Time Varying Exchange Rate Pass-Through in South Africa

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Abstract[2]

The relationship between the rand and domestic inflation holds important implications for the conduct of monetary policy, both as an indicator of success in managing expectations and in highlighting structural obstacles to the attainment of the inflation target. The pass-through of shifts in the rand to consumer price inflation has been well documented in South Africa. Although estimates of the absolute level of pass through vary, some studies document a decline in pass through over time. In order to better illuminate the policy implications of this decline, this paper seeks to add to the literature in two ways. Instead of averaging pass through over a discrete time period, the pass through function is decomposed into a number of time varying impulses. This has the advantage of providing deeper insights of pass-through over time and across various monetary policy regimes. Secondly, the existing literature on the factors influencing the degree of pass through will be synthesised and added to. Factors that may affect pricing decisions such as the magnitude and speed of exchange rate changes, the degree of competition and market conditions will be investigated alongside structural factors such as the monetary policy regime.

JEL codes: C3, E31

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[2] This version of the paper is still work in progress. Results should not be quoted unless permission is granted by the authors. The views of this paper are those of the authors and do not constitute the views of the National Treasury of South Africa. The authors would like to thank Catherine Macleod for valuable inputs. The authors are especially thankful to Jouchi Nakajima and Adrian Raftery for their advice on the time varying model and the Bayesian Model Averaging model.

1. Introduction

Exchange rate pass-through to prices in South Africa receives a fair amount of attention in the media and in academia. It is important to those charged with setting monetary policy given the implications for inflation. It is also very relevant to consumers, who feel the impact of pass-through on their disposable income, and firms that feel the impact in their inputs costs and profits.

High exchange rate pass-through poses serious monetary policy challenges, especially in a country like South Africa where authorities do not target the exchange rate. Abstracting from capital controls, should monetary policy interest rates move in response to exchange rate movements? The trilemma (Obstfeld and Taylor, 2004) has been well documented – one would have to give up monetary policy independence under exchange rate targeting.

Investigating only monetary policy responses to exchange rate pass through however ignores a number of other factors that influence pass through. Factors that could influence pass through ain addition to the extent of exchange rate depreciation due to interest rate differentials include the structure of industries, the price elasticity of demand for goods, fiscal policy, the economic cycle and price stickiness. This implies that other policy tools also affect price setting behaviour.

The empirical literature in South Africa finds wide-ranging estimates of exchange rate pass-through to consumer prices. Part of this can be attributed to the methodology, data used or the sample under investigation. The majority of these studies use a fixed sampling window to analyse pass-through effects. This approach however fails to account for changing market conditions that influence pass-through. The economic cycle, changing monetary policy objectives and import composition would ensure that pass-through effects are not constant over time. Pass-through effects can also differ depending on whether the exchange rate depreciates or appreciates, leading to asymmetric pass-through. There are two gaps in the exchange rate pass-through literature that we try to bridge; exchange rate pass-through at each point in time and across regimes, and the determinants of exchange rate pass-through. We obtain pass-through coefficients over time by using a nonlinear Vector Autoregression (VAR) that is able to capture asymmetries in the economy. We use the pass-through elasticities as a dependent variable and study the impact of a set of regressors. Devereux and Yetman (2002) provide the theoretical foundation for the empirical study, but we also control for other variables. Specifically we take an agnostic approach to the importance of variables. We control for a number of potential explanatory variables in a Bayesian Model Averaging framework. We try to stay as close to the literature as possible, which motivates the use of a VAR.

Using the model of Devereux and Yetman (2002), we provide a theoretical overview of exchange rate pass-through in the next section. This is followed by a literature review in Section 3. Section 4 describes the empirical methodology. Section 5 presents the empirical results and Section 6 concludes.

2. Theoretical background

We follow Devereux and Yetman (2002), who argue that exchange rate pass-through is endogenous to monetary policy, to illustrate the link between exchange rates and inflation. Devereux and Yetman (2002) develop a model of pass-through in a price-stickiness setup for importing firms and empirically test the extent of pass-through under volatile and high inflation settings. They show that exchange rate pass-is higher when inflation is high. Firms follow a Calvo (1983) setup where some firms adjust prices immediately and others do not to adjust prices. By combining this equation with the recursive formulation of setting the import price index, they derive an equation for imported goods prices analogous to the New Keynesian Phillips curve:

$$\pi_t = \eta(\lambda + \theta_t + q_t) + \beta E_t \pi_{t+1} \qquad (1)$$

π_t is the imported goods inflation rate, $q_t = s_t + p_t^* - p_t$ is defined as the real exchange rate that is equal to the nominal exchange rate (s_t) adjusted for price differential between foreign prices (p_t^*) and domestic prices(p_t), and θ_t is the distribution costs faced by firms. $\eta = (1 - \beta\kappa)(1 - \kappa)/(\kappa)$. κ is the probability that firm prices will remain unadjusted for any given period. β is the discount rate and λ is the monopoly markup. The intuition of equation (1) is that imported goods inflation will be higher when the real exchange rate is higher than its flexible price equilibrium given by $-(\lambda + \theta_t)$. Then, the degree to which the exchange rate can deviate from its flexible price equilibrium depends on the degree of price rigidity: The higher κ the lower η, which implies a fall in the deviation of the exchange rate from its equilibrium. . Devereux and Yetman (2002) link (1) to uncovered interest parity and a Taylor rule that targets only inflation:

$$i_t = i_t^* + E_t s_{t+1} - s_t \qquad (2)$$

$$i_t = \varphi + \delta\pi_t + u_t \qquad (3)$$

i_t is the domestic interest rate, i_t^* is the foreign interest rate, φ is a parameter that measures the target nominal interest rate, δ is the monetary policy response to inflation and u_t is a random shock to the interest rate that follows an AR(1) process ($u_t = \gamma u_{t-1} + \varepsilon_t$)

Combining (2) and (3) yields:

$$\varphi + \delta\pi_t + u_t = [i_t^* - E_t(p_t^* - p_t)] + E_t q_{t+1} - q_t + E_t \pi_{t+1} \qquad (4)$$

Equation (4) implies a relationship between the inflation rate, exchange rate and interest rate. It is assumed that distribution costs and foreign real interest rates are modelled as AR(1) processes: ($r_t^* = \rho r_{t-1}^* + v_t$) and ($\theta_t = u\theta_{t-1} + \epsilon_t$) where $r_t^* = [i_t^* - E_t(p_t^* - p_t)]$

Equation (1) and (4) form a system of the domestic inflation and the real exchange rate. The solutions for inflation and the real exchange rate are:

$$\pi_t = \frac{\varphi}{\delta - 1} + r_t^* A1 + A2u_t + A3\theta_t \qquad (5)$$

$$q_t = \frac{\varphi(1-\beta)}{\eta(\delta-1)} - \lambda + B1r_t^* + B2u_t + B3\theta_t \qquad (6)$$

A1=$\frac{\eta}{\{\eta(\delta-\rho)+(1-\rho)(1-\rho\beta)\}}$	B1=$\frac{(1-\rho\beta)}{\{(\delta-\rho)\eta+(1-\rho)(1-\rho\beta)\}}$
A2=$\frac{-\eta}{\{\eta(\delta-\gamma)+(1-\gamma)(1-\gamma\beta)\}}$	B2=$\frac{-(1-\rho\gamma)}{\{(\delta-\gamma)\eta+(1-\gamma)(1-\gamma\beta)\}}$
A3=$\frac{\eta(1-\eta)}{\{\eta(\delta-u)+(1-u)(1-u\beta)\}}$	B3=$\frac{-\eta(1-u)}{\{(\delta-u)\eta+(1-u)(1-u\beta)\}}$

The nominal exchange rate is determined by rewriting (4) into the domestic price level and using (6):

$$p_t = \frac{\varphi}{(\delta-1)} + A1r_t^* + A2u_t + A3\theta_t + p_{t-1} \quad (7)$$

$$s_t = \frac{\varphi}{(\delta-1)} + (B1 + A1)r_t^* + (B2 + A2)u_t + (B3 + A3)\theta_t - B1r_{t-1}^* - B2u_{t-1} - B3\theta_{t-1} +$$

$$s_{t-1} - (p_t^* - p_{t-1}^*) \quad (8)$$

Using (7) and (8) they derive the pass-through coefficient as a function of the domestic interest rate shock, the foreign interest rate shock and the distribution shock. They calibrate each parameter based on a number of studies for the US. We restrict our analysis of this model by varying two key parameters of this model while keeping the rest as calibrated in Devereux et al. (2008). The two parameters that vary in our analysis are κ and δ. The results show that strict inflation targeting and high percentage of firms that do not adjust their prices reduce the pass-through effect on consumer prices. The incomplete pass-through in this framework is due to the presence of slow price adjustment costs (κ) and the persistence of monetary policy shocks (u). We use this framework as the basis for the empirical work.

3. Literature review

Exchange rate pass-through is not complete. The literature has focussed on trying to understand why pass-through is incomplete. Reasons range from industry type, substitution effects between traded and domestic goods, the price elasticity of demand for goods, composition of imports, inflation expectations and menu costs.

It is expected that pass-through will be high under perfectly competitive markets. This is because firms' prices are set where their marginal revenue is equal to marginal cost. Any increase in marginal cost, which could come about through a weaker currency, will result in higher prices. Corsetti et al. (2002) argue that imperfectly competitive firms play a role in low exchange rate pass-through. These firms are able to absorb exchange rate shocks as they already operate at a mark-up over marginal cost. Firms in imperfectly competitive markets will however not necessarily absorb exchange rate shocks. Their willingness to absorb shocks depends on how demand for their goods changes under higher inflation and it also depends on the availability of substitutes.

Incomplete pass through could also be a result of menu costs or slow adjustment in price setting. Imports are mainly intermediate goods to which foreign currency pricing applies, so the pass-through is complete for prices "on the docks". By contrast, retail prices, as a combination of imported and local goods prices, are set in local currency and are adjusted only periodically due to menu costs (Engel (2002)). Exchange rate movements could thus be incorporated in retail prices, but only periodically, blurring the direct link between exchange rate changes and domestic inflation.

By the time imported goods reach consumers through wholesale and retail networks, their prices accumulate a substantial local input of services such as transportation, marketing and advertising, which partly cushions the impact of the exchange rate changes on final retail prices (Burstein et al (2002)).

Consumers switch from imported goods to lower-quality, cheaper local brands when larger exchange rate depreciations occur (Burstein et al (2002)). Similarly, when the local currency strengthens, consumers might switch to higher-quality, more expensive brands, so inflation might not decline in tandem with exchange rate appreciation.

Inflation responses decline under shifts in the composition of imports from “high pass-through” (and low value added) goods to “low pass-through” (high value added) goods (Campa and Goldberg (2002)). In more developed countries, pass-through is nearly complete for energy and raw materials and is considerably lower than unity for food and manufactured products. A shift in the composition of imports from raw materials to manufactured goods could thus lead to a decline in the measured exchange rate pass-through for both import and consumer prices.

Taylor (2000) conjectured that the slowdown in the pass-through – and the higher pass through for emerging market than industrial countries – was due to credible monetary policy which increases firms’ willingness to absorb exchange rate fluctuations in their profit margins and to perceive exchange rate shocks as temporary.

Time varying pass-through is not a new concept. Bussière (2007) shows that asymmetries in exchange rate pass-through cannot be ignored and that price rigidities play an important role. An exchange rate depreciation allows exporting firms to become more price competitive allowing them to increase the quantity of goods they export without changing their prices. These firms will however keep prices unchanged only until they have reached full capacity or when adjustment costs become too high. Sekine (2006) estimates time varying pass-through for six industrial countries by controlling for shifts in parameters in a single equation stochastic volatility model. Sekine (2006) find that pass-through to Japan, Germany, the United Kingdom, the United States of America (US), France and Italy has declined over time. Low and stable inflation is cited as a source for this. Shioji (2012) estimate exchange rate pass-through for Japan using a time-varying parameter VAR model without stochastic volatility. Shioji (2012) finds that pass-through has declined in both import and domestic prices over time.

3.1 Pass-through in South Africa

Parsley (2010) estimates the exchange rate pass-through to domestic prices using variations of a pooled panel and individual product price data from the Johannesburg region (gathered by the Economist Intelligence Unit). He finds exchange rate pass-through of between 0.14 and 0.27 per cent over two years depending on the model specification. He also estimates the long-run reversion to purchasing power parity (PPP) following an exchange rate movement using an error correction specification and finds deviations from PPP to have a half-life of 16 months. Parsley (2010) repeats the estimation controlling for trend and include interactions of the trend with the error correction term and exchange rate pass-through. The coefficient on the error correction interaction term is insignificant while that on the exchange rate interaction is significant but negligible suggesting little increase in pass-through over the twenty year sample covered (1990 to 2009).

Razafimahefa (2012) estimates exchange rate pass-through to domestic prices for a number of countries in Sub-Saharan Africa using a VAR and investigates determinants of pass-through. His results show that pass-through is lower in countries with more flexible exchange rate regimes and in countries with higher incomes. In countries with flexible exchange rate regimes, a large increase in money supply is associated with higher pass-through, while sustainable fiscal policies are associated with lower pass-through. Exchange rate pass-through to CPI one and two years ahead of 0.13 and 0.16 respectively are found for South Africa.

Nogueira (2006) estimates exchange rate pass-through using a structural VAR approach for a number of countries prior to and following the adoption of inflation targeting. He finds an exchange rate pass-through of 0.12 for South Africa prior to inflation targeting, which fell to 0.09 post-inflation targeting.

Fedderke and Scaling (2005) apply an expectations augmented Phillips curve framework to investigate the link between inflation, unit labour costs, the output gap, the real exchange rate and inflation expectations. Using a Johansen VECM they find that exchange rate pass-through to the general price level - measured by the GDP deflator - is 0.23 in the long-run.

Rigobon (2007) argues that the difference between a credible and non-credible central bank is the extent to which nominal shocks are accommodated by the monetary authority. When the central bank is credible then shocks to the nominal exchange rate on inflation would be small. The effect of pass-through could be bigger if the monetary policy reacts to accommodate the exchange rate shock. Rigobon (2007) also does a robustness check by estimating pass-through on individual prices. Averaging over these results yield the same pass-through estimate than estimating pass-through on aggregate prices.. His rolling regressions show a decline in pass-through since inflation targeting.

Aron et al. (2012) estimate exchange rate pass-through to import prices over the sample period 1980 to 2009. Although not estimating the impact on prices, they examine the change in pass-through following structural breaks in 1995 and after the adoption of inflation targeting. They employ both single equation models and a Johansen Vector Error Correction (VECM) system, controlling for domestic and foreign costs, domestic demand and structural breaks. In order to incorporate longer run information into their single equation estimations, they include a long-run equilibrium correction term and lagged dynamic terms (predating the period over which pass-through is calculated). They find 12-month exchange rate pass-through of between 0.44 and 0.5 per cent using their single equation model, with the pass-through declining after trade liberalization in 1995 (0.49 prior to 1995 and 0.46 after). Little change in pass-through was found before and after the adoption of inflation targeting. A long run pass-through of 0.55 was found in response to an exchange rate shock in the Johansen system of equations.

Table 1: Exchange rate pass-through estimates for South Africa

Authors	Cumulative pass-through (quarters)
Akinboade, Niederman and Siebrits (2002)	0.86 – CPI
Aron and Muelbauer (2007)	0.10 (q1), 0.15 (q7) – CPI
Fedderke and Schaling (2005)	0.23 – CPI
Mihaljek and Klau (2008)	0.12 (pre -2000), 0.08 – CPI
Edwards and Lawrence (2007)	0.85 per quarter – PPI
Noguira (2006)	0.60 (before IT), 0.1 (after IT) - CPI
Rigabon (2007)	0.12 – CPI
Razafimahefa (2012)	0.13 (q1), 0.16 (q2) –CPI
Parsley (2010)	0.25 (two years) - CPI
Aron et al. (2012)	0.30 (six months), 0.5 (1 year) Import prices

4. Methodology

4.1 Using a nonlinear VAR to extract time varying pass-through impulse responses

Time varying impulses allows us to study the evolution of exchange rate shocks to the economy with the emphasis being on the impact on consumer prices. This paper estimates a time varying structural VAR, where time variation comes from both the parameters and the variance covariance matrix of the model's innovations. This reflects simultaneous relations among variables of the model and heteroscedasticity of the innovations (Primiceri, 2005). To accomplish this, a Monte Carlo Markov Chain algorithm is used to estimate the coefficients and the multivariate stochastic volatility. Estimating time variation is a pretty well developed field (see Sims (1993), Stock and Watson (1996) and Cogley and Sargent (2001)). However, these studies impose restrictions on the variance covariance matrix that is supposed to evolve over time. Most of these models are limited to reduced form models that are usable only for data description and forecasting (Primiceri, 2005). With drifting coefficients one essentially also captures the learning process. The drifting coefficients are meant to capture possible nonlinearities or time variation in the lag structure of the model. The multivariate stochastic volatility is meant to capture possible heteroscedasticity of the shocks and nonlinearities in the simultaneous relations among the variables of the model. The basic modelling structure follows Primiceri (2005). Start with the following model:

$$y_t = c_t + B_{1,t}y_{t-1} + \cdots + B_{k,t}y_{t-k} + u_t \tag{9}$$

where y is an *nx1* vector of observed endogenous variables, *c* is an *nx1* vector of time varying coefficients that multiply constant terms, *B* is an *nxn* matrix of time varying coefficients and *u* are heteroskedastic unobservable shocks with variance covariance matrix Ω. The triangular reduction of Ω is defined by:

$$A_t \Omega \mathrm{A}_\mathrm{t}' = \Sigma_\mathrm{t}\Sigma_\mathrm{t}' \tag{10}$$

where A is the lower triangular matrix

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha_{nn,t} & 1 \end{bmatrix} \quad (11)$$

And Σ_t is the diagonal matrix

$$\Sigma_t = \begin{bmatrix} \sigma_{11,t} & 0 & \cdots & 0 \\ 0 & \sigma_{22,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{nn,t} \end{bmatrix} \quad (12)$$

It follows that

$$y_t = c_t + B_{1,t}y_{t-1} + \cdots + B_{k,t}y_{t-k} + A_t^{-1}\Sigma_t\varepsilon_t \quad (13)$$

Stacking in a vector *B* all the right hand side coefficients can be rewritten as:

$$y_t = X_t' B_t + A_t^{-1}\Sigma_t\varepsilon_t \quad (14)$$

$$X_t' = I_n \otimes [1, y_{t-1}', \ldots, y_{t-k}'] \quad (15)$$

The dynamics of the model's time varying properties are specified as random walks:

$$B_t = B_{t-1} + v_t \quad (16)$$

$$\alpha_t = \alpha_{t-1} + \zeta_t \quad (17)$$

$$\log(\sigma_t) = \log(\sigma_{t-1}) + \eta_t \quad (18)$$

The innovations are assumed to be jointly normally distributed while assuming the following for the variance-covariance matrix:

$$V = Var\left(\begin{bmatrix} u_t \\ v_t \\ \zeta_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \quad (19)$$

Here I_n is an identity matrix while Q, S and W are positive definitive matrices. S is block-diagonal, with blocks corresponding to parameters belonging to separate equations. Furthermore it is assumed that Q, W and S take on an Inverse-Wishart prior distribution which is the conjugate prior for the covariance-variance matrix of a multivariate normal distribution. To reduce the number of parameters in the model, we restrict the model to include only three variables — output, inflation and the nominal exchange rate.[3] This is a slight modification of Aaron et al (2012) who use unit labour costs instead of output and import prices instead of consumer prices. The choice of the zeros in the off diagonal matrix in V is to reduce the numbers of parameters required to be estimated while also avoiding having to pick priors for them to ensure that those parameters are not ill-determined. The standard deviations σ_t are assumed to evolve as random walks. This presents an advantage of focussing on permanent shifts and reducing the number of estimated parameters in the estimation procedure (Primiceri, 2005). The first seven years are used to calibrate the prior distributions. The mean and the variance of B and A are OLS point estimates and four times its variance. The normal prior for B is taken from the literature (Primiceri, 2005). In the same vein we follow Primiceri (2005) (and references within) in assuming a log-normal prior for σ_t. Degrees of freedom and scale matrices are needed for Q, S and W. For Q the degrees of freedom are set to 28 which is the size of the initial subsample while W and S1 and S2 are set to 4, 2 and 3 respectively. The scale matrices are set as a constant fraction of the variances of the OLS estimates in the initial subsample. The result of the paper are obtained by assuming the following values; kQ = 0.01, kS = 0.1, kW = 0.01. These priors are uninformative and tell us about the amount of time variation. Large values for K would imply more time variation. These are summarised as follows:

$$B_0 \sim N\left(\hat{B}_{OLS}, 4V\left(\hat{B}_{OLS}\right)\right)$$
$$A_0 \sim N\left(\hat{A}_{OLS}, 4V\left(\hat{A}_{OLS}\right)\right)$$
$$\log(\sigma_0) \sim N(\log(\sigma_0)\,, I_n)$$
$$Q \sim IW\left(k_Q^2 27 + V\left(\hat{B}_{OLS}\right), 27\right)$$
$$W \sim IW(k_W^2 4 I_n, 4)$$
$$S_1 \sim IW\left(k_S^2 2V\left(\hat{A}_{OLS}\right), 2\right)$$
$$S_2 \sim IW\left(k_S^2 3V\left(\hat{A}_{OLS}\right), 3\right)$$

4.2 The determinants of exchange rate pass-through

The second part of the analysis looks at the estimates of the determinants of exchange rate pass-through. We test the theoretical model of Devereux et al. (2002) by estimating the impact of the degree and volatility of inflation and exchange rate depreciation on the time varying pass-through impulses. We measure the degree of inflation and exchange rates by including squared terms of inflation and the exchange rate. Volatility measured by standard deviations. We control for a measure of competitiveness by using the same calculation as Fedderke et al. (2005) where pcm= (Y-

[3] All data are sourced from the South African Reserve Bank Quarterly Bulletin. Output is the output gap which is calculated as the deviation of real GDP (seasonally and annualised) from potential GPD (HP-filtered real GDP). The exchange rate is the nominal effective exchange rate.

WL-RK)/Y.[4] We also control for government debt as a percent of GDP, the output gap.[5] All data is sourced from the South African Reserve Bank.

We use a Bayesian Model Averaging (BMA) approach in making inference regarding the parameters. BMA selects the best models by averaging out over variables. In essence, BMA determines the variables that should be included in a model and is suitable when there are a large number of regressors (Starkweather, 2011). BMA also accounts for model uncertainty, thus limiting over-confident inference and decisions regarding parameters (Hoeting et al., 1999).

BMA is explained as follows (Clyde, 2003): Let X be the *nxp* matrix of independent variables of Y. Assume a linear regression $Y = X\beta + \epsilon$ has standard inference $\epsilon \sim N(0, \sigma^2 I)$. If X is large and we are uncertain about which of the $q = 2^p$ models of the model space $M = [M_1, M_2, \dots M_q]$ is the best one, then BMA helps by incorporating this uncertainty and averaging over the best models. This is achieved by assigning prior probability distributions to the model parameters $\beta$and σ^2 and the models M_k. M_k is assumed to come from a prior distribution $M_k \sim \pi\ (M_k)$ and the vector of parameters are generated from the conditional distributions $\beta_w | \sigma^2$, $M_k \sim \pi(\beta_w |\ M_k, \sigma^2)$ and $\sigma^2 |\ M_k \sim \pi(\sigma^2 | M_k)$ where $\Omega = w_1, \dots, w_p$ represents a vector of zeroes and ones indicating inclusion or exclusion of the variables in the model M_k. The parameterisation follows the following conditional model $Y | \beta_w, \sigma^2, M_k \sim N(X_w, \beta_w, \sigma^2 I)$. The posterior of the model is given by:

$$p(M_k | Y) = \frac{p(Y|M_k)\pi(M_k)}{\sum_{k=0}^{q} p(Y|M_k)\pi(M_k)} \qquad (19)$$

Equation (19) summarises the model uncertainty after observing the data. We are interested in the parameters and its uncertainty. This can be expressed as:

$$E(\beta_k | Y) = \sum_{k=0}^{q} p(M_k|Y) E(\beta_k | M_k, Y) \qquad (20)$$

$E(\beta_k | Y)$ is the weighted expected value of β_k across every model specification and is determined by the priors of the model.

The model prior is set in such a way to reflect the lack of knowledge (i.e. uncertainty with regard to sign and/or magnitudes of the relevant coefficients), hence $p(M_k) \propto 1$. For this purpose, a non-informative prior, Zellner's *g*-prior, is used with the assumption of a large value for *g* which indicates uncertainty as to whether or not the coefficients in question are equal to 0.

5. Results

We present the results in two stages. The first set of results report on Section 4.1 which extracts the pass-through coefficients at each point in time (sample = 1981q4 -2012q4). Section 5.2 reports on the determinants of pass-through.

[4] Y is nominal GDP, WL is compensation of employees and RK is the cost of capital adjusted for depreciation.

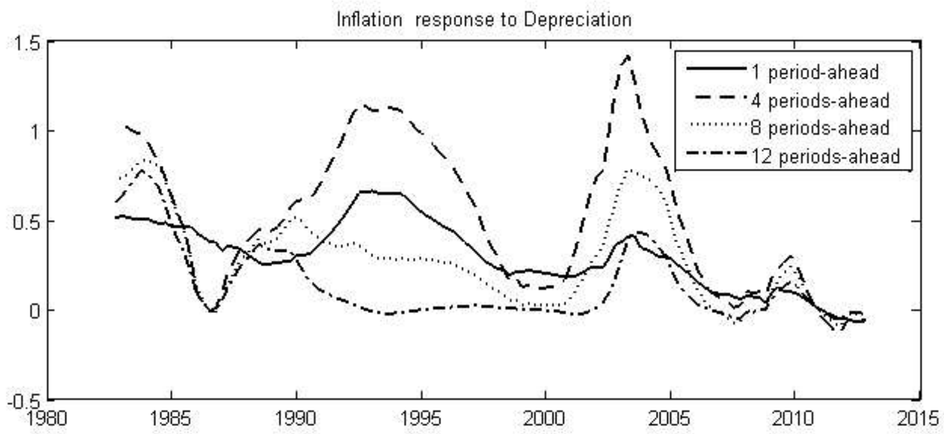
[5] The output gap is calculated as the difference in GDP from potential GDP expressed as a ratio on potential GDP. Potential GDP is calculated with the HP filter with lambda = 1600.

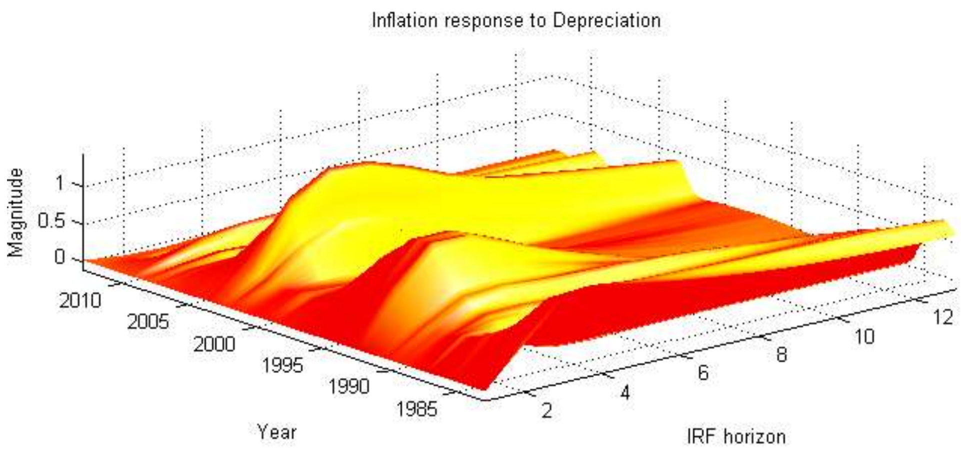
5.1 Pass-through impulse responses at each point in time

Our model provides impulse responses at various forecast horizons. We represent in Figure 1 the two and three dimensional aspects of the pass-through coefficients over a 1, 4, 8 and 12 quarter horizon. The three axes on the three dimensional figure are the impulse response horizon (in quarters), the magnitude (the size of the pass-through) and the year of the shock respectively.

On average, the peak in pass-through is reached in the fourth quarter. The highest pass-through occurred during 2002, which corresponds to Rigobon's (2007) findings. Since 2005, pass through over the different horizons has been close to zero.

Figure 1: Exchange rate pass-through





Averaging over the sample period (Table 2) yields high pass-through coefficients that are in line with some of the other studies shown in as shown in Table 1. The average contemporaneous pass-through is 0.30 and is 0.52 over four quarters. The effect disappears over a three year horizon. The cumulative average pass-through is complete over a 12 quarter period.

These average estimates are however for the most part significantly different to pass through at any given period of time historically, highlighting the risk of basing policy responses on average coefficients.

Table 2: Average pass-through elasticities

Impulse response horizon	Pass-through coefficient
1-quarter	0.30
4-quarters	0.52
8-quarters	0.28
12-quarters	0.14
Cumulative 12-quarters	1.24

5.2 The determinants of exchange rate pass-through

Our equations test the same explanatory variables as in Devereux et al. (2002); inflation, inflation squared, the exchange rate, exchange rate squared and the variance of both inflation and the exchange rate. In addition we control for the size of government debt, the output gap and a measure of market concentration. Our results (see Table 3 and Figure 2) show that inflation has a mean coefficient of 1. This is well within the range of Devereux et al. (2002). Furthermore, the results suggest that exchange rate pass-through increases with inflation but only slightly more under very high inflation rates. The variance of inflation also increases exchange rate pass-through. Interestingly exchange rate depreciation has an insignificant impact on pass-through. The mean coefficients are virtually zero. This is also confirmed by the inclusion probability or the probability that the coefficients of these variables are not equal to zero – both exchange rate depreciation and exchange rate depreciation squared enter the BMA only 13 percent and 11.4 percent of the time, respectively.

The mean coefficient on the market concentration variable is negative. This indicates that pass-through is lower under imperfectly competitive markets than under pure competition. Firms do not pass on the exchange rate depreciation to prices when they have market power. Higher government debt increases the exchange rate pass-through. While we do not directly test for the reasons for this it could be due to an expectation that higher debt results in higher inflation or that higher debt might lead to monetary policy instability.

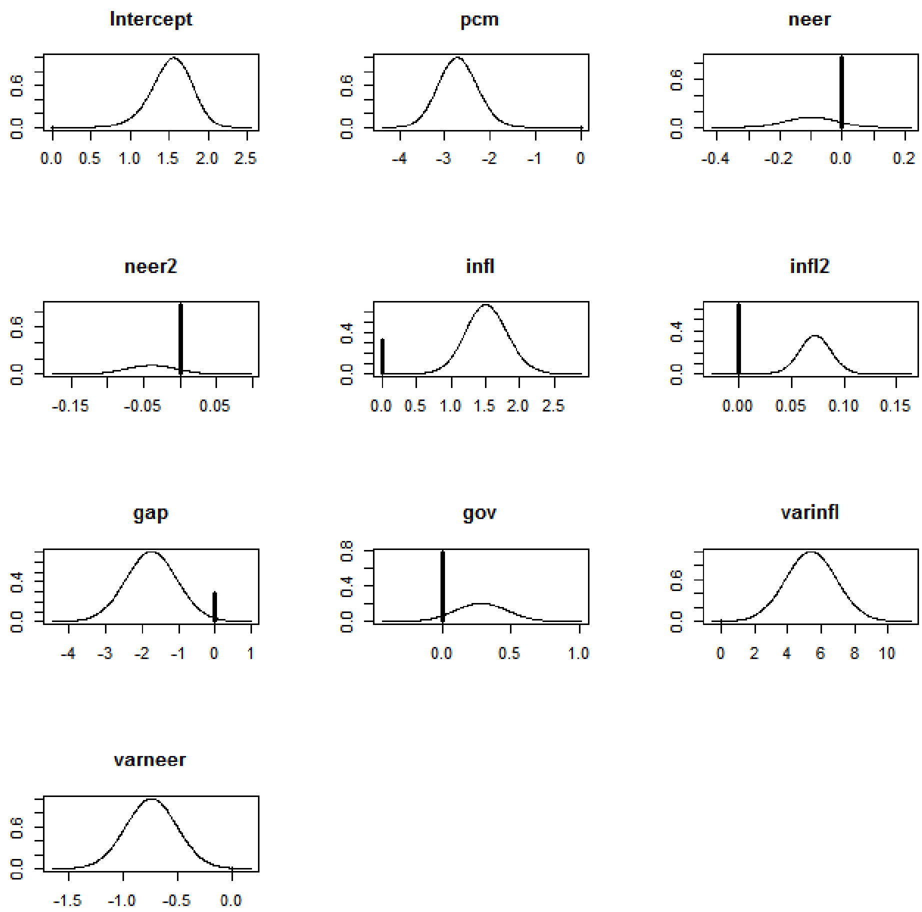
Finally the coefficient on the output gap is also negative. Thus, when the economy is growing at a slower rate than potential exchange rate pass-through is less. Slower consumption demand, lower capacity utilisation and higher unemployment (or lower levels of labour force participation) could explain the lower pass-through during these periods.

The low exchange rate pass through in recent years in South Africa reported in 5.1 above is consistent with the prevailing market conditions over this period where the output gap has been negative and inflation has been relatively well behaved.

Table 3: The determinants of exchange rate pass-through

Variable	Inclusion probability	Mean	Standard deviation
Market concentration (PCM)	100	-2.71	0.43
Neer	13.0	-0.01	0.04
Neer-squared	11.4	0.00	0.01
Inflation	66.6	1.00	0.77
Inflation-squared	36.0	0.02	0.04
Output gap	70.8	-1.23	0.99
Government debt (gov)	20.8	0.06	0.14
Variance inflation	100	5.39	1.53
Variance Neer	100	-0.74	0.23

Figure 2: Exchange rate pass-through



6. Conclusion

We extracted pass-through impulses at each point in time. We show that the exchange rate pass-through to consumer prices has declined over time. Both the volatility and the magnitude of pass-through have declined significantly since the South African Reserve Bank implemented inflation targeting. We test whether inflation targeting has been the source of the lower pass-through by controlling for a number of other macroeconomic variables. The results show that high inflation variability is a large source of pass-through. Inflation post inflation-targeting has been less volatile and lower. This suggests that credible inflation targeting (lower and less volatile inflation) has reduced the extent to which firms pass on exchange rate depreciations to prices. Exchange rate pass through is also shown to be sensitive to market conditions – suggesting pass through is lower during recessions or periods of slow economic growth.

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