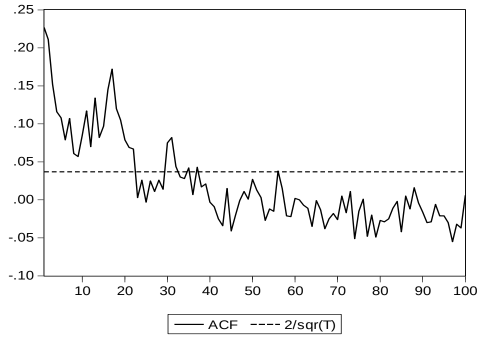
Botswana



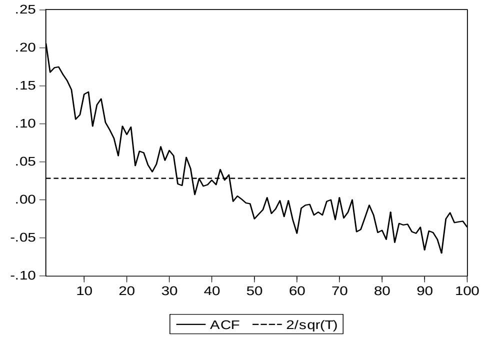
Brazil



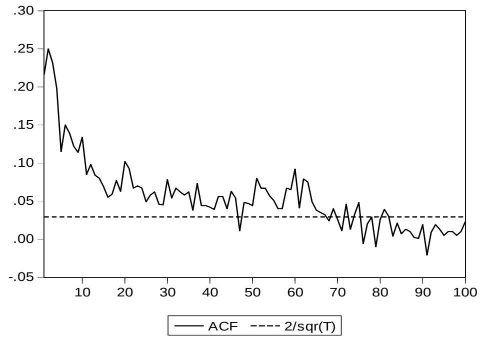
Russia



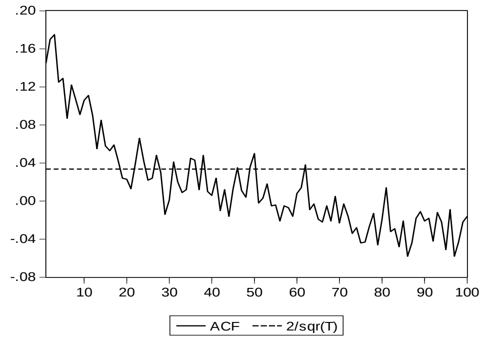
India



China



South Africa



US