Price transmission between international and local fertilizer prices: the case of South Africa

A report submitted to the National Agricultural Marketing Council (NAMC)

(Client)

By

Zerihun Gudeta Alemu (Prof.)

(Service provider)

August 2010

Executive Summary

This study analyzed the various aspects surrounding the relationships between local and international prices of fertilizer. Four types of fertilizers, commonly used in South Africa were considered. This included ammonia, urea, DAP, and MOP (Muriate of Potassium) . The study was motivated by the need to uncover the reasons for the widening gaps between local and international prices, which started to be clearly seen after the international market witnessed unprecedented surge in energy prices (Figure 2).

Several studies have analyzed the links between energy prices and prices of commodities of their choice. Here the interest goes beyond that. We ask why the gaps between local and international prices of fertilizer have been increasing (Figure 2). What factors are driving the increase in the price gap? What roles do boarder prices and the exchange rate play in this regard?

The increase in the gap has the implication that changes in international prices are not passed through completely. The question that begs answer is whether this presumed incomplete price transmission is true. If yes, is it symmetrical i.e. do local prices respond similarly to both upward and downward movements in the international fertilizer prices? Such discrepancies have welfare implications and provide *prima facie* case for policy intervention. It is referred to in the literature as asymmetric price transmission (APT). We also asked two related questions. What factors contribute to APT in cases where APT is confirmed? And what contributions do fluctuations in the

exchange rate and world prices individually make to the overall change in the price gaps?

To answer this and other related questions, we applied two complementary sets of methods yet with varying degree of precision. The paragraphs that follow summarize the results.

In general, changes in local prices (caused by movements in the exchange rate and world prices) are caused to the greater extent by non policy factors (Figure 3). The literature defines non policy factors as those relating to deficiencies in market (market power), physical (transportation and storage), commercial (market information), and institutional (credit and regulating laws) infrastructure. We also found the following: changes in international prices are not completely transmitted to local price (Table 2) and that much of the increase in the price gaps is attributable to fluctuation in the exchange rate (Figure 4).

Next, we reexamined the above results using econometric techniques. Notable results from this exercise are that local price depends positively on contemporaneous as well as lagged values of the world price and the exchange rate (Table 3); shocks regardless of their origin - driven by the exchange rate or world price or both - affect local prices (Table 3); local prices respond more quickly to negative shocks than positive shocks, implying that those involved in local fertilizer trading react more quickly to shocks that squeeze their profit margin than those that stretch them (Table 3 & 4); and it takes more or less similar months for positive and negative shocks emanating from changes in the boarder price and the exchange rate to be completely eliminated (Figures 5 & 6), implying that both play important role for movements in local prices.

Content **Page**

List of tables **Page**

List of figures **Page**

1. Background

South Africa relies on imports to satisfy close to one-half of its fertilizer needs. This makes local prices dependant on movements in the international price in Rand terms (after the exchange rate is applied to international price at an international harbor prices quoted in USD in the international market). Landed price is affected by movements in the exchange rate and boarder price. The exchange rate and boarder price, although to varying degree, contribute to movements in local prices. Studies show that fluctuation in the exchange rate explains much of the variation in the local prices in developing countries. Figure 1 shows the relationship between landed and local prices. It is evident from the figure that local prices have traced landed prices throughout the study period.

As demonstrated by Figure 1, local and landed prices trended positively until they entered episodes of spikes in 2008. Note that the year 2008 marks the beginning of crisis in the energy market. Its effect was translated into fertilizer price through its first and second round effects, which impacted the demand for and supply of fertilizer in the international market. The trends have taken a different twist though since 2008. This is confirmed by Figure 2, which shows movements in the price gaps, defined as the difference between local and landed prices. According to Figure 2, the price gaps are getting bigger for all fertilizer types considered.

This study takes as its major objective the study of the relationships between local and landed prices of four fertilizer types – ammonia, urea, dap, and map. In the process, it will address the following specific questions: does the increase in the price gaps we alluded to above have anything to do with incomplete transmission of changes in the international price to the local price? In cases where changes are not passed thorough completely, how do local fertilizers prices react to increases and decreases in the landed prices? And do border prices and the exchange rate affect local prices differently?

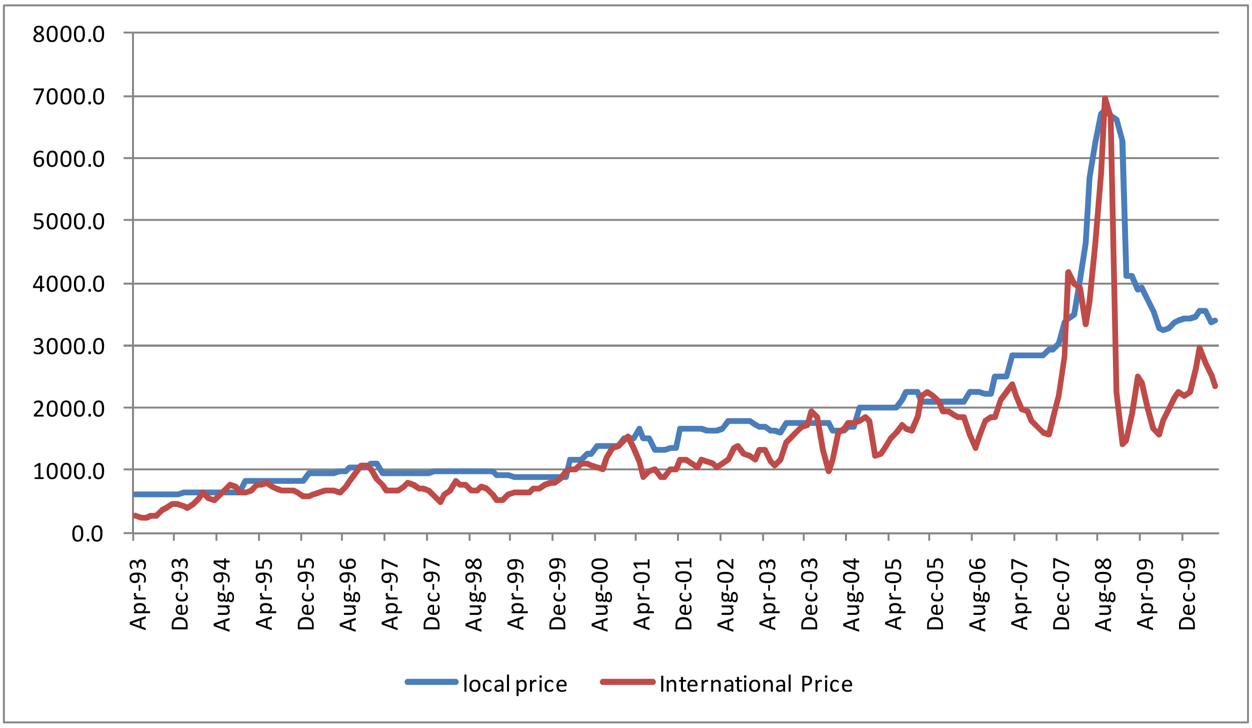

Figure 1a: ammonia

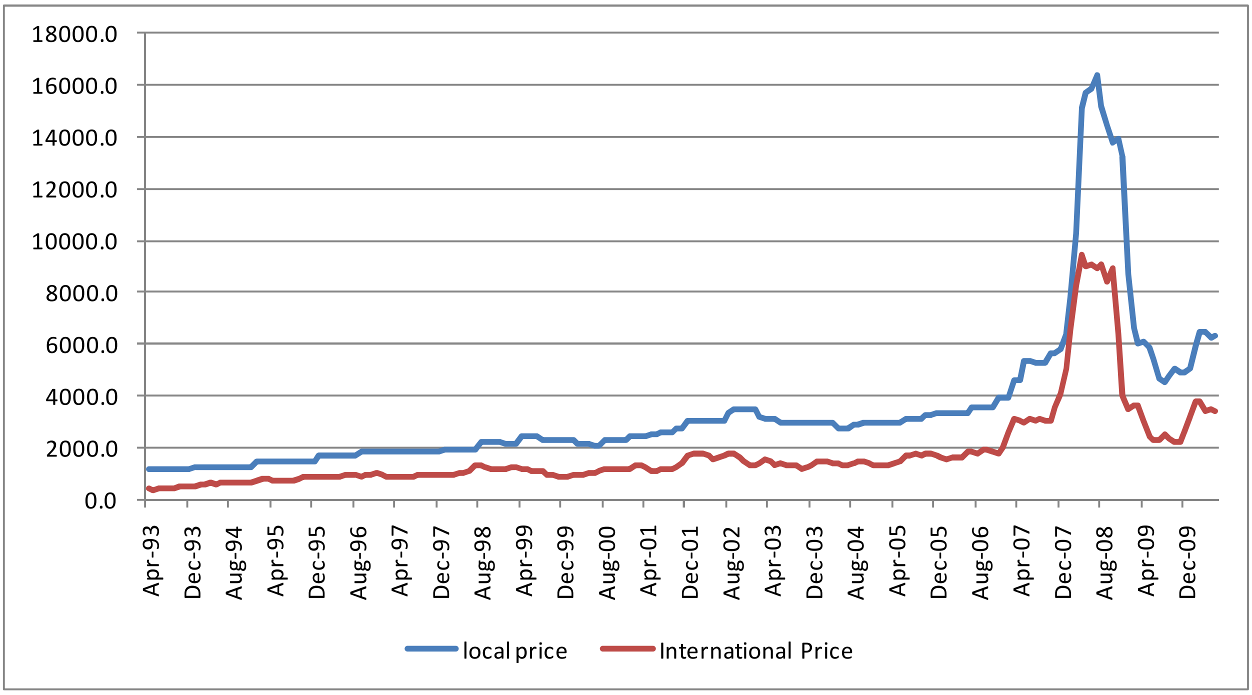

Figure 1b: dap

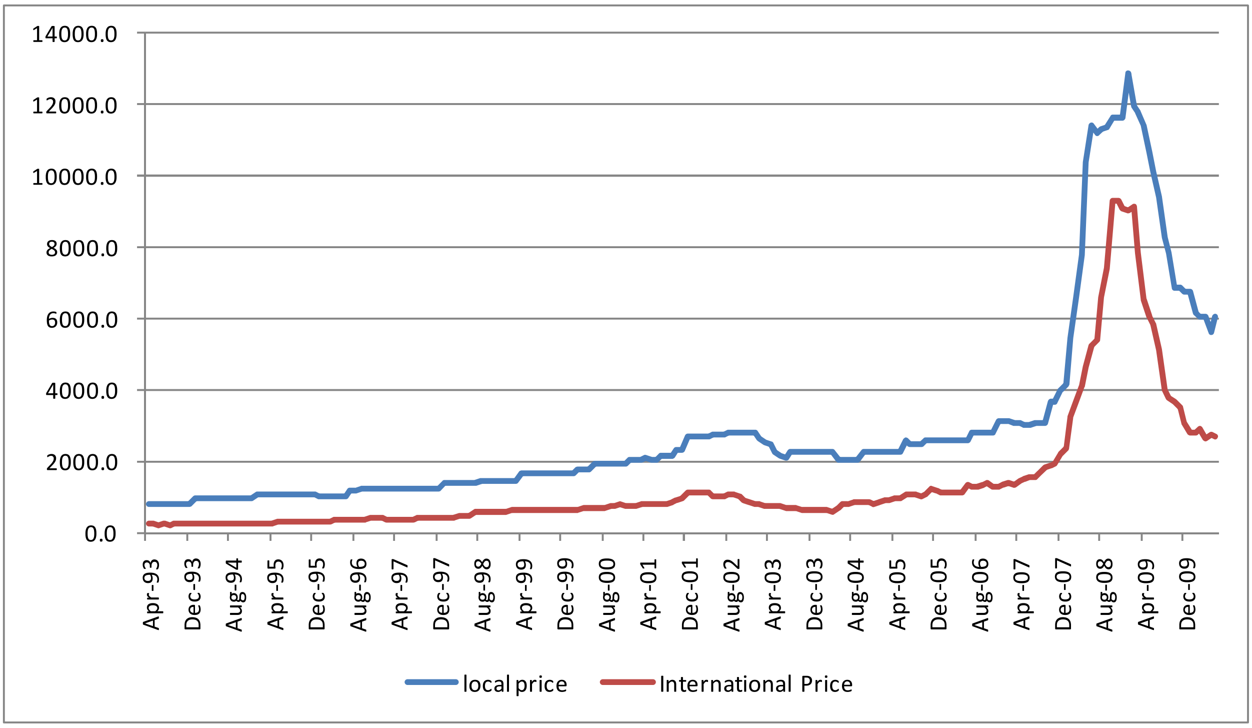

Figure 1c: mop

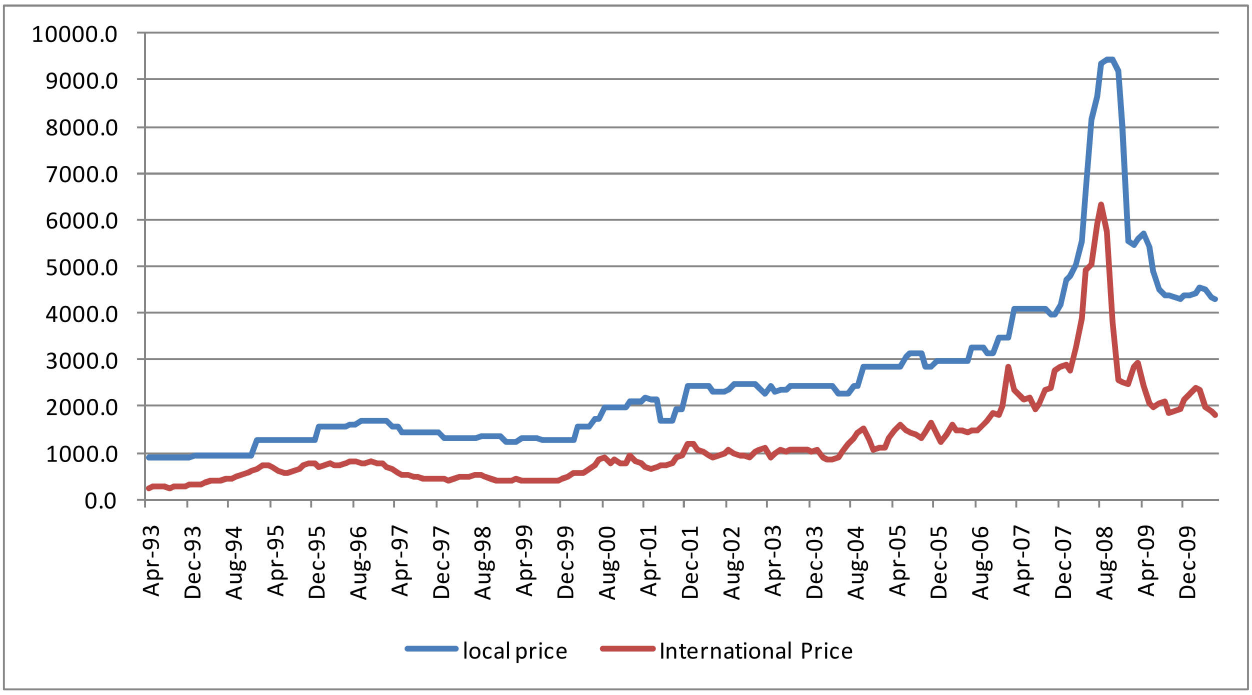

Figure 1d: urea

Figure 1: Local and international fertilizer prices

We attempt to answer these and other related questions in two stages. In stage one we analyze trends in local and international fertilizer prices, price gaps, and the contribution of non price factors to the widening price gaps. This will be done by decomposing price gaps. In stage two, we estimate a host of competing econometric model to quantify dynamic relationships between local and international prices, to conduct a formal statistically tests to check for the presence or absence thereof of asymmetry in price transmission, and to determine if positive or negative asymmetric price transmission best characterizes the way local price responds to changes in world prices and the exchange rate.

2. Fertilizer price trends

The fertilizer industry is one of the oldest industries in South Africa. It has for many years supplied the local market with different types of fertilizers. These include ammonia, urea, Di-ammonium phosphate (DAP), and Muriate of Potassium (MOP).

Local prices of fertilizers have shown marked increase recently. This has been attributed to international market conditions. This is to be expected as close to half of South Africa's current fertilizer demands are met though imports. Except for urea, which is entirely sourced through imports, demand for the remaining three is partly met through local production.

Available literatures on the subject classify the conditions responsible for the hike in fertilizer prices in the international market into two groups – demand and supply. On the demand side, increase in crop prices was considered as one of the major reasons. It was directly attributed to a host of factors - increases in incomes of people living in fast growing economies like China and India, bad weather conditions in major food producing countries, implementation of protectionist trade policies by major exporting nations, etc. This led to an increase in the demand for fertilizer. The working of substation effects in the global energy market is also partly to blame. Attracted by increases in the price of Brent crude oil in the world market, increased production of alternative sources of energy, such as bio fuel, put an upward pressure on the demand for crops as food crops are used in bio fuel production.

Table 1: Factors Affecting International Fertilizer prices

Variable	Ammonia		KCL		Dap		Urea	
	Pearson	Spearman	Pearson	Spearman	Pearson	Spearman	Pearson	Spearman
Ammonia	-	-	-	-	.454**	.244	.479**	.420**
Natural gas	.351**	.400**	-	-	-	-	.238	.207
Brent crude	.427**	.374**	-	-	.288*	.201	.411**	.195
US maize	.140	.066	.515	.014	.286*	.064	.220	.074
GDP Global	.288*	.202	449**	.158	.467**	.400**	.391**	.402**
Stock	.354**	-.024	.632**	.080	.384**	.066	-.085	-.175
Sulphur	-	-	-	-	.589**	.412**	-	-
Phosphate Rock	-	-	-	-	.705**	.339**	-	-

*, ** respectively stand for level of significance respectively at 5% and 1%.

On the supply side, increases in the costs of production of nitrogen based fertilizer types (ammonia, urea, DAP, and MAP) played an important role. Ammonia (NH_3) is used as a major input in the industrial production of urea and DAP. It is made up of nitrogen (N) and hydrogen (H_3). Hydrogen is produced from natural gas, which accounts for the greater proportion of the total cost of ammonia production. The price of natural gas increased significantly during this time. This was attributed not to a decline in its production or stock of natural gas but due to an increase in its demand following increase in the price of Brent crude oil, its major substitute.

Table 1 summarizes results on the relationship between international prices of fertilizers and factors affecting demand for and supply of fertilizer in the international market. Growth in the world Gross Domestic Product (GDP) and the US maize price are used as proxies for factors affecting international prices of fertilizers on the demand side. According to the results found, growth in the world economy has a significant effect on the prices of all types of fertilizers considered in this study. Increase in crop prices measured by increase in US maize prices however has significant effect only on the price of DAP.

On the other hand, we assumed that supply of maize in the international market to depend on factors with direct effect on the costs of production of fertilizers. Results indicate that the international price of ammonia is significantly affected by the price of natural gas, available stock, the price of Brent crude oil; the price of DAP by the prices of ammonia, phosphate rock, sulphur, and by Brent crude oil; the price of urea by the price of ammonia and Brent crude oil, etc. The a priori expectation was that urea and the US maize price would be highly correlated, but according to Table 1 this is not the case. US maize prices show a high level (significant) of correlation only with KCL (MOP) and DAP.

Figures 1a through 1d summarize the relationships between local and international fertilizer prices. They show that local price responded positively to changes in the international fertilizer prices. It is evident from the same figures that during the months between December 2007 and August 2008, fertilizer prices showed marked increase. These could be attributed to the influence of external factors such as above average hikes in oil prices in the world market. It is also evident from the figures that local fertilizer prices responded differently to corresponding increases (December 2007 – August 2008) and decreases (after August 2008) in international prices.

3. Factors contributing to increasing price gaps: price decomposition

In this section we analyze whether price gaps between local and international prices have shown any systematic movements over time. Price gap is defined as the difference between the local price for fertilizer and its boarder price in terms of domestic currency. It is an indicator that can be used to measures the level of gains from fertilizer trade through effective integration of the local into the world market. A local fertilizer market is said to be well integrated if local and boarder prices are similar after some adjustments for domestic transaction costs are made. Therefore, measuring the price gaps and identifying variables contributing to the change is crucial to understand the fertilizer market better.

Figures 2a through 2d provide measures of price gaps for the four fertilizer types. Results show that the gaps are getting wider. This is especially so after December 2007. To be able to determine what variables contribute to the increasing gap, we decomposed the changes in the gaps into a number of variables, labeled differently in the literature as policy and non policy variables.

Policy related variables could be further categorized into -explicit and implicit. Examples of explicit policy include support for local fertilizer producers in the form of budgetary (e.g. subsidy) and non budgetary (e.g. tariff) mechanisms to keep local prices well above boarder prices. Implicit policy on the other hand refers to those changes in the gap attributable to interactions among the exchange rate, the world fertilizer price, and a policy variable. Examples of a policy variable includes, tariff, trade quota, etc. In this study, we assume that policy factors play limited role. This is because domestic fertilizer producers in South Africa get no support from their government.

In addition to policy, non-policy variables could explain part of the change in the price gaps. Researches show that non–policy variables play important role in the developing countries. Broadly speaking, they include deficiency in market conditions attributable to poor market infrastructure. They cause price gaps by impeding transmission of changes in the world price and the exchange rate into the local price. This could occur through a number of channels. The most important ones, relevant to a developing country like South Africa, include the presence of market power in the fertilizer market, which allows economic agents not to pass the changes completely from boarder prices to local prices; and deficient physical (transportation & storage), commercial (market information), and institutional (credit and regulating laws) infrastructure.

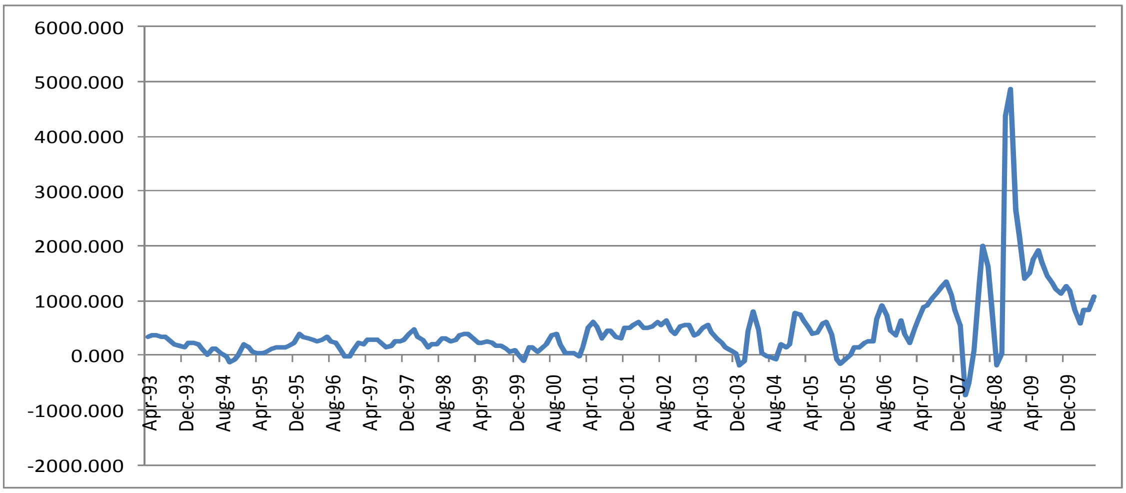

Figure 2a: gaps between local and international prices of ammonia

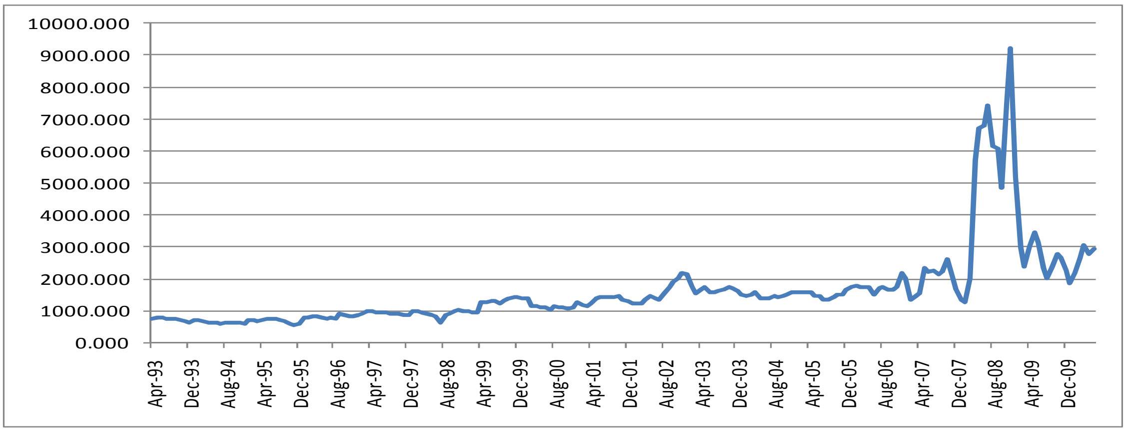

Figure 2b: gaps between local and international prices of dap

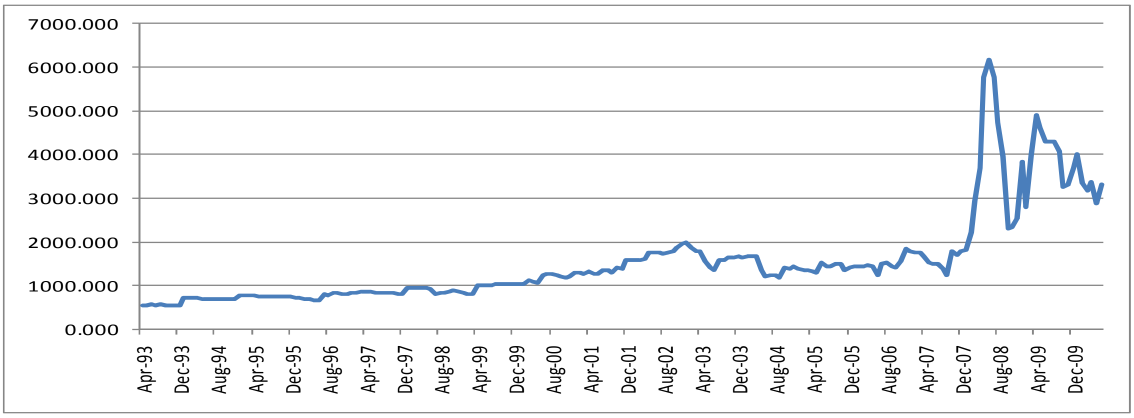

Figure 2c: gaps between local and international prices of mop

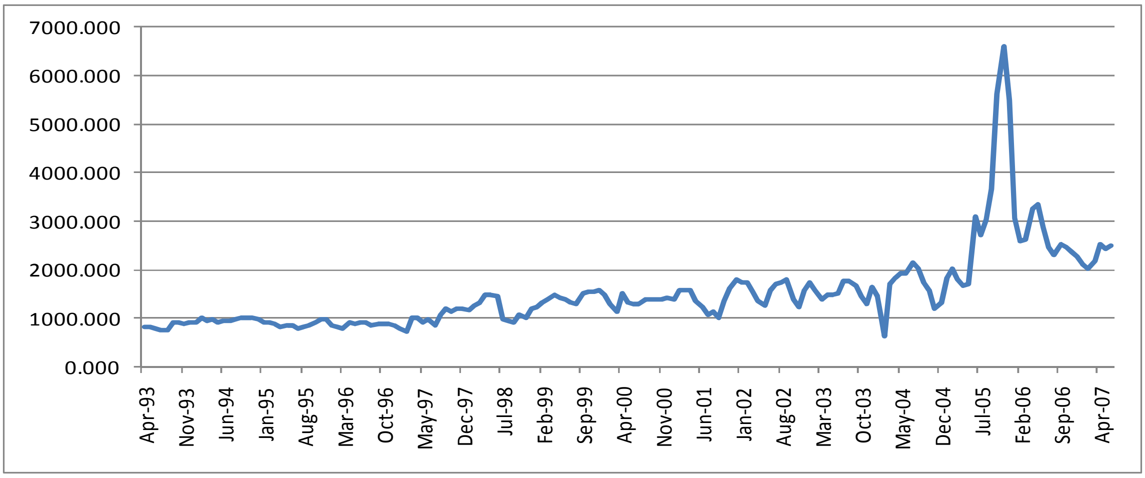

Figure 2d: gaps between local and international prices of urea

The exchange rate is one of the factors that would directly affect local prices. A fluctuation in the exchange rate alone could therefore contribute for a larger price gap. A trend analysis on the exchange rate indicated that this is indeed the case in the South African fertilizer market – trends in the price gaps correspond, *inter alia*, with fluctuating exchange rate. This particularly has been evident since 2006. If combined with important causes of incomplete price transmission such as market power and deficient market infrastructure, its effect on price gaps could be much greater.

The method applied to decompose price gaps is explained in Appendix 1. It was originally developed by the Organization for Economic Cooperation and Development (OECD). It had the objective of determining the support that governments give to local producers, which could come in the form of, say, introduction of a managed price policy to prevent price transmission from international (hereafter referred to as landed price as it is the product of world price and the exchange rate) to local price. The methodology was later expanded by Liefert (2009) to go beyond the calculation of Producer Support Estimates (PSE). This is to allow identification of the degree to which changes in specific variables (policy/ non policy) drive changes in commodity price gaps.

Figures 3a through 3d summarizes these results. They show the contributions that policy and non policy factors make to changes in price gaps for the four fertilizer types. Since South African fertilizer producers receive little support from the government, the policy factors refer to changes in the price gap attributable to price disparities (fluctuation in the world price and the exchange rate). The non policy factors on the other hand refer to deficiency in market conditions which impede price transmission and thus cause incomplete price transmission of changes from border price to domestic (local) price. The Figures show that much of the changes in the price gaps occurred as a result of incomplete price transmission (non policy factors). This has been particularly the case since December 2007.

Next, we asked if the incomplete transmission we found earlier had to do with asymmetry in price transmission (APT). If so, we ask if Peltzman's (2000) approach of classifying asymmetry -positive or negative APT - characterizes the local fertilizer market. The other criteria could be to classify APT on the basis of speed and magnitude of price transmission or both. See Meyor & Cramon-Taubadel (2004) for graphical explanation on this.

APT has redistribution and welfare implications. These provide a *prima facie* case for policy intervention (Meyor & Cramon-Taubadel, 2004). The redistribution effect emanates from the possibilities that some groups benefit from price reduction (fertilizer consumers) or increase (fertilizer producers and middle men) than would be the case under conditions of symmetry. The welfare effect, on the other hand, arises out of the existence of market power, which under normal circumstances could lead to welfare losses.

We conducted a preliminary investigation to determine if changes in border prices of fertilizer are completely transmitted to local fertilizer prices. This was simply to crudely verify a priori expectation that there is incomplete transmission. It is crude in the sense that it fails short of describing APT in terms of positive/negative and size/magnitude. These are matters that would be taken up later with the application of robust econometric technique. For the time being we analyze the relationship between local and boarder price using a Price Transmission Elasticity (PTE) we described in Appendix 1.

The PTE could take a value equal to 1, the case of symmetric price transmission (SPT), or a value different from one, the case of asymmetric price transmission (APT). The literature distinguishes between two types of APT - positive and negative- depending on how suppliers respond to the effect a shock exerts on their profit margin.

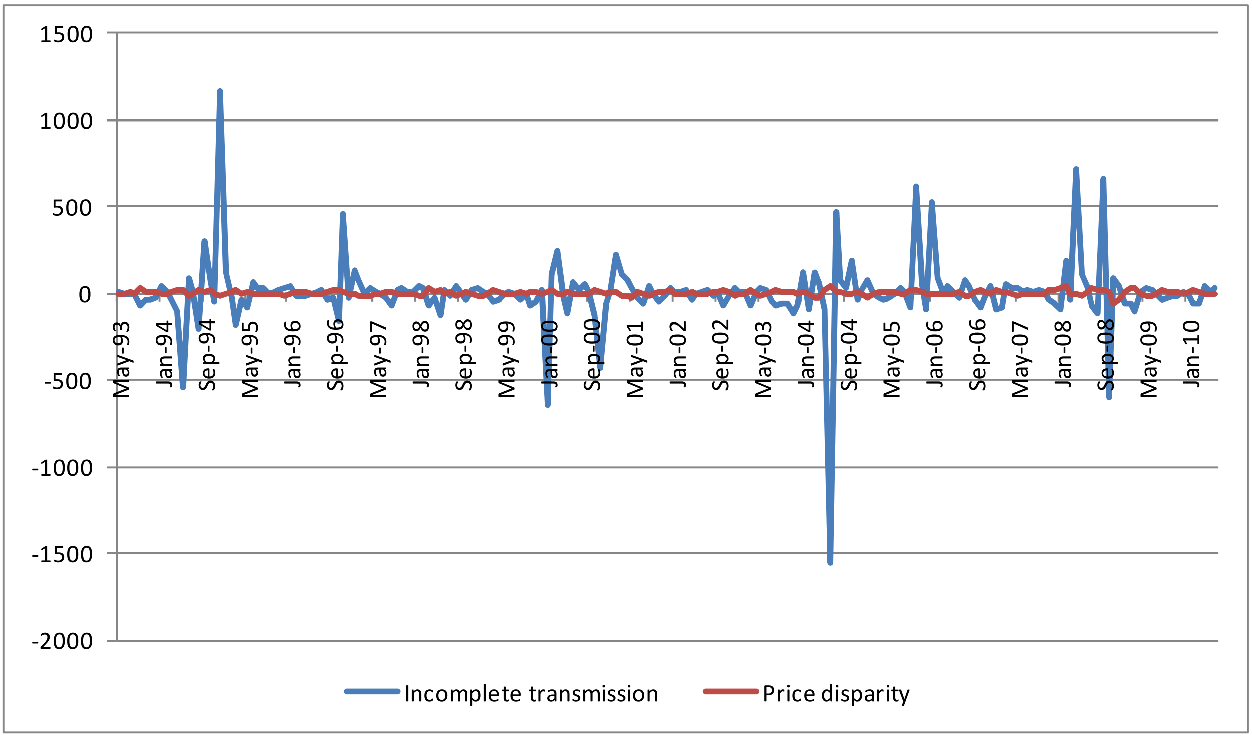

Figure 3a: ammonia

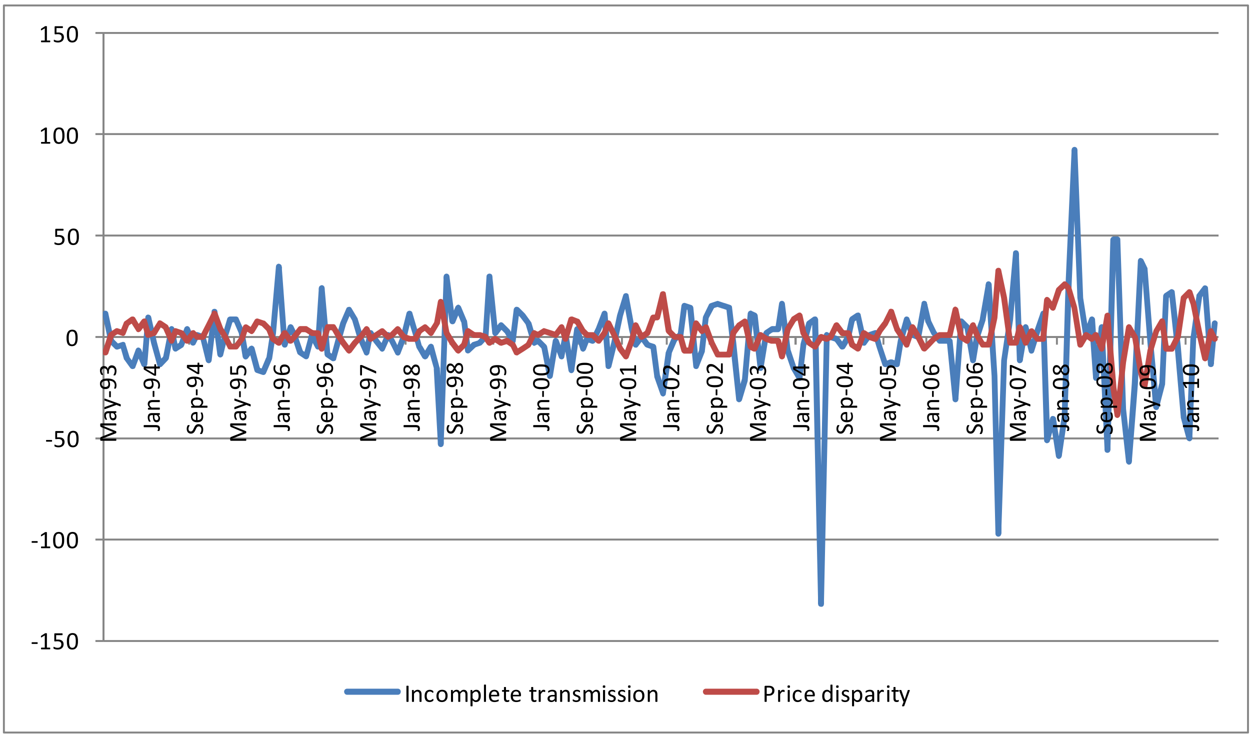

Figure 3b: dap

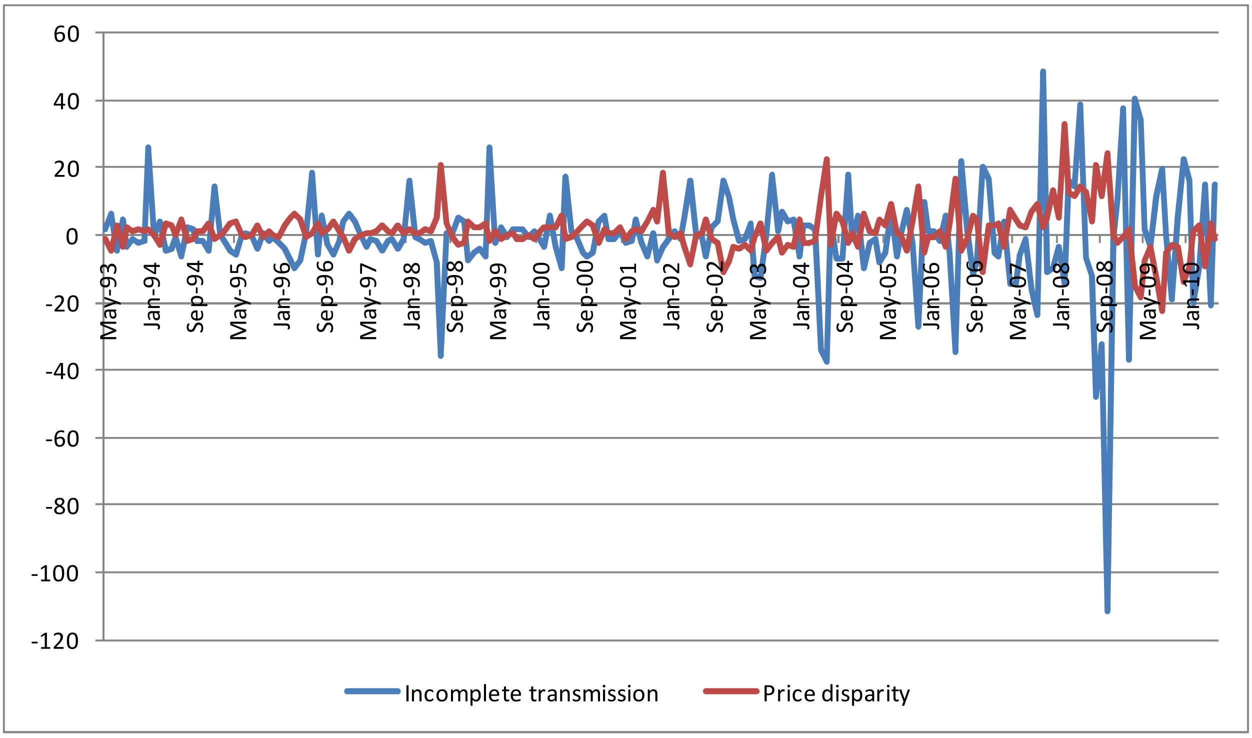

Figure 3c: map

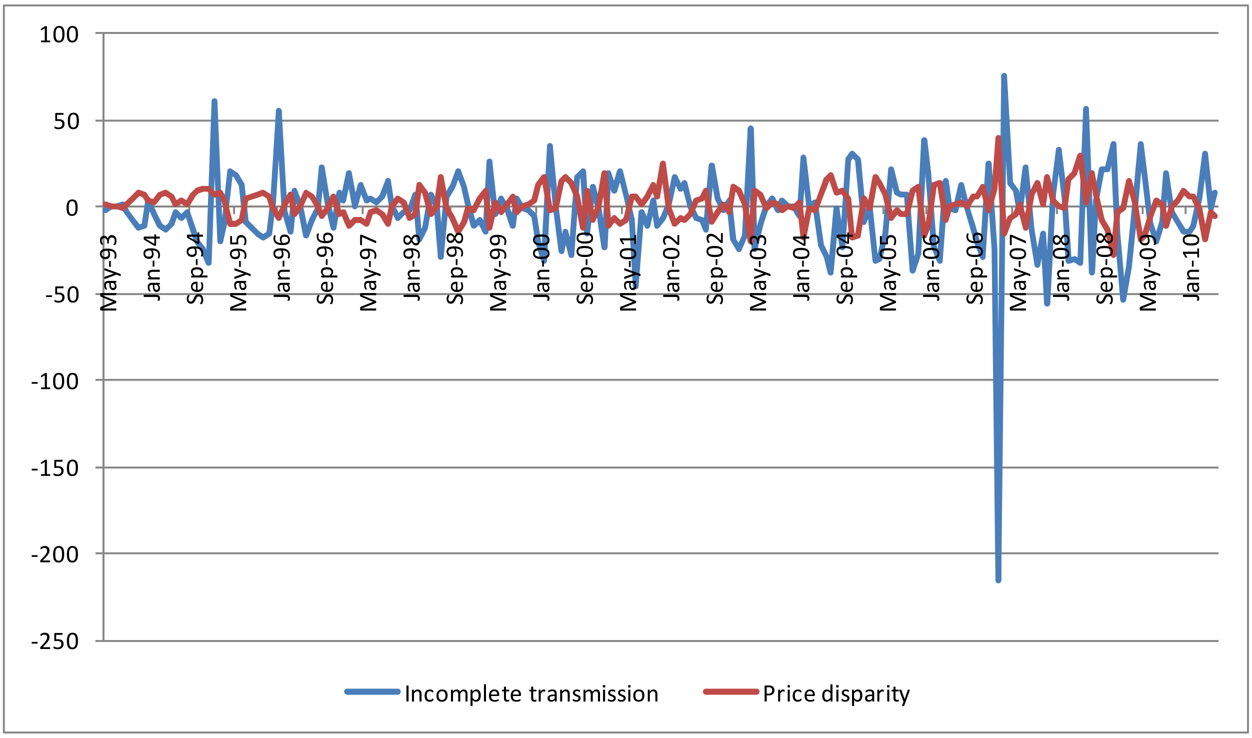

Figure 3d: urea

Figure 3: Factors causing changes in the price gaps

Positive APT occurs when local price is more responsive to shocks that increase the landed price. Negative APT, on the contrary, is the case where suppliers in the domestic market react more quickly to shocks that decreases landed price. Positive APT is common in market structures characterized by market power which could lead to anticompetitive behavior. Negative APT, on the other hand, is characteristics of oligopolistic market structure.

Table 2: The responsiveness of local fertilizer prices to changes in landed prices

Type	1% increase in $P_t^w X_t(1+t)$				1% decrease in $P_t^w X_t(1+t)$			
	e=0	0<e<1	e=1	e>1	e=0	0<e<1	e=1	e>1
Ammonia	32	59	0	9	25	56	0	19
Urea	32	44	0	24	18	54	0	28
DAP	33	42	0	25	27	40	0	33
MAP	37	39	0	24	24	52	0	24

Source: Authors computation

Table 2 gives a summary of results from price transmission elasticity estimates. It covers the period January 2005 through June 2010 - a period characterized by marked fluctuations in local and world fertilizer prices. According to the results found, neither the positive nor the negative changes in the landed prices were completely transmitted to the local prices (P_t^d). This is according to columns 4 and 8 of Table 2, which demonstrated outright rejection of unitary price transmission. This confirms that APT characterizes South African fertilizer markets.

The evidence provided in Table 2 however is not conclusive. It does not aid to classify the behavior of the markets as a positive or a negative APT. For example, consider how ammonia suppliers responded to an increase and decrease in landed prices. According to Table 2, responses were inelastic (i.e. 0<e<1) in 59% and 54% of the cases, respectively. This gives inconclusive result as it satisfies the characteristics of both negative and positive APT. A positive (negative) APT is a situation where PTE is elastic (inelastic) when price increases and inelastic (elastic) when it decreases.

The discussions hitherto indicated that much of the changes in the price gaps could be ascribed to non policy factors. This is to be expected since those engaged in fertilizer production get little protection from external completion by the government. We also found that changes in landed prices are not completely transmitted to local prices. The question that remains yet to be answered is the role that changes in the exchange rate and world price have played to the upward trend in the price gaps between local and landed price. To answer this we decomposed the net effect of policy and non policy factors to the change in the price gap into those that occurred due to changes in the exchange rate and world prices. Results are summarized in Figures 4a through 4d. According to the results found, the exchange rate plays the dominant role. For example, in May 2008, the price gap for ammonia increased by about 98%. The exchange rate and the world price respectively accounted for about 79% and 19% of the change (Figure 4a).

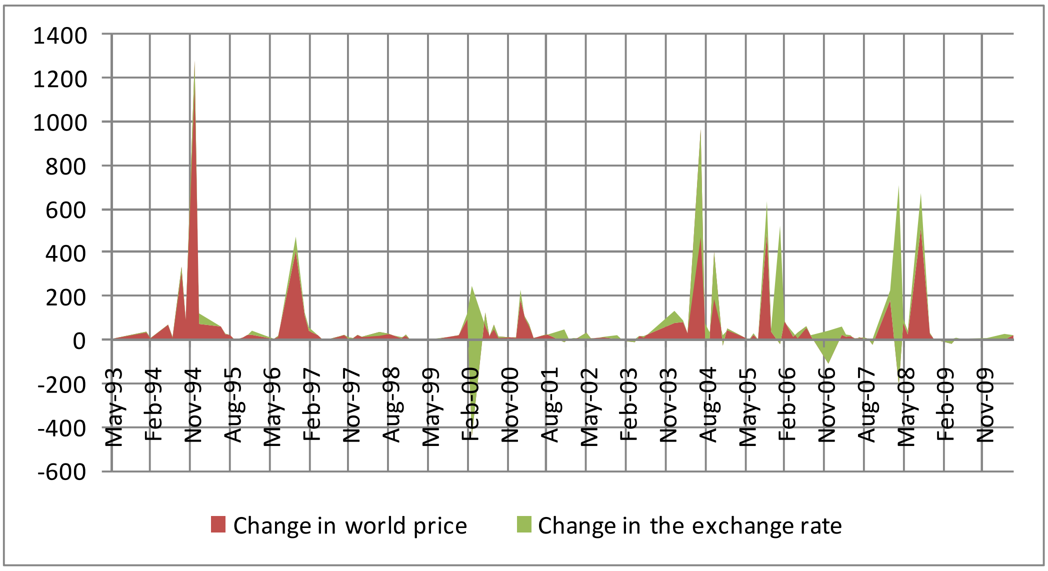

Figure 4a: ammonia

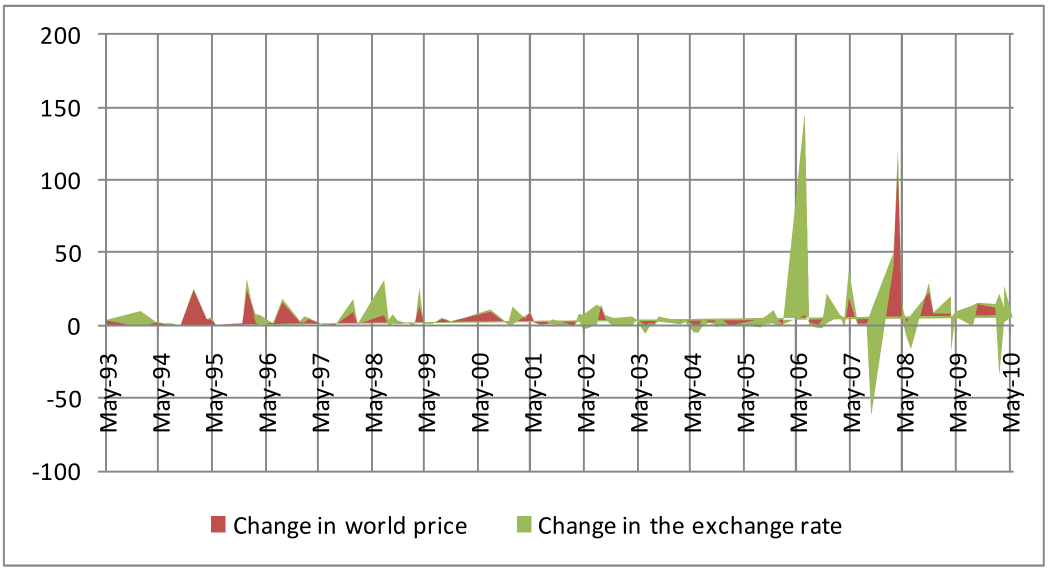

Figure 4b: dap

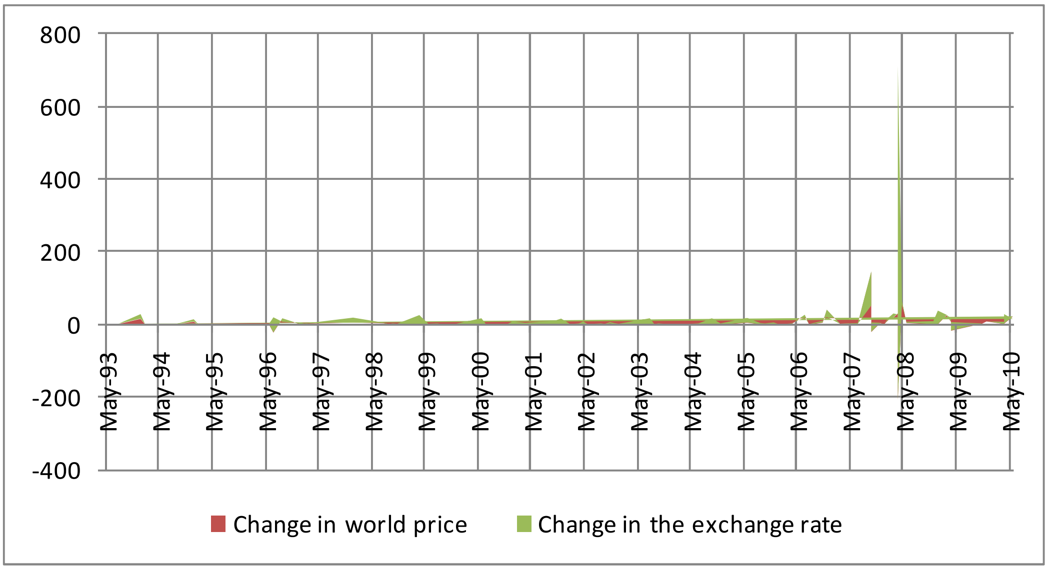

Figure 4c: mop

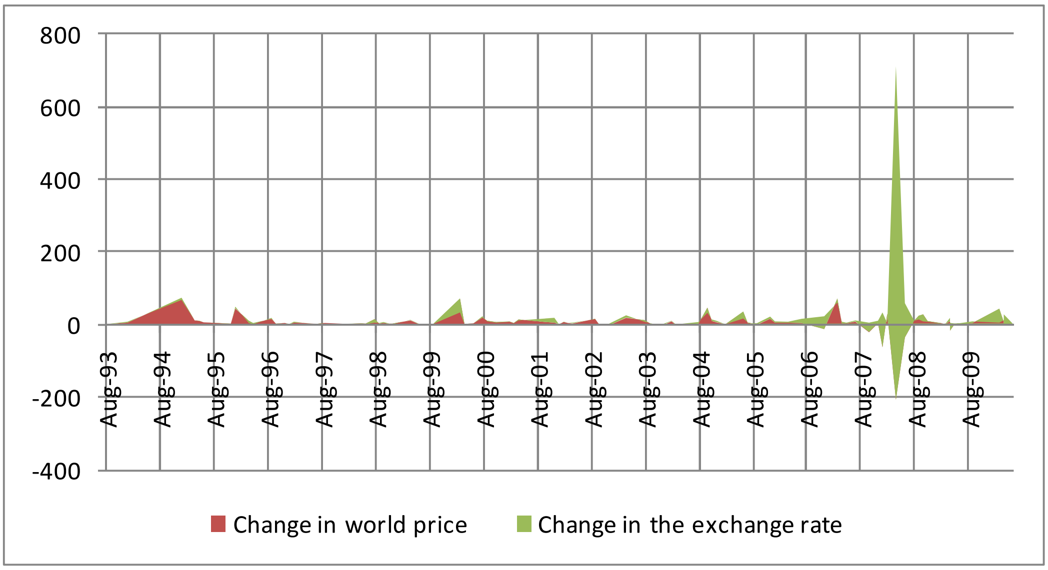

Figure 4d: urea

Figure 4: the contribution of the exchange rate and world price to the price gap

Measuring Price Transmission: Econometric Approach

In the previous section, we found that changes in landed prices are not completely transmitted to local price. We couldn't however further dig into the result to determine if local price responds differently to increases and decreases in the landed price. In other words, we were constrained by the method applied to ascertain the presence of asymmetric price transmission. To help us determine whether suppliers respond differently to positive and negative shocks, we applied a different methodology. Appendix 2 describes the methodology used in this study.

Next, we analyze results from the econometrics study. The method helped give much clear answers to questions we raised earlier i.e. the presence or absence thereof, of incomplete price transmission. If yes, how do traders react to positive and negative changes in landed prices? How long does it take for positive and negative changes in the world price and the exchange rate to be eliminated? Which criterion of APT is better suited to fertilizer markets in South Africa – negative or positive APT? Answers to these and other related questions could give insight into the type of market structure that characterizes the local fertilizer industry and the level of importance that one could attach to the exchange rate compared with the world price.

Table 3: Price transmission

Variable	Ammonia	Mop	Urea	Dap
ρ_1 [a]	0.097	-0.121**	-0.096**	-0.269**
ρ_2 [a]	-0.177**	-0.359**	-0.533**	-0.723**
ϕ [b]	14.111	11.871	29.751	12.503
$\rho_1=\rho_2$ [c]	9.796**	6.201**	26.54**	2.808***
γ [e]	-0.078	-0.047	0.008	-0.065

Source: Authors computation

*, **, *** represent respectively level of significance at 1%, 5%, and 10%.

Table 3 summarizes price transmission estimates for the four fertilizer types studied. The results are based on Momentum Consistent Threshold Autoregressive Models (MC-TAR). The MC-TAR model was selected with the help of some goodness of fit criteria which we discussed at some length in Appendix 2.

Second and third rows of Table 3 give degree of persistence of positive and negative discrepancies from equilibrium. For example, in the case of mop, 12% of the positive and 36% of the negative discrepancies in profit margin persist to the following month. This means that local prices react much quickly to increases rather than decreases in the landed price. The implication is that the local fertilizer industry responds much quickly to shocks that squeeze its profit margins than to shocks that stretch them. This is typical of positive asymmetric price transmission. This incomplete price transmission, according to the literature, could be the result of deficiency in the market infrastructure that characterizes the fertilizer industry.

Next, we estimated an error correction model (ECM). Here we analyze parameter estimates of dynamic variables (current and lagged variables). It allows analysis of causal relationships between local prices, the exchange rate, and the world prices. We also analyzed adjustment coefficients. They indicate how quickly long run disequilibria are corrected. According to Table 4, all the variables have the expected signs. A look into the level of significance of contemporaneous and lagged value changes of the world price and exchange rate shows the presence of dynamic relationships. Local prices are affected positively by its own lagged values, contemporaneous and lagged values of the world price, and contemporaneous and lagged values of the exchange rate.

We next analyzed the adjustment parameters. Their sign and size help determine how local prices reacts to positive and negative emanating from changes in the world price and the exchange rate, and how quickly the effect of such shocks on the local price could be eliminated. Positive shocks are shocks that affect profit margins of those involved in local fertilizer trade positively (i.e. decrease in the international price). Negative shocks on the other hand affect profit margin of local fertilizer traders negatively (i.e. increase in the international price of fertilizer). According to the results found, shocks, regardless of their origin, affect local price. We found that adjustment coefficients are significant and have the right sign. This indicates that positive and negative disequilibria are corrected. In addition, results show that the adjustment parameters have different sizes to the one for negative adjustment being the greatest in absolute terms. This implies that local price responds more quickly to negative shocks than positive shocks. Negative shocks could emanate from increase in either the world price or decrease in the value of the local currency. They squeeze profit margin of those involved in local fertilizer trade. This, as indicated earlier, is typical of positive asymmetric price transmission.

Table 4: Error Correction Model

	Ammonia	Map	Urea	Dap
Constant	0.002	0.003	-0.0008	0.003
ΔLP_{t-1}	-0.004	0.105***	0.061	0.152
ΔLP_{t-2}	0.122**	0.182*	0.116**	0.057**
ΔWP_{t}	0.076**	0.273*	0.001	0.046
ΔWP_{t-1}	0.006	0.068	0.04	0.194**
ΔWP_{t-2}	0.148*	0.094	0.096**	0.154**
ΔX_{t}	0.12**	0.077	0.158*	0.061
ΔX_{t-1}	0.136**	0.004	0.05	0.083
ΔX_{t-2}	0.203*	0.081	0.098	0.126**
err^{+}_{t-1}	0.094	-0.143*	-0.114*	-0.174*
err^{-}_{t-1}	-0.118*	-0.15*	-0.449*	-0.398*
Adj. R^2	0.29	0.344	0.437	0.551
DW	1.92	2.03	1.984	2.012
F-Statistic	9.48*	11.643*	16.788*	25.943*

Source: Authors computation

*, **, and *** represent respectively level of significance at 1%, 5%, and 10%.

Next, we used results presented in Table 3, to conduct impulse response analysis. Impulse response analysis is useful because it helps uncover the time period it takes for a unit shock in either the world price or the exchange range to be eliminated. We did this for the four types of fertilizers covered in this study. Figure 5a through 5d summarizes the response of local price to a unit increase (negative shock) and decrease (positive shock) in the world price. We also analyzed the effect of a one unit increase and decrease in the exchange rate on local price. Results are summarized in Figures 5a through 5d.

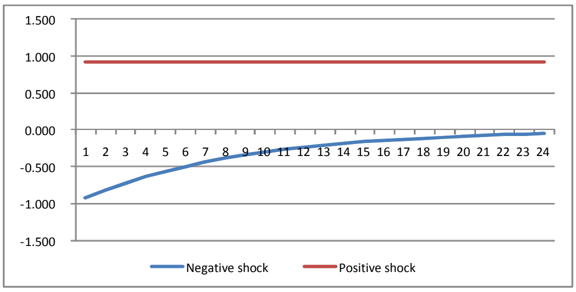

Figure 5a: Ammonia

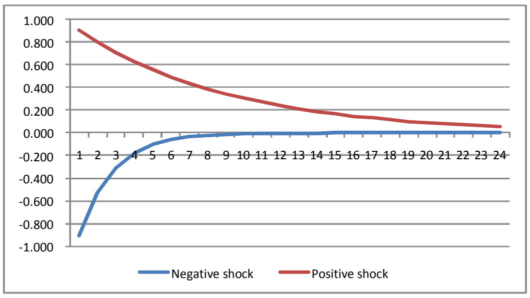

Figure 5c: Urea

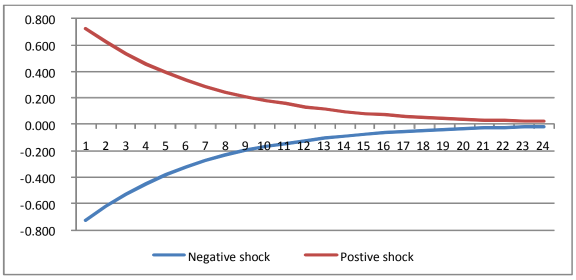

Figure 5b: Map

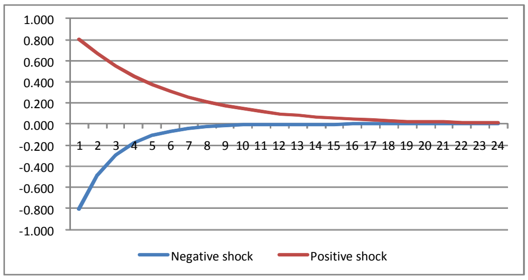

Figure 5d: Dap

Figure 5: Response of local fertilizer prices to shocks in world price of fertilizer

To fix ideas, we demonstrate how the impulse function was estimated using Ammonia as example. A unit increase in world price (a negative shock to traders' marketing margin) decreases the profit margin by about 0.92 units. This is corrected by a factor of 0.12 every month. Similarly, an increase in the exchange rate (a negative shock to the marketing margin) will result in a decrease in the marketing margin by about 0.88 units. In both cases, the disequilibria are corrected by a factor of 0.12 every month. Applying similar approaches this time assuming a unit decrease in the world and exchange rates (examples of positive shocks), one finds that in general, in the long run, the margin in the ammonia industry is corrected more rapidly when squeezed than when it is stretched (Figure 5a & 6a). With ammonia/LAN, looking at the graphs, it is clear that a positive shock (a decrease in international prices or a strengthening of the exchange rate), statistically has no significant relation. This means that, statistically there are no significant relation between a price decrease in international prices or appreciation of the Rand and the price of local LAN (limestone ammonium nitrate). This occurrence points to irregularities in the local ammonia and downstream products.

In general, Figures 4 and 5 shows that it takes less months for negative shocks to be eliminated than positive shocks. In addition, results indicate that the world price and the exchange rate, exhibit similar pattern of adjustment for negative and positive shocks. For example, the number of months it takes to eliminate a negative world price shock is not much different from what it takes to eliminate a negative shock in the exchange rate.

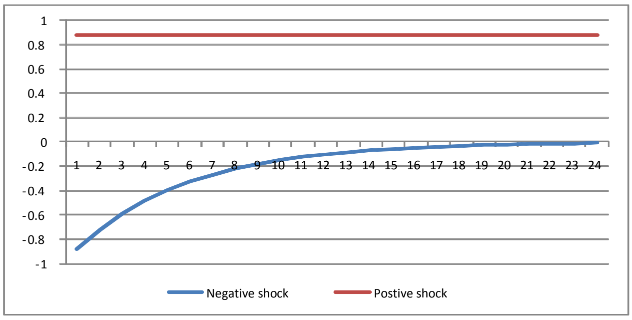

Figure 6a: Ammonia

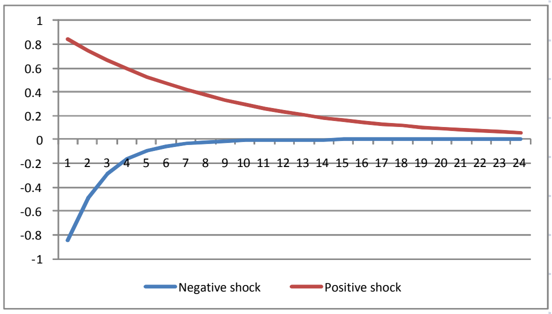

Figure 6c: Urea

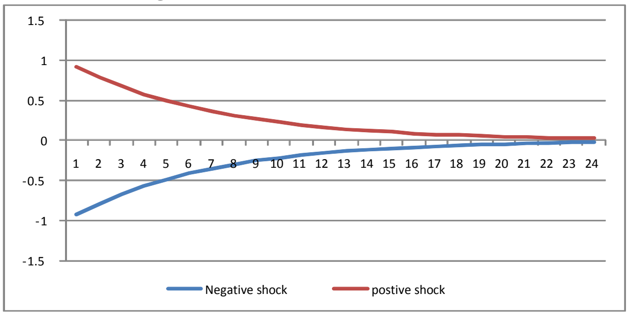

Figure 6b: Map

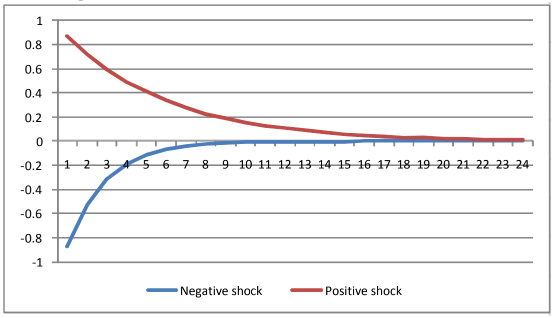

Figure 6d: Dap

Figure 6: Response of local fertilizer price to shocks in exchange rate

4. Summary of results and conclusions

Two sets of results are presented here – based on price decomposition and estimation of econometric models. Results from price decomposition show that changes in the price gap are to a larger extent dominated by non policy factors; price transmission estimates indicate that the relationship between local and landed prices is characterized by incomplete price transmission; and that compared with the world (boarder) price, much of the variation in the price gaps occur as a result of the exchange rate.

The following gives summary of results from the application of econometric techniques. They reinforced the ones we expounded earlier: local price depends positively on contemporaneous as well as lagged values of the world price and the exchange rate; shocks regardless of their origin (driven by the exchange rate or world price or both) affect local prices; local prices respond more quickly to negative shocks than positive shocks, implying that those involved in fertilizer trading react more quickly to shocks that squeeze their profit margin than those that stretch them; and it takes more or less similar months for positive and negative shocks emanating from changes in the boarder price and the exchange rate to be completely eliminated implying that both play important role for movements in local prices.

References

Enders, W. & Granger, C.W.J. (1998). Unit-root tests and adjustment with an example from the term structure of interest rate, *American Statistical Association*, 16(3): 304–11.

Enders, W. & Siklos, P. (2001). Cointegration and asymmetry in price adjustment, *Journal of Business and Economics Statistics*, 19(2): 166–76.

Meyer, J. & Von Cramon-Taubadel, S. (2004). Asymmetry in price transmission: a survey, *Journal of Agricultural Economics*, 25(3): 581–611.

Petrucelli, J. & Woolford, S. (1984). A threshold AR(1) model, *Journal of Applied Probability*, 21: 270–86.

Liefert, W.M. (2009). Decomposing changes in agricultural price gaps: an application to Russia, *Agricultural Economics,* 40, 15 -28.

Liefert, W.M. (2005). Decomposing changes in agricultural price gaps, *Working paper 05-02, International Agricultural Research Consortium*, available at www.iatrcweb.org.

Appendix A: Price decomposition

The price gap (G) between local and landed price is computed as

[1] $G = p^d - p^w X$

Where G is the price gap after adjustment for domestic transaction costs; p^d is local price of fertilizer; p^w is world (boarder) price expressed in USD; and X is the exchange rate.

To be able to compute factors responsible for over time change in the price gap (G) we difference [1] to get

[2] $\Delta G = \Delta p^d - \Delta(p^w X)$

Multiplying Δp^d by Δp^d by $1 = \left(\frac{p^d}{p^d}\right)$ and $\Delta(p^w X)$ by $1 = \left(\frac{p^w X}{p^w X}\right)$ we get

[3] $\Delta G = p^d \dot{p}^d - p^w X \, \overset{\cdot}{\overbrace{p^w X}}$

We then multiply $p^d \dot{p}^d$ by $1 = \overset{\cdot}{\overbrace{p^w X(1+t)}} \Big/ \overset{\cdot}{\overbrace{p^w X(1+t)}}$ to get [4]. where t is the tariff

rate; and $p^w X(1+t)$ is duty included landed price. The tariff rate t takes a value of zero as South African fertilizer imports are not subjected to tariff.

[4] $\Delta G = p^d e \, \overset{\cdot}{\overbrace{p^w X(1+t)}} - p^w X \, \overset{\cdot}{\overbrace{p^w X}}$

Where $e = \dot{p^d} / \overbrace{[p^w X(1+t)]}^{\cdot}$ is the price transmission elasticity (PTE).

To isolate the effect of incomplete transmission, we insert in [4] $(e + k - k)$, where, $k = 1 - e$, such that $e + k = 1$. In addition we replace absolute change by percent change. This gives [5]

$$[5] \qquad \dot{G} = \frac{p^d \overbrace{\dot{p^d}[p^w X(1+t)}^{\cdot}}{p^d - p^w X} - \frac{p^w X \widetilde{p^w X}}{p^d - p^w X} - \frac{p^d k \overbrace{[p^w X(1+t)]}^{\cdot}}{p^d - p^w X}$$

Equation [5] has got three terms in its right hand side. The last term would drop out if transmission from landed price to domestic price were complete (e=1, such that k=0). This means that this term explains variations in price gaps caused by incomplete transmission. By implication the first two terms explain changes in the price gap under conditions that there is complete transmission.

Equation [5] needs to be further decomposed in a manner that the final form of the equation contains not more than one of the terms expressed as a percent change and also that no term contains the percent change of either a sum or a product of two or more of these variables. For details on this see Liefert (2005).

Appendix B: Econometric Approach

We estimate [1] to establish long run relationships between local and international prices.

[1] $P_t^d = \partial + \partial_1 p_t^w + \partial_2 X_t + \varepsilon_t$

Where,P_t^d,P_t^w, and X_t are local price, world (boarder) price, and the exchange rate respectively, and ε_t is the error term. Conventionally, the presence of a long-run relationship among the variables is tested by estimating [2].

[2] $\Delta\varepsilon_t = \rho\varepsilon_{t-1} \sum_{i=1}^{k} \Delta\varepsilon_{t-i} + v_t$

Where, ρ is adjustment parameter, and ε_t is as defined before. Cointegration is said to exist when the null hypothesis of no cointegration, i.e. $\rho = 0$ in [2] against its alternative hypothesis of cointegration, i.e. $-2 < \rho < 0$ is rejected.

However, the conventional methodology is criticized because of the assumptions it makes about adjustments towards equilibrium. It assumes (implicitly) that adjustment is symmetric. This may not be true when local fertilizer prices respond differently to changes in the world price and the exchange rate. This is true when the nature of the market structure allows local fertilizer traders to respond more quickly to shocks that squeeze their profit margin than those that stretch them.

To address this shortcoming, Enders & Siklos (2001) extended [2], with asymmetric adjustment toward equilibrium being made part of the alternative hypothesis. This requires estimation of [3].

[3] $\Delta\varepsilon_t = \rho_1 I_t \varepsilon_{t-1} + \rho_2 (1 - I_t)\varepsilon_{t-1} + \sum_{i=1}^{k} \Delta\varepsilon_{t-i} + v_t.$

Where, ε_t is as defined before, $\rho_1 \,\&\, \rho_2$ are adjustment coefficients, k is the lag length whose value is determined using the Akiake (AIC) and Swartz (SC) information criteria;

and I_t is the Heaviside indicator which takes a value of 1 and zero depending on the relationships between ε_t and τ see [4].

$$[4] \qquad I_t = \begin{cases} 1 \; if \; \varepsilon_{t-1} \geq \tau \\ 0 \; if \; \varepsilon_{t-1} < \tau \end{cases}$$

Where, τ is the threshold and taking any value depending on the type of model estimated. In the case of a Threshold Autoregressive Model (TAR) it takes a value of zero. This makes [5] different from [4] in that it allows actors in the market to respond differently to upward and downward swings in the exchange rate and world prices.

The necessary and sufficient conditions for cointegration are that $\rho_1 \& \rho_2$ be less than zero and that $(1+\rho_1)(1+\rho_2)<1$ for any value of τ (Petrucelli & Woolford, 1984, as cited in Enders & Siklos, 2001).

In addition to TAR, Enders & Siklos (2001) introduced two other competing models with alternative adjustment specifications but within the threshold frameworks. These include the Momentum Threshold Autoregressive Model (M-TAR) and Momentum Consistent Threshold Autoregressive Models (MC-TAR).

M-TAR allows the threshold to depend on changes in previous levels of ε_t. It is appropriate when deviation from the long run exhibits more 'momentum' in one direction than the other. It also comes handy in cases when monetary authorities react more to inflationary situations that increases the deviation but not decrease it. This requires specifying the Heaviside indicator as [5]

$$[5] \qquad M_t = \begin{cases} 1 \; if \; \Delta\varepsilon_{t-1} \geq \tau \\ 0 \; if \; \Delta\varepsilon_{t-1} < \tau \end{cases}$$

Where, M_t is the Heaviside indicator and ε_{t-1} is as defined before.

The theoretical justification for estimating MC-TAR is similar to that of M-TAR. The only difference is with regards to the value of the threshold τ which is no longer fixed at 0. It is considered unknown. It is determined along side with the values of ρ_1 & ρ_2. This is done by searching for it over the potential threshold variable space by minimizing the Residual Sum of Squares in [3]. Hence, the Heaviside indicator may be specified as [6].

[6] $$MC_t = \begin{cases} 1 \; if \; \Delta\varepsilon_{t-1} \geq \tau * \\ 0 \; if \; \Delta\varepsilon_{t-1} < \tau * \end{cases}$$

Where, MC_t is the Heaviside indicator, ε_{t-1} is as defined before, and $\tau *$ takes a value different from 0.

Two types of tests are performed on the estimates from [3]. First, to check for cointegration by jointly testing for the null hypothesis that $\rho_1 = \rho_2 = 0$ against its alternative hypothesis of $\rho_1 = \rho_2 \neq 0$. Second, to test for symmetry in adjustment by testing the null hypothesis of $\rho_1 = \rho_2$ against its alternative of $\rho_1 \neq \rho_2$.

To conduct the first test, a non-standard testing procedure is recommended as parameters are identified only in the alternative hypothesis. Enders and Siklos (2001) run a Monte Carlo experiment to compute critical values. These critical values are compared against the F-statistics to test the no cointegration null hypothesis. They labeled the F-statistic Φ for TAR and M-TAR models and its analog Φ^* for the MC-TAR model. The test statistics Φ and Φ^* are used only on conditions that $\rho_1$and $\rho_2$satisfy the convergence conditions $\rho_1, \rho_2 < 0$. For the second, standard Wald test is applied. It is found that OLS estimates for $\rho_1 \& \rho_2$ have an asymptotic multivariate normal distribution (Tong, 1990, as cited in Enders & Granger, 2001). Failure to reject the null hypothesis reduces [3] to [2].

Finally, the three competing models are compared to determine the model that best fits the data. The resulting ECM in the context of which impulse response functions are computed takes the form given by [7].

$$[7] \quad \Delta p_t^d = \sum_{i=1}^{k} \beta_i \Delta p_{t-i}^d + \sum_{i=0}^{k} \alpha_i \Delta p_{t-i}^w + \sum_{i=0}^{k} \varphi_i \Delta X_t + \gamma_{11} \epsilon_{t-1}^{+ve} - \gamma_{12} \varepsilon_{t-1}^{-ve} + v_{1t}$$

$$-\gamma_{22} \varepsilon_{t-1}^{-ve} + v_{2t}$$

Where, $\varepsilon_{t-1}^{+ve} = I_t \varepsilon_{t-1}$, $\varepsilon_{t-1}^{-ve} = (1 - I_t)\varepsilon_{t-1}$, v_t is the residual term, and p_t^d, p_t^w,and X_t are as defined before.