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ABSTRACT

Exchange Rate Pass-through and Monetary Policy in South Africa*

Understanding how import prices adjust to exchange rates helps anticipate inflation effects and monetary policy responses. This paper examines exchange rate passthrough to the monthly import price index in South Africa during 1980-2009. A methodological innovation allows various short-run pass-through estimates to be calculated simply without recourse to a full structural model, yet without neglecting the long-run relationships between prices or the effects of previous import price changes, and controlling for domestic as well as foreign costs. Pass-through is incomplete at about 50 percent within a year and 30 percent in six months, averaging over the sample. Johansen analysis of a cointegrated system using impulse response functions largely supports these short-run results, but as it includes feedback effects, implies lower pass-through for exogenous exchange rate shocks. Equilibrium pass-through, ignoring feedback effects, is around 75 percent. Shifts in pass-through with trade and capital account liberalisation in the 1990s are explored. There is evidence of slower pass-through under inflation targeting when account is taken of temporary shifts to foreign currency invoicing or increased hedging after large exchange rate shocks in the period. Further, pass-through is found to decline with recent exchange rate volatility and there is evidence for asymmetry, with greater pass-though occurring for small appreciations.

JEL Classification: C22, C32, C51, C52, E3, E52 and F13
Keywords: asymmetic pass-through, exchange rate pass-through, exchange rate volatility, falling pass-through, import prices, monetary policy, South Africa and trade openness

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1. Introduction

For most developing and emerging market countries, financial markets are increasingly linked. Many have adopted floating exchange rates and eliminated capital controls. This exposes them to speculative pressures, contagion and easily reversible capital flows. Monetary policy-makers in small, open economies thus may face challenges with greater imported inflationary pressures and exchange rate volatility. There has been recent renewed interest in the extent to which exchange rate movements affect prices, and the channels through which this occurs. Understanding the nature of the adjustment of aggregate import prices to exchange rate changes, and through import prices eventually to other aggregate domestic prices, is important for anticipating inflationary developments and hence monetary policy responses.

Exchange rate pass-through refers to the degree to which a country's prices change in response to a change in its exchange rate.[1] Exchange rate pass-through to prices is incomplete if exchange rate changes elicit less than equi-proportionate changes in prices. Pass-through to prices can be asymmetric when exchange rate depreciation elicits a price response of a different magnitude to an appreciation or when smaller changes elicit a different proportionate response from larger changes.[2] The time dimension is critical: very long run or "equilibrium" measures differ from estimates of pass-through within a shorter period (one or two years, perhaps), usually considered most relevant for monetary policy.

The sizeable literature on pass-through (see surveys in Menon, 1995; Goldberg and Knetter, 1997) has changed focus over the years. During the late 1980s and 1990s, empirical work focussed on modelling exchange rate pass-through by analysing firm-level strategic price-setting behaviour, mainly at industry-level pass-through in industrialised countries, with disaggregated data. However,

[1] The original definition of exchange rate pass-through referred to the percentage change in *import* prices in response to a one percent change in the exchange rate (now called *Stage 1* pass-through). This definition has since been extended to address the effect of exchange rate movements on producer or consumer prices (*overall* pass-through). The effect of a change in import prices on producer or consumer prices is known as *Stage 2* pass-through. Typically, the sensitivity to the exchange rate will decline down the chain of prices, from import prices through producer to final consumer prices, as the proportion of non-traded goods and services increases in the consumption basket.

[2] It is important to recognise that exchange rate changes are not always the same as exogenous exchange rate shocks. The pass-through from exchange rate changes could well be different than from exchange rate shocks and this distinction will be explored further in this paper.

the recent volatility in exchange rates and persistent trade imbalances has galvanised interest in the effect that pass-through has on monetary policy choices. Further, two seminal theoretical contributions have renewed interest in empirical exchange rate pass-through models: the micro-founded New Open Economy Macroeconomics (Obstfeld, 2002) and Taylor's staggered pricing model (Taylor, 2000). These have been harnessed to explain the empirical observation that exchange rate pass-through to aggregate import prices has declined in many industrialised countries since the 1980s, despite strong economic demand. Both explore how differences in firms' price setting behaviour can influence the transmission of monetary policy through changing the degree of exchange rate pass-through. For instance, Taylor (2000) suggests how a low inflation environment through credible monetary policy commitments to explicit targets can explain lowered exchange rate pass-through. A burgeoning recent literature has widened the focus to embrace developing and emerging market countries, and to both disaggregated and aggregate import, producer and consumer price indices. There are at least two advantages in the use of aggregate data. The first is that the weights applied to prices in the aggregate prices indices reflect their economic relevance. The second is that with aggregate time series data one can use a systems approach and disentangle exogenous shocks from mere changes in variables such as the exchange rate, thus exploring feedback effects e.g. from the monetary policy reaction function.

South Africa (SA) is an important emerging market country, an exemplar for African monetary policy, and a key destination for emerging market capital flows. SA has undergone several economic regime changes in recent decades, enhancing the importance of the exchange rates to import prices link. The currency was floated in various arrangements including a dual exchange rate regime from mid-1979 (Aron et al., 2000); the trade account was quite rapidly opened after 1990 (Edwards et al., 2009); the capital account to non-residents was fully opened from Spring 1995 shortly after the first multi-racial, democratic elections in 1994 (Leape and Thomas, 2009); and the monetary policy regime altered in 2000, with an official policy of targeting the domestic inflation rate, resulting in lower average inflation rates relative to the preceding decades (Aron and Muellbauer, 2009a; Van der Merwe, 2004).

There has been little focus on pass-through to import prices in SA. Available estimates are for equilibrium pass-through, but the structure of lags in the short to medium-run, so important for monetary policy, remains unrevealed. The literature survey in Section 3 also shows that recorded estimates emanate from models which omit important control variables and lags, and do not control for the considerable structural change.

This paper examines pass-through to import prices in SA after six months and a year, and in the very long-run. The simplest models commonly employed in the literature on pass-through are formulated in first differences only, thus excluding the equilibrium correction terms that capture long-run relationships between import prices and foreign prices and import prices and domestic prices. As pointed out by de Bandt et al. (2008), the neglect of the long-run terms is a misspecification of the model if co-integration between these long-run level variables is actually present, and will bias the reported pass-through measures. The failure to find co-integration, they argue, is due to not taking sufficient account of structural breaks. At the other extreme, many studies employ the Johansen methodology to find a long-run relationship between the exchange rate, foreign prices and import prices (typically neglecting destination country domestic prices), but report only the long-run equilibrium pass-through coefficient (usually without feedback effects from an impulse response analysis), and not pass-through at more policy-relevant horizons of from six months to two years.

This paper estimates exchange rate pass-through to import prices in SA during 1980-2009 using various monthly models of both the single equation and system model type, controlling for domestic and foreign costs, domestic demand and structural breaks. Using dynamic single equation equilibrium correction models we introduce a methodological innovation to allow the inclusion of long-run terms as well as dynamic terms, and to calculate pass-through at equilibrium and after six and twelve months. This method allows various short-run pass-through estimates to be calculated simply without recourse to a full structural VAR model (SVAR). The results are largely supported by the systems approach using a SVAR model embodying various long-run homogeneity restrictions, when generating short-run pass-through estimates from impulse response functions. However, the SVAR model, unlike the single equation approach, takes account of potential offsetting feedbacks affecting the exchange rate too, for instance from monetary policy.

The analysis is then extended in a number of directions that carry implications for the conduct of monetary policy. First, it is of interest whether exchange rate pass-through, following the pattern in some other inflation targeting countries, fell under the new inflation-targeting monetary regime. The structural change from the rapid trade liberalisation after 1990 and the opening of the capital account in 1995 may also have affected pass-through, and we test for this. Other changes in pass-through could be connected to shifts in the proportions of imports invoiced in foreign currency. Second, it is common to assume that exchange rate pass-through is both linear and symmetric. The implication is that large and small exchange rate changes, and appreciations and depreciations, should exert similar proportional effects on import prices. This paper tests for non-proportional adjustment in both directional and size dimensions. Finally, we also test for any impact of exchange rate volatility, another kind of non-linearity, on pass-through.

In the remainder of the paper, Section 2 discusses exchange rate pass-through and monetary policy. Section 3 outlines the conceptual issues underlying the estimated empirical models, and reviews the associated SA empirical literature. The methodology and data for South Africa are discussed in Section 4, and results of the empirical estimations in Section 5. Section 6 concludes.

2. Pass-through and monetary policy

The monetary policy implications of gradual or incomplete pass-through from the exchange rate turn critically upon the country's monetary policy framework, and the nature and size of the triggers for changes in the central bank's policy instruments.

In an exchange rate targeting set-up, parity changes are typically very infrequent. Their effects on the domestic wholesale and retail prices of tradable products are apt to be rapid and large, especially for importables. In the wake of devaluation, money wage rates and non-traded goods prices, if they are flexible at all, should register a modest initial rise, and then a trickle of continuing declining increases as competitiveness gains are gradually eroded by the elevated pressure of aggregate demand. Unless or until the new parity becomes suspect, longer term inflation expectations will presumably stay close to those of partner countries.

If capital mobility restrictions are minimal, the "impossible trinity" implies that an exchange rate targeter cannot pursue an independent monetary policy. SA, officially an inflation targeter since 2000, is among the countries who have given up attempts to target the exchange rate. Nevertheless, large fluctuations in capital flows pose major policy challenges, for example to consider increasing reserve accumulation in the face of strong private capital inflows. The OECD (2010) has urged this policy on the South African authorities to avoid 'excessive' exchange rate appreciation. Another is whether and how to try sterilise the monetary effects of any increases in foreign exchange reserves.

With a floating exchange rate, short-run uncertainty about the exchange rate will affect price setting behaviour, quite possibly resulting in slower pass-through. Eventually, after a decade or so, one might expect close to full pass-through for a permanent exchange rate change at least to import prices in a small open economy. For large countries, pass-through would be smaller, if only because nominal prices would tend to move in the opposite direction elsewhere, and there may be other reasons, such as previous price changes in anticipation of the exchange rate change, or real disturbances that provoke that change as well as changes in relative prices, which prevent eventual full pass-through to consumer prices.

It is evident from the work of Gopinath et al. (2010a, 2010b) that pass-through speeds will depend greatly on currency invoicing patterns, and also how they are affected by actual or anticipated exchange rate variability. In many middle income economies, especially smaller ones, local currency invoicing will in any case be the exception, not the rule, even for their imports. This would point to faster pass-through there. A survey in Fendel et al. (2008), however, suggests that for German exporters to African emerging market countries, local currency pricing predominantly prevails.

Central banks in countries with freely floating currencies need to watch nominal and real exchange rates closely, because of the bearing they have on the future values of the output gaps, the growth rates of money aggregates, and the different measures of inflation. But exchange rates should affect monetary policy decisions only indirectly, through these effects. There should be no room for exchange rates as independent elements in the central banks' reaction functions[3]. Ho and McCauley

[3] This need not preclude an element of exchange rate smoothing. The Reserve Bank of Australia, for example, has long espoused a policy of letting the markets guide the exchange rate path but intervening to limit volatility.

(2003) distinguish three views on the role of the exchange rate under inflation targeting: the 'strict constructionist', the flexible inflation targeter and the Singaporean approaches. The first of these sees policy responding to exchange rate fluctuations only to the extent that they affect forecast or actual inflation. The flexible inflation targeter view accepts that the exchange rate can be a valid objective of monetary policy, together with inflation and output. Ho and McCauley discuss why the exchange rate matters, and particularly for emerging market inflation targeters, and show that policymakers in both industrial and emerging market inflation-targeting countries have in practice responded to the exchange rate more than the strict constructionist view would suggest (that is, "above and beyond its impact on inflation"). The responses they document include not only monetary policy, but also verbal and sterilised intervention and other instruments. They argue that explicitly forswearing intervention can itself result in problems for policymakers, and use the experience of SA in 2001-02 (see Aron and Muellbauer, 2009a) as a cautionary example in this regard. For Singapore, meanwhile, and now Malaysia, the exchange rate is seen as a policy instrument, best viewed as subject to some implicit Taylor Rule.

None the less, the way independent changes in the exchange rate affect the domestic price indices, even when they occasion no direct policy rate reaction, will depend on policy makers' responses in relation to the inflation outlook. Murchison (2009) argues convincingly that the more vigorously the central bank acts to insulate inflation and hold it to target, the weaker the pass-through should be; when price mark-up shocks are included in his study, he finds this follows.

The best known empirical paper on the extent to which central banks in English speaking inflation targeting countries do respond to exchange rates in their monetary policy decisions is Lubik and Schorfheide (2007). Using a variety of Bayesian statistical approaches, but under assumptions they agree may be extreme (such as that of full, immediate pass-through for import prices), these authors find consistently that Australia and New Zealand do not, while Canada and the United Kingdom apparently do, respond to exchange rates (at least to some degree). While Lubik and Schorfeide do not include SA in their enquiries, there are two papers that look specifically at SA from

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The recent paper by Roger et al. (2009) commends such a policy, finding it advantageous for all economies, and particularly those where risk premia may be large and variable.

this standpoint. Taken together, their findings point to only a modest sensitivity of policy rates to exchange rates. Ortiz and Sturzenegger (2007) for 1997-2006, find an almost zero coefficient on the exchange rate in the SA Reserve Bank's reaction function. Harjes and Ricci (2010) cover a somewhat fuller post-apartheid period, and assume that the reaction function does not respond directly to the exchange rate, but only to the classical gaps in output and inflation. Their results imply that an immediate 10 percent unanticipated appreciation in the exchange rate would tend to trigger, on average, a policy rate reduction of 30 basis points at once, and a cumulative one of 100 basis points after a year. The inflation reduction following this large exchange rate jump is quite small too (about 0.6 percent a year later), a little smaller than it would otherwise have been, given the policy rate cut that would follow. Similar conclusions follow from a more normative approach by Alpanda et al. (2010). They construct a small open economy DSGE model for SA, and estimate it using Bayesian methods. They find that the optimal Taylor rule places a heavier weight on inflation and output than the estimated Taylor rule, but almost no weight on the depreciation rate of the currency.

More generally, exchange rates, policy interest rates, market interest rates, other asset prices, aggregate output and inflation are all intricately interrelated variables. For example, a data announcement may create expectations of a policy reaction and cause the exchange rate and other asset prices to react. Unpicking the tapestry and saying how one part "affects" another over time may well involve arbitrary judgements. These worries aside, do estimates of exchange rate pass-through differ between middle income countries (like SA) and advanced economies? Do the results obtained, for instance, by Mumtaz et al. (2006) for the UK – that pass-through speeds, much as they differ across product groups, are now modest, and have fallen appreciably in recent years – extend to less advanced countries? The broad answer is that pass-through speeds do not appear to have fallen as much in the less advanced countries as in the richest. But there are exceptions. Alvarez et al. (2008) report high speeds for Chile, with little evidence of declines over time, and no significant indications of asymmetry either (depreciation triggers bigger price rises than appreciation does falls, but not significantly in the aggregate data). Ghosh and Rajan (2007) report that Asian economies' pass-through time-profiles have changed very little, too.

A similar picture is given for Indonesia by Ito and Sato (2008). But the four other economies they investigate (Korea, Malaysia, the Philippines and Thailand) show markedly lower pass-through speeds on various criteria, and also rather lower when data after the 1997 crisis are compared with those for a longer span. One point that distinguishes Indonesia is the fact that the size of the depreciations in the five years from 1997 dwarfed those of the other five: this could suggest the kind of non-linear response typical of menu costs; another, as the authors point out, that Indonesia's (nominal) monetary base reacted strongly to the (nominal) exchange rate. A further possibility is that in the face of a highly volatile and depreciating currency, there was a switch from domestic to foreign currency invoicing, which would have increased pass-through. The Indonesian experience appears to contradict Garcia-Solanes and Torrejon-Flores (2010), who argue that risky and indebted countries should display lower pass-through from exchange rates, because the balance sheet effects offset competitiveness effects on aggregate demand. Since 2005 Indonesia has become an official inflation targeter, like all the others, except Malaysia, in the Ito-Sato sample, and inflation rates have fallen; perhaps later data may in time point to smaller pass-through from the exchange rate.

Pass-through from the exchange rate thus seems to have dropped in some middle income countries, yet not in others. Theory suggests that pass-through will be weak in risky countries with large foreign exchange dominated debts, and also in (presumably low-risk, mature) inflation targeting countries with a particularly large Taylor coefficient on inflation deviations. Frankel et al. (2005) in a cross-country study of the 1990s find that only part of the downward trend in pass-through to imported goods prices can be explained by monetary regime changes. Their evidence supports a role for rising distribution and retail costs in contributing to the decline in the pass-through in less advanced countries, inter alia. With this intriguingly complex background, it is important to see what can be learned from SA's experience.

A forward looking central bank will be interested in the entire future expected path of prices, and in the main components (such as import prices) that make up the relevant consumer price indices, whether core or headline. This concern will be most apparent for inflation targeters. But it is not limited to them. One reason for taking exchange rate pass-through very seriously is that agents' expectations of future inflation may well, in time, come to reflect perceptions of the way in which the exchange rate (among other variables) influences future prices. Anchoring inflation expectations, while always important, is an essential prerequisite for successful inflation targeting.

Another critical point is the fact that monetary policy instruments appear to affect inflation with a set of distributed lags. Maximum impact is widely thought to occur at about eighteen months to two years. So exchange rate movements that happen now have a specially important bearing on current monetary policy decisions at, and up to, such a horizon. Any lingering impact beyond that point may therefore be allowed for, and corrected, by subsequent policy decisions. Both the policy maker, and the better informed private sector agents, may to some degree anticipate such subsequent decisions; and policy rate smoothing should come to bear similar implications.

3. Conceptual issues and empirical survey

3.1. Pass-through and mark-up

We illustrate the micro-founded mark-up equation that has become common currency in much empirical analysis of pass-through, at both aggregate and disaggregate price levels.

The import price index P^M of a country can be defined as the price index P^X of the exporter to that country, converted to domestic currency using the exchange rate E (expressed in foreign currency per unit of domestic currency of the destination country, so that a rise in the exchange rate is a appreciation[4]).

$$p^M = P^X/E \tag{1}$$

Expressing the prices in logs, denoted by lower case letters, gives

$$p^M = p^X - e \tag{2}$$

The exporter's prices are expressed as a markup ($mkup^X$) over exporter marginal costs ($mcost^X$).

[4] This corresponds to the definition of the South African effective exchange rate used in the empirical work in this paper.

$$P^X = MKUP^X MCOST^X \tag{3}$$

Using lowercase letters to reflect logarithms, equation (2) can rewritten as

$$p^M = mkup^X + mcost^X - e \tag{4}$$

The mark-up is a function of an industry-specific fixed factor independent of the exchange rate, γ, and of macro-variables, including the exchange rate. Campa and Goldberg (2005) formulate the mark-up in terms of the nominal exchange rate but the real exchange rate is more relevant: it is more difficult to get a large mark-up if domestic prices in the destination market are low relative to the foreign prices expressed in domestic currency. This can be addressed by including the *real* exchange rate.

$$mkup^X = \gamma + \varphi(e - w^X + w^M) \tag{5}$$

The exporter's marginal costs are postulated to rise with market wages, w^X, in the exporter country, commodity prices such as oil prices, $pcom^X$, and an index of demand conditions in the exporter country, y^X, and demand in its destination markets, y^M.[5]

$$mcost^X = \sigma_1 w^X + (1 - \sigma_1) pcom^X + \sigma_3 y^X + \sigma_4 y^M \tag{6}$$

Combining the above equations, import prices can be generally specified as:

$$p^M = \gamma - (1 - \varphi)e + \varphi w^M + (\sigma_1 - \varphi) w^X + (1 - \sigma_1) pcom^X + \sigma_3 y^X + \sigma_4 y^M \tag{7}$$

Equation (7) generalises the formulation of Campa and Goldberg by introducing the importing country's relative domestic costs into the mark-up function, and exogenous commodity prices into the exporter's marginal cost function. The pass-through coefficient is $\beta = -(1 - \varphi)$. If $\varphi = 0$, so that $\beta = -1$, then there is producer-currency pricing. If $\varphi = 1$, so that $\beta = 0$, then there is (complete) local-currency pricing and the exporters fully absorb exchange rate fluctuations in their mark-ups.

[5] Of course there may be costs that fluctuate with the exporter's own trade-weighted exchange rate.

3.2. *The empirical specification*

Equation (7) can be expressed as a long-run log linear regression specification and this is conventionally used in the empirical literature, to estimate exchange rate pass-through to import prices using several different methodologies.[6]

$$p_t = \lambda + \beta e_t + \alpha_1 w_t^X + \alpha_2 pcom_t^X + \alpha_3 w_t^M + \alpha_4 y_t^X + \alpha_5 y_t^M + \varepsilon_t \quad (8)$$

where p are local currency import prices, λ is a constant, e is the (nominal) exchange rate, w^X and w^M are control variables representing exporter costs and domestic costs, $pcom^X$captures a further element of exporter's costs stemming specifically from commodity prices, such as oil prices, and y^M and y^X control for the real GDP growth of the destination market and exporter's market. The omission of control variables that are correlated with exchange rates could result in biased estimates of the pass-through coefficient, β.

Plausible restrictions on equation (8) are as follows: long-run homogeneity (lack of money illusion) at a given exchange rate implies: $1 = \alpha_1 + \alpha_2 + \alpha_3$. Long-run homogeneity taking into account variations in the exchange rate implies: $\beta = -(\alpha_1 + \alpha_2)$. Then long-run pass-through is measured by $\beta = -(1 - \alpha_3)$. In the short run, these long-run restrictions might not hold. At one extreme, complete pricing in the long-run to the domestic market (local currency pricing) would imply $\beta = 0$; at the other, complete pass-through (that is, with producer currency pricing) would mean $\beta = -1$ and $\alpha_3 = 0$. Note that the long run is defined here conditional on domestic costs (typically domestic unit labour costs). In the very long run, these might themselves be influenced by the exchange rate and foreign prices, which would raise very long run import price pass-through.

Equation (8) is treated in various ways in the empirical literature. In one approach the equation (or a simpler version of it omitting several controls) is estimated as it stands, as a single equation, using contemporaneous data to capture the long-run equilibrium pass-through represented

[6] Generally simpler versions are used, omitting controls for domestic costs and commodity prices, and sometimes also demand controls. Sometimes a time trend is also included to capture long-run evolutions in, for example, global trade openness or productivity levels. Then, an intercept term appears in the differenced form of equation (8), see below.

by β (De Bandt et al., 2008). These variables should be thought of as forming a single co-integrated relationship, but properly the (multi-equation) Johansen method should be used to test for multiple co-integrating vectors (Johansen, 1988; Johansen and Juselius, 1990). In order to ascertain pass-though in the medium run, for example, after one year, the vector equilibrium correction model with dynamic terms should be formed, to include the co-integrating vectors. Then identification restrictions need to be imposed, to allow generation of the impulse response functions in the system to a unitary exchange rate shock. The pass-through coefficients for different lags can then be obtained from the cumulated impulse response function.[7]

In other studies, the possibility of long-run relationships is assumed away (or not found when tested for). Instead, a first differenced version of this single equation relationship is estimated for subsets of the control variables, and with up to *n* lags on the different variables to allow for a gradual adjustment to the exchange rate (for example, Campa and Goldberg, 2005)[8],

$$\Delta p_t = c + \sum_{i=0}^{n} [\beta_i \Delta e_{t-i} + \alpha_{1i} \Delta w_{t-i}^X + \alpha_{2i} \Delta pcom_{t-i}^X + \alpha_{3i} \Delta w_{t-i}^M \\ \alpha_{4i} \Delta y_{t-i}^X + \alpha_{5i} \Delta y_{t-i}^M] + \varepsilon_t \quad (9)$$

where c is a constant. In this case, the *short run* pass-through (after one period) is given by $-\beta_0$, while the *medium run* elasticity is given by $-\sum_{i=0}^{n-1} \beta_i$ for pass-through up to n periods. For instance, if n is 4 and quarterly data are used this measure would give pass-through after one year. If the changes in the log of the exchange rate are exogenous shocks, and the other variables in equation (9) are exogenous, then $\sum_{i=0}^{n-1} \beta_i$ will approximate the impulse response function cumulated up to n periods.

In the empirical application of this paper, it is shown that this approximation can be improved upon by also controlling for long-run information, including endogenous import prices, dated t-n or

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7 See also the vector auto-regressive model (VAR) analysis, identified with a Cholesky decomposition assuming a particular ordering of the price variables, and estimated in differences; the seminal article is McCarthy (2007).

8 The Campa and Goldberg specification for a quarterly model and expressed in aggregate price index terms is: $\Delta p_t = \tau + \sum_0^4 a_i \Delta e_{t-i} + \sum_0^4 b_i \Delta w_{t-i}^X + c \Delta y_t^M + \epsilon_t$, where y_t^M is the real GDP of the destination (importing) country. Note that they define $\sum_0^4 a_i$ as 'long-run' pass-through. In our terminology it would be 'pass-through after five quarters' since it reflects the cumulative effect of five quarterly shocks.

older. The reason is that if the Δe_{t-i} terms are truly independent shocks they will also be independent of p_{t-12}. Including relevant exogenous controls should improve the efficiency of the estimated β_is from the regression of (9).

Most papers assume assume linearity of price adjustment and do not test it against alternatives. Theoretical justifications for size asymmetries include the presence of menu costs in price adjustment. A firm might absorb small exchange rate changes in its mark-up, with a size threshold for an exchange rate change having to be crossed before price adjustment occurs. On the other hand, if large exchange rate changes are regarded as less permanent than small ones, pass-through may be larger for the latter. Market competition and capacity constraints might explain directional asymmetries. To increase market share, a firm might reduce its mark-up after a depreciation, and not pass on the price increase, but respond to an appreciation by allowing the import price to fall. The opposite effect occurs if there are capacity constraints in their distribution networks that limit potential sales (Pollard and Coughlin, 2003). Then the import price may not fall as far with an appreciation, but the import price could rise with depreciation. There is scarce but mounting evidence of various types of nonlinearities both on the first stage of the pass-through, that is, to import prices, and on the final stage, that is, to consumer prices. The majority of papers follow Pollard and Coughlin (2003) in testing for short- to medium-run asymmetries by distinguishing the large from the small exchange rate changes, the appreciations from the depreciations, or a combination of the above.

Finally, as noted in the empirical studies of Frankel et al. (2005) and de Bandt et al. (2008), exchange rate variability around the trend may reduce pass-through. Menu pricing theory suggests that exporters adopt a wait-and-see approach when faced with frequent transitory changes in the exchange rate (Froot and Klemperer, 1989; Taylor, 2000). If the exchange rate change seems permanent rather than the result of noisy temporary shocks, exporters will modify local prices without fear of loss of market share.

3.3 South African import price studies

For SA there are few published studies on pass-through to import prices, and all are at an aggregate level. These are summarised in an analytical typology table, Table 1. The equilibrium pass-through measures reported by the three studies may be thought of as pass-through in the very long run. These measures are distinct from pass-through in a policy-relevant horizon of six months to two years, for instance as generated by an exchange rate shock through cumulated impulse response functions. There are no published measures for SA of pass-through in the short- to medium–term.

Nell (2004) estimates an autoregressive distributed lag (ARDL) model using quarterly rates of change over 1987-1998, with two lags in import prices and one in each of the domestic producer price index and exchange rate variables. He reports a long-run (equilibrium) coefficient of 0.77 after imposing the restriction that the coefficients on the exchange rate and foreign price variables are equal in magnitude.

The other two studies reported in Table 1 use the Johansen method to find the equilibrium co-integrating vectors for subsets of at most three of the constituents of equation (8): exchange rate, import prices and foreign prices. Controls for demand, commodity prices and domestic costs are absent. Given the relevance of these controls in our own results, these co-integrating equations appear to be mis-specified through omitted variables.[9] Rangasamy and Farrell (2002) estimate a Johansen-type vector equilibrium-correction model (VECM), using monthly data, 1980-2001. The long-run pass-through coefficient of 0.78 is obtained from a single co-integrating vector and restricting the coefficients on the exchange rate and foreign price variables to be equal in magnitude. This study omits domestic costs. The co-integrating vector and the adjustment coefficients enter only the import price equation in the VECM: thus, inferences are made from a conditional model of this equation alone. The coefficient on the equilibrium-correction term (-0.059) suggests a gradual adjustment to shocks, with import prices adjusting to correct about 6 percent of any disequilibrium in the long-run relationship each month. The half-life of this process is just over 11 months.

[9] Particularly key are the foreign oil prices, and the destination market unit labour costs, see Section 5.

Karoro et al. (2009) also adopt a VECM approach to measuring long-run pass-through. They estimate (symmetric) equilibrium pass-through using the Johansen approach based on a VAR with two lags, which seems very short for monthly data. Different proxies for the exporter's production cost are used, resulting in long-run pass-through measures varying between 0.75 and 0.82. The speed of adjustment is about 6 percent per month. This study also omits domestic costs and hence long-run homogeneity is not satisfied. Most implausibly, the coefficient on foreign prices is far larger than that on the exchange rate. They also report asymmetric equilibrium pass-through measures[10], using the methodology of Wickremasinghe and Silvapulle (2004). They include in their equilibrium pass-through relationship (i) a cumulated depreciation series in addition to the exchange rate and foreign price variables, and (ii) both cumulated depreciation and appreciation series, with the exchange rate variable being excluded. They find that the equilibrium pass-through to import prices is greater for depreciations (0.72) than for appreciations (0.64), and that the null hypothesis of no asymmetry is marginally rejected at the 5 per cent level. They find no significant equilibrium asymmetry in the pass-through of large and small changes in the exchange rate.

Persistent asymmetries in equilibrium would violate long-run homogeneity (see Section 5): this suggests the results of Karoro et al. (2009) might be due to a persistent omitted variable or a structural break. Only one of the three studies attempts to check for robustness to the sometimes profound structural change in SA that can confound analysis of co-integrating vectors, such as changing trade openness. None of these studies attempts to test for changing pass-through over time, and two largely pre-date the inflation targeting period and while the third runs to 2005.

This analysis of past studies for SA motivates our approach, which models with monthly data over 1980-2009, including the inflation targeting era. We concentrate on pass-through horizons of six months up to one year. We control for domestic demand and foreign and domestic costs, test for an impact from exchange rate volatility, test for a role of openness and changing pass-through over time, and test for possible short-run non-linearities while controlling for structural change. None of the

[10] In Karoro et al. (2009) it is stated that changes of the exchange rate are cumulated (equations 7, 8, 11 and 12, pp. 388-9). This is apparently an error, and in fact they are correctly cumulating the changes in the *log* of the exchange rate (communication with authors).

above has previously been done for SA. Finally, we check these results using the Johansen procedure with five monthly lags, and also calculate equilibrium pass-through.

4. Methodology and data

4.1 Data

This study explores monthly pass-through from the exchange rate to import prices over 1980-2009. Table 2 defines the underlying data series and presents basic statistics, including stationarity statistics.

The first set of variables comprises the import prices, exchange rates, foreign cost proxies and domestic cost proxies. The dependent variable is the monthly import price index, base 2000, from Statistics South Africa, and seasonally adjusted by the South African Reserve Bank. The nominal effective exchange rate is shown in Figure 1, and is defined so that a rise denotes appreciation, see Table 2. Campa and Goldberg (2005) observe it is difficult to find a primary control variable capturing the shifting relative costs of a country's aggregated trading partners. Like them we construct trade-weighted foreign cost proxies for trading partners by computing w^X in equations (7) as $w^X = \log NEER + logP - logREER$. The corresponding real effective exchange rate (see Table 2) is sourced from the South African Reserve Bank, and uses producer prices. This measure captures changing weights over time.

In addition to using price proxies for costs, we follow Marazzi et al. (2005) and include a measure of commodity prices, in this case dollar oil prices. The prices of petrol and other processed fuels included in imports, respond with a lag to changes in crude oil prices. Also, the import price index includes crude oil, and therefore it is important to control for these changes in oil prices. No previous study for SA has included commodity prices.

We control for both domestic as well as foreign costs. Our measure of unit labour costs for the manufacturing sector is from the South African Reserve Bank, and is quarterly and seasonally adjusted. For the monthly regressions, a step function of the quarterly unit labour costs data is used, and smoothed with a 3-month moving average.

The second set of variables is the demand controls. No study of South African pass-through to aggregate import prices (or to the aggregate CPI) has employed both domestic and foreign demand measures. We opted for monthly advanced countries' industrial production indices and SA's manufacturing production index, see Table 2. Rates of growth were defined from changes in the logs of these variables after seasonally adjusting them. We also constructed gaps, using a Hodrick Prescott filter. However, the end-point problem is exacerbated by the severity of the post-2007 recession and it was decided not to use these gaps. The growth measures were smoothed with a 3-month moving average.

In testing for the impact of exchange rate volatility on observed pass-through, volatility measures were defined as the standard deviation of monthly exchange rate changes over the preceding one, two, three, four or five years (see also Devereux and Engel, 2003). This variable was interacted with the change in the log of the exchange rate, see below.

To capture the possible asymmetric effects of exchange rate changes in the short-run, three sets of dummies were defined, following Pollard and Coughlin (2003). Zero-one dummies were defined for appreciation and depreciation, large changes and small changes in the exchange rate, and a combination of the two. To determine if pass-through is asymmetric in the direction of the change in the exchange rate, two dummy variables were defined to distinguish the months in which the rand appreciated, AP_t, from those in which it depreciated, DP_t, see definitions in Table 2. Interacting these dummy variables with the exchange rate index provides separate estimates for pass-through under appreciations and depreciations (in Section 4.2).

Similarly, to determine if pass-through is asymmetric in the size of the change in the exchange rate, two dummy variables are defined to identify months in which the absolute value of the exchange rate change exceeded a threshold, for large changes, L_t, and small changes, S_t, see definitions in Table 2. We chose a threshold of 3 percent in the first instance and tested this against alternative thresholds. Interacting these dummy variables with the exchange rate index provides separate estimates for pass-through under large and small exchange rate changes (Section 4.2).

A combination of the two then leads to the definition of four dummies, LDP_t , SDP_t, LAP_t and SAP_t, for large and small depreciations, and large and small appreciations, see Table 2.

Interacting these dummy variables with the exchange rate index and including combinations of up to three of the four terms: $LDP_t \times \Delta logNEER_t, SDP_t \times \Delta logNEER_t, LAP_t \times \Delta logNEER_t, SAP_t \times \Delta logNEER_t$ to the equations in Section 4.2 provides separate estimates for pass-through under large and small exchange rate appreciations and depreciations.

Finally, we tested for the effect of structural change on the pass-through coefficient. We include proxies for structural change directly in the pass-through equation and interacted with the change in the log of the exchange rate. We use a measure of real openness defined as ratio of real exports plus real imports to real GDP, and expressed as a 12-month moving average, with underlying data sourced from the South African Reserve Bank. The use of real variables in this construction removes potential biases: see Aron and Muellbauer (2007). Pass-through is also examined for subsets of the overall sample, isolating periods of structural change, for example the opening of the capital account or the adoption of inflation targeting, using step dummies defined in Table 2.

4.2 Estimation methodology

We test various models at monthly frequencies, over different samples for robustness. We employ a methodological innovation that permits the estimation of short-run pass-through controlling for domestic demand and foreign and domestic costs, while including the long-run equilibrium terms and the lagged dependent variable in single equation models. As de Bandt et al. (2008) emphasise, the long-run equilibrium correction terms are generally excluded from single equation models in the pass-through literature (for instance, Campa and Goldberg, 2005). These differenced-only models are then potentially mis-specified, thus biasing the resulting measures of pass-through if the long-run terms had been relevant. Moreover, when equilibrium terms are included, for example when using a Johansen approach, only the *equilibrium* pass-though is calculated, and this is almost invariably without the feedback effects from an impulse response analysis. Arguably this is of less interest for monetary policy than measuring pass-through horizons of up to a year or two.

We begin with differenced models with twelve monthly lags, with lags in import price inflation restricted to be at a lag-length of twelve months or more, but in all cases incorporating the controls for foreign and domestic demand and costs, to generate pass-through over a year. In the differenced equation below, pass-through over a year is given by $-\sum_{i=0}^{11}\beta_i$,

$$\Delta p_t = c + \sum_{i=0}^{11}[\beta_i \Delta e_{t-i} + \alpha_{1i}\Delta w_{t-i}^X + \alpha_{2i}\Delta pcom_{t-i}^X + \alpha_{3i}\Delta w_{t-i}^M + \alpha_{4i}\Delta y_{t-i}^X + \alpha_{5i}\Delta y_{t-i}^M + \alpha_{6i}\Delta p_{t-i-12}] + \epsilon_t \quad (10)$$

The expected signs are negative for the exchange rate changes (a rise denotes appreciation, see Table 2), positive for the log changes in oil prices, foreign prices and unit labour costs, and positive for increased demand. Note that the lagged dependent variable term can only be included prior to the maximum (12-month) lag of the exchange rate or else 12-month pass-through cannot be calculated from $\sum_{i=0}^{11}\beta_i$.

We also repeat the Campa and Goldberg regression specification with monthly data which uses fewer controls than equation (10) above.

$$\Delta p_t = c + \sum_0^{11}\beta_i \Delta e_{t-i} + \sum_0^{11}\alpha_{1i}\Delta w_{t-i}^X + \alpha_5 \Delta_3 GDP_t + \epsilon_t \quad (11)$$

The next stage is to examine better specified models including equilibrium correction long-run terms in domestic and foreign prices that impose long-run price homogeneity. The composite equilibrium correction term is shown in equation (12) below,

$$ecm_{t-12} = [\ \alpha_1(w_{t-12}^X - e_{t-12}) + \alpha_2(pcom_{t-12}^X - e_{t-12}) + \alpha_3 w_{t-12}^M - p_{t-12}] \quad (12)$$

where foreign prices are expressed destination country's domestic currency terms. Long-run homogeneity implies $\alpha_1 + \alpha_2 + \alpha_3 = 1$,[11] see discussion below equation (8). Incorporating this error correction term in a single equation, gives the speed of adjustment, γ.

$$\Delta p_t = c + \gamma ecm_{t-12} + \sum_{i=0}^{11}[\beta_i \Delta e_{t-i} + \alpha_{1i}\Delta w_{t-i}^X + \alpha_{2i}\Delta pcom_{t-i}^X + \alpha_{3i}\Delta w_{t-i}^M + \alpha_{4i}\Delta y_{t-i}^X + \alpha_{5i}\Delta y_{t-i}^M + \alpha_{6i}\Delta p_{t-i-12}] + \epsilon_t \quad (13)$$

[11] In the single equation models, the Johansen cointegrating vector weights are imposed, see Table 2 for details.

The equilibrium correction terms in this single equation can only be included prior to the lags of the exchange rate (that is, at t-12) or else 12-month pass-through cannot be calculated from $\sum_{i=0}^{11}\beta_i$. The inclusion of any relevant information dated t-12 or earlier should improve the accuracy of the approximation by $\sum_{i=0}^{11}\beta_i$ of the cumulated impulse response function: see discussion in Section 3.[12] The usual misspecification of the single equation model, caused by omission of long-run terms, is obviated by including the lagged equilibrium correction terms at a lag of twelve months.

The results are reported in Table 3 for 12-month pass-through estimates, first without selection, and then using automatic selection with *Autometrics* (Doornik, 2009) to select parsimonious models from these general models with equilibrium correction. When automatic selection is used in Tables 4 and 5, which report pass-through estimates over 12 months and 6 months, respectively, we use "parsimonious longer lags" (PLL) for all variables except the exchange rate, in order to overcome a well-known problem with Vector Auto Regression (VAR) models. These models aim to preserve generality by not imposing an a priori structure on models, but suffer from the 'curse of dimensionality', as increases in lag lengths or in the number of variables covered rapidly raise the number of parameters to be estimated. In practice, the gain in generality from using a VAR comes at the cost of restricting the number of variables and lag lengths that can be considered. One way of achieving a better trade-off between these objectives is to impose other restrictions such as the 'parsimonious longer lags' (PLL) used in this paper. PLL here takes the following form: for variables in differences, full generality of lags is permitted at lag lengths of zero to two months; lags at three months or longer appear as the 3-month change, Δ_3; lags at six months or longer appear as the 6-month change, Δ_6; and as Δ_{12}, if 12 months or longer.[13] Compared to unrestricted lags up to 23 months, 24 parameters are thus replaced by 6 parameters. Formulating the 'general unrestricted model' in this way offers benefits, enabling longer lags to play a role and permitting smoother responses to shocks.

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[12] A conventional model is also run with the equilibrium correction terms at t-1 (without calculating pass-through) to check whether estimated long-run pass through, $\alpha_1 + \alpha_2$, is similar, see Section 5 below.

[13] For instance, instead of: $\Delta w_t^X, \Delta w_{t-1}^X, \Delta w_{t-2}^X, \Delta w_{t-3}^X, \ldots \Delta w_{t-22}^X, \Delta w_{t-23}^X$, with PLL, the lags take the form: $\Delta w_t^X, \Delta w_{t-1}^X, \Delta w_{t-2}^X, \Delta_3 w_{t-3}^X, \Delta_6 w_{t-6}^X, \Delta_{12} w_{t-12}^X$, using only 6 parameters instead of 24 parameters, but covering the same two years with monthly, quarterly, six monthly and annual changes.

Next we test for the impact of structural change through trade and capital account liberalisation in SA after 1990 and especially from 1995, again using automatic selection with *Autometrics* (Doornik, 2009) to select parsimonious models. Trade liberalisation, especially quota reductions, might be expected to reduce the monopoly power of importers, making prices more sensitive to costs and so increasing pass-through. Capital account liberalisation in SA took the form of the lifting of controls on foreign investors with the effect of greatly deepening the foreign exchange market from the previously thin and illiquid financial rand market. In principle, the volatility and persistence of exchange rate shocks could be affected both in the transitional period and after the completion of liberalisation, with the likely longer-term effect of a reduction in uncertainty and more persistent exchange rate changes, and hence greater pass-through. First we test if trade openness alters pass-through, as in equation (14).

$$\Delta p_t = c + \gamma_1 \Delta_3 e_t \times openness_t + \gamma_2 \Delta_3 e_{t-3} \times openness_{t-3} + \gamma_3 \Delta_6 e_{t-6} \times openness_{t-6}$$
$$+ openness_t + \gamma ecm_{t-12}$$
$$+ \sum_{i=0}^{11} [\beta_i \Delta e_{t-i} + \alpha_{1i} \Delta w^X_{t-i} + \alpha_{2i} \Delta pcom^X_{t-i} + \alpha_{3i} \Delta w^M_{t-i} + \alpha_{4i} \Delta y^X_{t-i}$$
$$+ \alpha_{5i} \Delta y^M_{t-i} + \alpha_{6i} \Delta p_{t-i-12}] + \epsilon_t \quad (14)$$

where the composite equilibrium correction term is as in equation (12) with speed of adjustment, γ. The trade openness variable is expressed in real terms (see above). It is an I(1) variable, and is smoothed entering as a 12-month moving average lagged one month, interacted with the change in the log of the exchange rate[14], see Table 2. To preserve degrees of freedom, the interaction effects are defined with the 3-month and 6-month change in the log exchange rate, as shown in the first three terms after the constant of equation (14). The capital account openness change is captured by a step dummy that equals one after the liberalisation of the capital account in March, 1995 (see Table 2), and zero before, interacted with the change in the log of the exchange rate: see Table 2. The theoretically expected sign of the interacted variables is negative, if pass-through increases with greater trade and

[14] The interaction terms cover an annual change to match the short run exchange rate terms in duration: $\Delta_3 e_t + \Delta_3 e_{t-3} + \Delta_6 e_{t-6}$. Various other parameterisations are possible.

capital account openness. The trade openness measure and the capital account dummy both enter the general unrestricted model (GUM) separately as well as in interaction.

As well as testing for a different relationship between the exchange rate and import prices with trade and capital account liberalisation, we further check whether pass-through has altered with SA's monetary policy regime change. We cross the change in the log exchange rate, again using 3-month and 6-month changes with a step dummy specifically capturing the inflation targeting period[15], and the dummy itself is included in the general equation. The expected sign of the interacted variable is positive if the pass-through is decreased during an inflation targeting period of more stable prices.

Next we test for the impact on pass-through of exchange rate volatility using automatic selection with *Autometrics* (Doornik, 2009). Volatility is measured over different intervals, see Table 2, each interacted with the change in the log of the exchange rate, using 3-month and 6-month changes. The expected sign of the interacted variable is positive, if pass-through decreases with increased volatility. The volatility measure does not enter separately as it is not expected to have an independent effect on import prices.

$$\Delta p_t = c + \gamma_1 \Delta_3 e_t volatility_t + \gamma_2 \Delta_3 e_{t-3} \times volatility_{t-3} + \gamma_3 \Delta_6 e_{t-6} \times volatility_{t-6}$$
$$+\gamma ecm_{t-12} + \sum_{i=0}^{11} [\beta_i \Delta e_{t-i} + \alpha_{1i} \Delta w_{t-i}^X + \alpha_{2i} \Delta pcom_{t-i}^X + \alpha_{3i} \Delta w_{t-i}^M + \alpha_{4i} \Delta y_{t-i}^X$$
$$+\alpha_{5i} \Delta y_{t-i}^M + \alpha_{6i} \Delta p_{t-i-12}] + \epsilon_t \qquad (15)$$

where the composite equilibrium correction term is as in equation (12) with speed of adjustment, γ.

We test for the impact on pass-through of non-linearity, including measures of asymmetry (both of the direction and of the size of exchange rate changes), and using automatic selection with *Autometrics* (Doornik, 2009) to select parsimonious models from general unrestricted models in equilibrium correction form. To test the effects of asymmetries in direction and size of pass-through, we interact the asymmetry and size dummies with changes in the exchange rate. In the example below, a dummy for appreciation is interacted with Δe_t and several lags checked. Experimenting with

[15] This makes an economic interpretation more plausible, compared with using only a linearly increasing trend, which could have many economic interpretations, if significant.

the same lag structure as in equation (15) found that only shorter lags (up to t-3) were relevant for asymmetry, so it was decided to focus on pass-through over six months. The expected sign for size or directional asymmetries depends on the underlying reasons for asymmetry, if indeed asymmetry is found.

$$\Delta p_t = c + \sum_{i=0}^{3}[\gamma_i \Delta e_{t-i}\ DASYM_{t-i}] + \gamma ecm_{t-6} + \sum_{i=0}^{5}[\beta_i \Delta e_{t-i} + \alpha_{1i}\Delta w_{t-i}^{X} + \alpha_{2i}\Delta pcom_{t-i}^{X} + \alpha_{3i}\Delta w_{t-i}^{M} + \alpha_{4i}\Delta y_{t-i}^{X} + \alpha_{5i}\Delta y_{t-i}^{M} + \alpha_{6i}\Delta p_{t-i-6}] + \epsilon_t \quad (16)$$

where the composite equilibrium correction term is as in equation (12) with speed of adjustment, γ.

Finally, the Johansen multi-equation co-integration approach is included for completeness. The structure of the model is informed by the single equation model estimates. The equilibrium pass-through rate is estimated, and short-run pass-through rates are calculated from the impulse response functions that are generated from a structural VAR, identified by a number of theoretically-motivated restrictions.[16] The results can be compared with the single equation method which assumes exogeneity of right hand side variables in the model, including the exchange rate, whereas the Johansen method allows restricted interaction in all economically plausible directions amongst the three endogenous variables: import prices, the exchange rate and domestic prices.

5. Results

In this study, we address several questions. First, we ask what is the magnitude and speed of exchange rate pass-through to import prices, using different models including various specifications of single equations and the Johansen technique. Our models are richer than earlier studies, and do not omit the theoretically-motivated variables in exporter and destination market demand and cost controls. Second, we test whether the exchange rate pass-through elasticities have changed over time in SA with structural change or regime change, as found in industrial countries. Third, we examine whether

[16] These include strict exogeneity of foreign producer and commodity prices, long-run homogeneity and currency translation, and are sufficient to identify the impulse response function.

exchange rate volatility has an impact on exchange rate pass-through to import prices. Fourth, we look for evidence for non-linear import price responses to the exchange rate.

5.1. Single equation approaches

The choice of 1980 as a starting date for our empirical work post-dates the switch in SA from a fixed exchange rate regime to a floating, managed exchange rate, after the second quarter of 1979, and avoids problems associated with the fixed-to-floating regime shift (see Appendix 1 and its table).

The first question is addressed in Table 3, where the pass-through after twelve months (that is, summing coefficients on twelve terms in the change in the log exchange rate) is reported for the full sample from 1980-2009, and for two sub-samples, from 1980 up to 1995 and from 1995 to 2009. The breakpoint is dated from March, 1995, when the capital account was liberalised (Section 4.2). We first estimate the fully general equations without reduction to parsimonious equations. The results are in columns 1-4, using models based on equations (10), (11) and (12). Columns 1 and 2 report equation (10) without and with the lagged dependent variable (at a lag of twelve months), respectively. Column 3 reports the Campa-Goldberg specification translated into monthly data in equation (11). Column 4 reports the equilibrium correction model of equation (13). In columns 5 and 6, parsimonious models are automatically selected from the general equilibrium correction model in equation (13), both with and without correcting for outlier observations.

The magnitude of exchange rate pass-through to import prices after one year ranges from 44 to 50 percent for the full sample, depending on the model. The different sub-samples demonstrate that the most stable coefficients are found for the equilibrium correction models. The equilibrium correction models for all samples pass Chow tests for parameter stability, but the three models in columns 1-3 fail the Chow tests, pointing to structural breaks and model misspecification. Indeed the models in columns 1-3 reveal lower 12-month pass-through for the post-1995 sample, while models including the equilibrium correction terms suggest greater stability of 12-month pass-through for pre- and post-1995 samples. The fit is also better for the selected equilibrium correction models. The equilibrium correction term builds in a ratio for foreign costs to that of domestic costs of 75 to 25, implying that *equilibrium* pass-through is about 75 percent, given domestic costs (see Figure 1). This is in line with earlier results (see Table 1) suggesting incomplete pass-through in the long-run.

The dynamic terms are dominated by the foreign prices and oil prices, while unit labour costs mainly operate in the long-run. The domestic demand control variable tends to have the correct positive sign at a short lag in the general models but is not significant in the selected models.[17] Foreign demand controls are always insignificant but usually with a negative coefficient.[18]

While pass-through appears reasonably stable after a year in the two sub-samples, especially in the better-specified models, there is a sharp differential between the pre- and post-1995 periods, even in the equilibrium correction models, when estimating pass-through after six months (not reported).[19] It appears that most of the action is in the first six months after an exchange rate shock, an effect which appears more pronounced after 1995 in the more open economy. This motivated the testing for various structural breaks reflecting changing trade and capital account liberalisation, using both 6-month and 12-month pass-through equilibrium correction models, and model selection.

These results for 12-month pass-through are reported in Table 4, which addresses our second question of whether structural change in SA is relevant for pass-through to import prices. First the equilibrium correction model was run in *Autometrics*[20] for the full sample, with the outlier selection on. Of the outliers, the majority were associated with the exchange rate (for example, crises in 1997 and 1998 and 2001/2); these were not included in our later models given the presence of the exchange rate in the equation. Four large outliers were chosen for inclusion in our models.[21] Pass-through after a year is reported for the full sample from 1980-2009 in all columns, using the equilibrium correction

[17] The best fitting measure is the current quarterly rate of acceleration of the log index of manufacturing output. The quarterly rate is measured as the 3-month moving average of the log index. The rate of acceleration is measured as the double 3-month difference. This incorporates the current month production index. One could object to this on the grounds of endogeneity bias. Lagging the measure by one month reduces the significance quite sharply, though it remains significant.

[18] Campa and Goldberg (2005) find a positive foreign demand growth effect, capturing a cyclically varying mark-up over unit labour costs. This is probably due to their use of foreign unit labour costs to measure foreign prices. Producer prices, as used in our paper, are likely already to incorporate this mark-up.

[19] The pass-through coefficients after six months are around 13 percent and 47 percent in the two sub-samples, respectively, and 34 percent for the full sub-sample, see Table 6 for further results on six-month pass-through.

[20] The chosen *Autometrics* parameters are for a target model size of 0.01, with robust t ratios (HACSE ratios) and switching off the normality and heteroscedasticity tests as a criterion for selection. Skewed exchange rate and price data typically fail normality tests while outliers cause heteroscedasticity.

[21] The outliers associated with the October 2008 financial crisis and the 1985 debt crisis were included, along with outliers in late 1990 expressed as an impulse in October and a change from December to November 1990. The last is linked with the Gulf War, but entering as a change, has no effect on the pass-through coefficient.

model of equation (13), plus chosen outliers, and supplemented by interaction terms with the exchange rate, as in equations (14), (15) and (16). The interaction terms are defined in Table 2.

In column 1, pass-through after twelve months for the parsimonious equilibrium correction model is shown, where the general equation included terms interacting the capital account step dummy with the change in the log of the exchange rate (equation (14)). The pass-though is measured at 49 percent before 1995, with greater pass-through during the first three months in the more open regime after 1995, and lower pass-through after six months, compared to the previous regime. The net effect is to reduce pass-through after twelve months from 49 to 46 percent. In column 2, we test whether trade openness has a similar effect: though liberalisation started earlier in the 1990s, it accelerated after 1995, and the path of our trade openness variable is broadly similar to that of the capital account step dummy. We indeed find a similar effect, in a slightly less well-fitting model, where pass-though is measured at 43 percent at the average value of trade openness for 1980 to 2009, with greater pass-through during the first three months with greater trade liberalisation, and lower pass-through afterwards. At the average value of trade openness since 2005, the net effect after a year is under half a percent lower than the average for 1980 to 2009. In column 3 of Table 4, the same general equation as in column 1 is used to test whether shifts in the monetary policy regime made any difference to pass-through. Column 3 dates the shift to March 2000 when inflation targeting was introduced formally. It suggests a fairly stable overall picture, with 12-month pass-through of 45 percent before March 2000 and 46 percent afterwards, and the same pattern of faster pass-through in the first half year and slower in the second half. In all equations, the equilibrium correction term in foreign and domestic prices is significant. The demand control variable at a very short lag has the correct sign in general models but is not selected.

The third question examined is whether exchange rate volatility affects exchange rate pass-through to import prices (equation (15)). The various volatility measures (Table 2) give positive effects showing that pass-though declines with greater volatility. The measure with the strongest positive and significant interaction effect is volatility in the past year interacted with the current 3-month change in the log exchange rate. Exchange rate volatility peaked in the mid-1980s, around the debt crisis (Figure 1). For post-1987 samples, the coefficient on volatility is lower and less significant, though the hypothesis of a stable coefficient is just acceptable. Adding this measure of volatility to each of the different specifications including interaction effects, see column 4, the general pattern still reveals higher pass-through in the first six months, followed by lower pass-through in the second six months, as shown in columns 1 to 3. At the average value of volatility, 12-month pass-through before 2000 is estimated at 51 percent. Taking into account the shift in pass-through from 2000, pass-through falls to 47 percent at the average value of volatility from 2005.

As noted above, a possible explanation for higher pass-through in the first six months after the currency crisis in 2001 is that some imports previously invoiced in domestic currency switched to foreign currency invoicing, in the wake of a volatile and depreciating exchange rate. Alternatively, exporters to SA pricing to the domestic market may have raised their margins as a buffer or hedge against potential losses on the exchange rate. Even if inflation targeting reduced pass-through, its effect might have been overwhelmed by the invoicing or margin switch. If so, pass-through should have fallen again as confidence in currency stability gradually returned. To capture such transition, we interact a smoothed 2003 step dummy with the 6-month rate of change of the exchange rate.[22] This is strongly significant and positive and shows no reversal after six months, see column 5 of Table 4. The net effect on 12-month pass-through is quite striking, showing a reduction to the 26 percent level from 2005. Though we cannot be certain, the circumstantial evidence is consistent with the shift in monetary policy leading to lower rates of import price pass-through. This is consistent with arguments by Mishkin (2009) and others.

The fourth question addressed is whether there is evidence for non-linear price responses to the exchange rate. These results are shown in Table 4, column 6 and in Table 5, where we report 6-month pass-through, as most of the action falls in the first six months. In Table 5 evidence, column 1 shows a baseline specification including the interaction of the inflation targeting step dummy with the 6-month rate of change of the exchange rate. Net pass-through after six months is estimated at 44 percent after 2000, compared with 25 percent before. Column 2 adds the interaction of the one year measure of exchange rate volatility with the current 3-month exchange rate change, while column 3

[22] Smoothing takes the form of a double 12-month moving average of a step dummy which is zero before 2003 and 1 from January 2003. The smoothed dummy makes the transition from 0 at the end of 2002 to 1 from January 2005.

adds the interaction of the 6-month rate of change of the exchange rate with the smoothed step dummy beginning in 2003. This confirms the results reported in Table 4, column 5, suggesting that the incidence of foreign currency invoicing or hedging margins may have fallen again after 2003 so that pass-through after six months was lower from 2005 compared to between 2000 and 2003, though still higher than before 2000. Net pass-through after six months is now estimated to be 34 percent, from 2005. Experimentation with non-linear and asymmetry effects suggested that the 4-month moving average of such effects gave the best simple summary. Including the 4-month moving average of *small changes*, $SM_t \times \Delta logNEER_t$, where SM is a dummy equal to one if that months exchange rate change was less than 3 percent, and otherwise zero, shows a significant result (t = -2.2) in the absence of volatility: not reported in Table 5. Column 5 reports results including instead the four month moving average of *small appreciations*, $SMAP_t \times \Delta logNEER_t$, where $SMAP$ is a dummy equal to 1 when the exchange appreciates by less than 3 percent, and is zero for depreciations and larger appreciations. This measure proves even more significant. Net 6-month pass-through from 2005 is estimated at 34 percent, but is higher for small appreciations. Since the volatility interaction effect is then insignificant, it is excluded in column 5. Of the four interaction possibilities, small appreciation, large appreciation, small depreciation and large depreciation, it is clear that small appreciation is the only significant one. Thus pass-through after six months increases with small appreciations.

An interpretation is suggested by Pollard and Coughlin (2003): it is consistent with strategic pricing to market behaviour, as firms attempting to increase their market share may increase pass-through when the destination market's currency is appreciating. However, as with the interaction of exchange rate volatility with the last three months' change in the exchange rate, it is clear that the significance of the effect owes much to the inclusion of the mid-1980s data. The coefficient is smaller and less significant on post-1987 data. Estimates for 12-month pass-through confirm that the asymmetry effect is more significant than the interaction of volatility with the current 3-month exchange rate change, see Table 4, column 6. Otherwise, however, the findings of a substantial fall in 12-month pass-through from 2005 are confirmed.

5.2. *The Johansen model*

Further evidence in favour of this model for import price inflation comes from a co-integration analysis (Johansen (1988); Johansen and Juselius (1990)), based on a version of the model shown in column 2 of Table 4, but for an equilibrium correction term dated at t-1 rather than t-12.

The initial VAR consists of three equations in the endogenous variables: log import prices, log unit labour costs, and the log nominal exchange rate. The results of non-stationarity testing were given in Table 2. We take a lag length of five, supported by the above single equation equilibrium model. Log foreign prices and log oil prices are treated as strictly exogenous and as part of the co-integration space. A linear trend and the capital account liberalisation step dummy (see Table 2) are included in the co-integration space. With a 3-equation system, the likelihood function is sensitive to large outliers in any of the equations, causing convergence problems. We therefore included impulse dummies for the largest outliers (that is, over three times the equation standard errors) in the unit labour cost and exchange rate equations.

The system also includes the same three dummies suggested by the single equation analysis, and interaction terms between the capital account liberalisation dummy and the exchange rate, and volatility and the exchange rate (see Table 2 for definitions). These variables capture temporal shifts in pass-through and are not part of a standard VAR analysis, but they are all stationary (I(0)) and should not affect co-integration.[23] We impose two fundamental restrictions on the long-run solution for the four I(1) variables. The first is the currency conversion restriction which implies that foreign prices enter the system converted into rand at the exchange rate. This implies that we can think of the long-run solution in terms of four rand variables: import prices, unit labour costs, rand foreign producer prices and foreign oil prices. The second is the homogeneity restriction which implies that doubling unit labour costs and rand foreign and oil prices must double import prices in the long-run.

[23] Kurita and Nielsen (2009) discuss the inclusion of such shifts in dynamics in co-integration analysis. They show that conventional asymptotic tables apply for statistical inference if the shifts in dynamics are for the second difference of, in this application, the log exchange rate. In our case, shifts in dynamics apply to the first difference of the log exchange rate. Then, parameter estimates should remain consistent, but the asymptotic distributions need some adjustment. We are grateful to Bent Nielsen for advising us on this point.

The key results (details in the appendix) are first, that the data accept there are two co-integrating vectors in the system. Second, the first of these can be interpreted as an import price equation and the second as a unit labour cost equation. The coefficients in the import price equation support those found for the long-run solution in the single equation analyses. The co-integrating vector has a weight of 25 percent on unit labour costs, 68 percent on foreign producer prices in rand and 7 percent on dollar oil prices converted into SA rand. In the unit labour costs equation, unit labour costs are driven by import prices in the very long run. Third, the exchange rate reacts only to the first co-integrating vector, and this restriction is accepted and imposed. Thus, recent exchange rate depreciations and rises in foreign prices are partly offset, for instance, due to monetary policy responses or to a partial correction to a previous overshooting. Indeed a 100 percent shock to the exchange rate results in a permanent shift of only 55 percent to the exchange rate. This feedback is not present is the single equation analysis because the exchange rate is there assumed exogenous. Fourth, impulse response functions which generate measures of pass-through for six and twelve month horizons, largely support single equation results but implying lower levels of pass-through for exogenous exchange rate shocks (due to the above feedback effect).

The comparison of the impulse response function implied by this system with the pass-through estimates from the single equation analysis is intriguing. At a one month horizon the co-integrated structural VAR model (SVAR) has a zero response in contrast to around 4.5 percent for the single equation, since the VAR includes only lagged variables but the single equation has current exchange rates and foreign prices. At six months, the SVAR estimates pass-through at around 21 percent in contrast to around 31 percent for the single equation estimates for a comparable specification. However, removing the contemporaneous exchange rate from the single equation estimates reduces the gap between the two estimates. At a 12-month horizon, the SVAR estimates pass-through at around 30 percent, contrasting with around 49 percent for a comparable single equation specification (including a contemporaneous exchange rate effect assumed exogenous). After two years, the SVAR implies pass-through of 35 percent and after 10 years, pass-through of 54 percent, approaching a long-run effect of 55 percent (constrained by the fact that only 55 percent of the initial exchange rate shock is permanent because of feedbacks).

The differences between the system and single equation results thus arise because the system incorporates feedback effects while the single equation does not, as exchange rates are assumed exogenous. Moreover, unit labour costs are assumed exogenous in the single equation analysis, but in the system there are additional feedbacks from the exchange rate to unit labour costs, and hence to import prices, in the second co-integrating vector. In the simple system analysed, there is not much option about what can influence domestic unit labour costs in the long-run. In a larger model, conceivably housing costs which are unaffected by the exchange rate, may be important in determining unit labour costs. Then, even if the 100 percent exchange shock were permanent, pass-through could be incomplete. Frankel et al. (2005) also find evidence for the increasing importance of local distribution costs: if these are non-traded, the same point applies. The differences between single equation and system estimates suggests that caution needs to be exercised in interpreting single equation pass-through estimates as responses to exogenous shocks.

6. Conclusions

This paper has tested the range of models found in the literature. Using dynamic single equation equilibrium correction models we introduce a methodological innovation to allow the inclusion of long-run terms as well as dynamic terms, and to calculate pass-through at equilibrium and in the policy-relevant horizons of six or twelve months. This method allows various short-run pass-through estimates to be calculated simply without recourse to a full structural VAR model (SVAR), yet without neglecting the long-run relationships between prices or the effects of previous import price changes. Our models control for domestic and foreign costs, and domestic demand. In single equation models we find that the theoretically-expected long-run homogeneity between import prices and foreign prices (oil prices and producer prices, expressed in domestic currency terms), and between import prices and domestic unit labour costs, is supported by the data. We thus do not expect to find long-run asymmetries as these would violate long-run homogeneity. However, we have tested for asymmetry and volatility effects in the short-run, and for changing pass-through with greater trade and capital openness and monetary policy regime changes.

Finally, we have used the Johansen method to form a SVAR, embodying various long-run homogeneity restrictions. This allows short-run pass-through estimates to be generated through impulse response functions, and compared with those from the dynamic equilibrium models above. There is reasonably close correspondence between the full SVAR estimates from a Johansen analysis and those of our single equation approach, but the SVAR implies lower levels of pass-through for exogenous exchange rate shocks, as it takes account of negative feedbacks affecting the exchange rate, for instance due to the reaction of monetary policy. Our estimates suggest that because of negative feedbacks, only around 55 percent of an initial exchange rate shock is permanent, and this necessarily reduces estimates of long-run pass-through compared to estimates from single equation models assuming exogenous exchange rate changes.

There is evidence that exchange rate volatility reduces pass-through. This effect operates only over the very short-run: volatility measured over the previous year tends to reduce exchange rate pass-through only for the most recent three months. This is in accordance with a wait-and-see approach to temporary exchange rate fluctuations noted in the literature. It was also investigated whether there were asymmetric responses to large and small exchange rate changes, and to the direction of change of exchange rates. We find that pass-through is higher for small appreciations. One interpretation of this effect suggested by Pollard and Coughlin (2003) is that firms attempting to increase their market share may increase pass-through by passing on price reductions more quickly when the destination market's currency is appreciating. The absence of this increase in pass-through for large appreciations may be reflective of a wait-and-see reaction to large changes.

There is also considerable evidence from single equation import price equations of more systematic shifts in exchange rate pass-through into import prices in SA, than implied by these volatility and asymmetry findings. Our conclusions are that long-run pass-through from the dynamic equilibrium correction models is incomplete and is measured at about 75 percent in a model controlling for domestic unit labour costs and treating exchange rate changes as exogenous.[24] Under

[24] To be clear, in our single equation models we impose the long-run solution found in the Johansen analysis for the import price cointegrating vector. But when freely estimating the error correction terms dated at t-1 in a single equation model, the weights given to the domestic and foreign prices from the Johansen analysis are supported. Dating the error correction terms at t-12, they are, as might be expected, not quite as well determined.

these assumptions, the one year exchange rate pass-through for the full sample is in the range 43 to 52 percent, see Table 4, but there is evidence that it has fallen to around 26 percent from 2005. The 6-month exchange rate pass-through was between 19 and 29 percent before 2000, rose to around 53 percent, and then declined again to around 34 percent from 2005: see Table 5.

How should these shifts be interpreted? The pass-through of exchange rate changes over the previous six months apparently increased after the opening of the capital account in 1995. A similar rise is measured using trade openness, driven mainly in SA by the removal of quotas and quantity restrictions. The rise is even more pronounced when the shift is dated after 2000, a year that marked the start of new monetary policy regime in the aftermath of the 1997-1998 exchange rate crisis. Controlling for this shift, the shifts associated with capital account and trade opening become insignificant. One might have expected a fall in pass-through in the inflation targeting era after 2000, if SA had followed the pattern of other countries discussed above. However, it appears the monetary policy regime change is confounded by its proximity to two of SA's largest currency crises, that in 1997-8 and a second exchange rate crisis in 2001. After both crises, measured pass-through remained high for several years. Our interpretation is that the sharp depreciations and volatility from these crises created uncertainty and an increase in hedging or foreign currency invoicing by exporters to South Africa, so that the level of pass-through to prices increased temporarily. With an appropriate dummy, we measure a transition to lower levels of pass-through beginning in about 2003. By 2005, this left pass-through from exchange rate fluctuations in the previous 6 months still higher than before 2000, but lower than in 2000-2003. Measuring pass-through over the 12-month horizon, however, gave clear evidence that pass-through after 2005 was lower than before 2000. The above offers a different interpretation from the commonly-held view in SA that depreciations above a certain threshold increase pass-through, and that this is why pass-through was high during 2001-2003. We find no evidence for such a threshold effect on South African data from 1980 to 2009.

It is plausible that the shift in SA's monetary policy regime to inflation targeting, as in other countries, reduced pass-through to import prices. Our results and interpretation suggest that the

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The Johansen-derived equilibrium pass-through measure of 75 percent assumes no feedbacks from the exchange rate or unit labour costs. This is what is usually reported in the literature, but differs from the longer-term measure found using an impulse response function and allowing for offsetting feedbacks, as we have discussed.

literature may have given insufficient attention to the currency invoicing mechanism in the link between the monetary policy regime and pass-through, see Gopinath et al. (2010a). If inflation targeting reduces exchange rate volatility in small and medium-sized economies, it could make it less unattractive to invoice in local currency, and so reduce exchange rate pass-through to import prices. However, as SA's experience in 2001 indicates, it is possible to have high exchange rate volatility even with inflation targeting. A switch to foreign currency invoicing may explain the Indonesian experience discussed earlier, where after five years of volatile and depreciating exchange rates, pass-through was higher.

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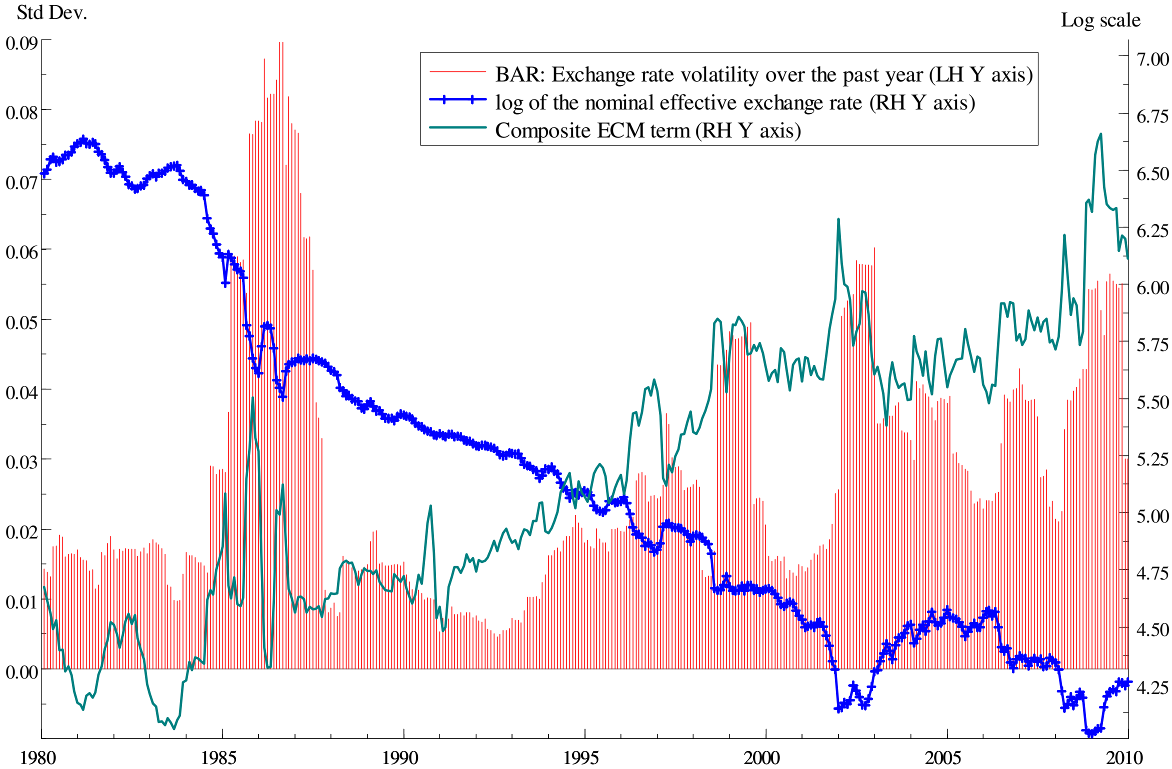
Figure 1:
Exchange rate volatility, the exchange rate and relative price terms



Sources: The volatility measure and exchange rate are defined in Table 2. The SA effective exchange rate is defined so that a rise denotes appreciation, see Table 2.
Note: The ECM composite term is defined as follows, see Table 2:
$ecm_t = [0.246ulc_t + 0.688fpricer_t + 0.066pcomr_t - p_t]$, with foreign and commodity prices in domestic currency terms.

TABLE 1:
Typology of South African studies of pass-through to import prices

Study	*Period*	*Methodology*	*Import price measure*	*Exchange rate measure*	*Domestic and foreign demand controls*	*Domestic and foreign cost controls*	*Is long-run price homogeneity satisfied?*	*Are coefficients on foreign price and exchange rate equal?*	*Long-run† import price pass-through coefficient*
Nell (2004)	1987q1-1998q4 quarterly	ARDL: log differences: 3 variable single equation	Import price deflator	Own nominal index, import trade weighted	No foreign or domestic demand controls	No domestic cost controls; includes trade-weighted foreign PPI.	No	Yes	0.77
Rangasamy and Farrell (2002)	1980-2001 monthly	Johansen method: 3 variable single equation (dynamic in VECM, 2 lags).	Import component of PPI	NEER (SARB)	No foreign or domestic demand controls	No domestic cost controls; includes foreign price index with fixed weights for the whole sample	No	Yes	0.78 (half-life of 11 months from VECM)
Karoro et al. (2009)	1980-2005 monthly	Johansen method: 3 variable single equation (dynamic in VECM, 2 lags – symmetric case).	Import component of PPI	NEER (IMF)	No foreign or domestic demand controls	No domestic cost controls; includes foreign price indices with fixed weights for the whole sample.	No	No, the coefficient on foreign prices is far larger than on the exchange rate.	*Symmetric:* 0.81, 0.82, 0.75 (3 measures of export prices) *Asymmetric:* 0.72 for depreciation; 0.64 for appreciation

Notes

1. NEER is nominal effective exchange rate index. VECM is a Vector Error Correction Model.
2. † long-run refers to the equilibrium measure, from the Johansen co-integrating vector as defined in the table. This is different to the policy-relevant horizon of up to two years (for example, as used by Campa and Goldberg, 2005). It also does not derive from an impulse response analysis and so excludes possible feedback effects.

TABLE 2:
Data Statistics and Variable Definitions

Empirical variable	*Theoretical nomenclature*	*Definition of variable*	*Mean*	*Std Dev.*	*I(1)†*	*I(2)‡*
$\log PIMPORT_t$	p	The log of the SA import price index, seasonally adjusted with base 2000 = 100. [Source: monthly, SARB].	4.11	0.701	-3.03*	-7.43**
$\log NEER_t$	e	The log of the trade-weighted SA nominal effective exchange rate index, with base 2000 = 100. A rise is appreciation. The recent series from 1990 is spliced to an earlier series for the 1980s in 1990. [Source: monthly, SARB].	5.17	0.755	-1.04	-14.7**
$\log ULC_t$	w^M	Log of unit labour costs in the SA manufacturing sector. [Source: quarterly, SARB]. Interpolated and smoothed in a 3-month moving average for monthly regressions.	4.04	0.790	-3.39*	-9.11**
$\log POIL_t$	$pcom^X$	Log of Brent oil price in dollars. [Source: monthly, IFS].	3.29	0.530	-1.93	-14.8**
$\log FPRICE_t$	w^X	Trade-weighted log foreign price index (uses wholesale price indices) calculated from monthly NEER and REER pairs. [Source: monthly NEER and REER, SARB].	4.53	0.134	-3.28	-18.4**
$\log SAPROD_t$	y^M	Log of SA manufacturing production index [Source: monthly, IFS]. The gap was also created from $\log SAPROD_t$ using the HP filter to measure excess demand. This was deseasonalised. The quarterly growth rate of this measure is $\Delta_3 \log SAPROD_t = \log SAPROD_t - \log SAPROD_{t-3}$, and was deseasonalised and smoothed in a 3-month moving average for monthly regressions.	4.39	0.183	-4.74**	-18.8**
$\log ADVPROD_t$	y^X	Log of advanced countries industrial production index [Source: monthly, IFS]. The quarterly growth rate of this measure is $\Delta_3 \log ADVPROD_t = \log ADVPROD_t - \log ADVPROD_{t-3}$, and was deseasonalised and smoothed in a 3-month moving average for monthly regressions.	4.43	0.131	-2.72	-11.3**
ecm_t	ecm_t	The composite error correction term is $ecm_t = [0.246ulc_t + 0.688fpricer_t + 0.066pcomr_t - p_t]$ where $pcomr_t = \log POIL_t - \log IFSRH_t$, using the bilateral $/rand exchange rate from the IMF, and $fpricer_t = \log FPRICE_t - \log NEER_t$ The weights derive from the Johansen analysis in this paper. Together with a linear trend and the capital account opening step dummy, these form a long-run co-integrating vector for the log of import prices	-3.25	0.165	-6.02**	-16.06**
DITARG2000	-	*Dummy for formal inflation targeting period: DITARG2000*equal to 1 from March, 2000 and 0 otherwise. Interaction effect: $\Delta_3 e_t \times DITARG2000_t$	-	-	-	-
DCURRINV	-	*Dummy to capture changes in currency invoicing after 2001:* defined as the 12-month moving average of the 12 month moving average of a dummy that is 1 from the beginning of 2003 and 0 otherwise. This smooths a transition from 0 in 2003to 1 in	-	-	-	-

Empirical variable	*Theoretical nomenclature*	*Definition of variable*	*Mean*	*Std Dev.*	*I(1)†*	*I(2)‡*
		2005. Interaction effect: $\Delta_6 e_t \times DCURRINV_t$				
$volatility$	-	The standard deviation of monthly exchange rate changes over the preceding year, and de-meaned prior to interaction with the exchange rate. Interaction effect: $\Delta_3 e_t \times$ $volatilityt{-}1$. Several measures were tried: over the preceding 2, 3, 4 and 5 years.	-	-	-	-
DCAPACC1995	-	*Dummy for the capital account*: *DCAPACC1995* = 1 from April 1995 and 0 otherwise. Interaction effect: $\Delta_3 e_t \times DCAPACC1995_t$	-	-	-	-
DTROPEN	-	*Real trade openness:* ratio of real exports plus real imports to real GDP, 12-month moving average, and de-meaned prior to interaction with the exchange rate. Interaction effect: $\Delta_3 e_t \times DTROPEN_{t-1}$	33.2	8.84	-2.52	-4.38**
D1985-11	-	Outlier (debt crisis) selected by *Autometrics*: impulse dummy equal to 1 in Nov.1985.	-	-	-	-
D1990-10		Outlier (Gulf War) selected by *Autometrics*: impulse dummy equal to 1 in Oct.1990.	-	-	-	-
ΔD1990-12	-	Outlier (Gulf War) selected by *Autometrics*: dummy change equal to 1 in Dec. 1990.	-	-	-	-
D2008-10	-	Outlier (financial crisis) selected by *Autometrics*: impulse dummy equal to 1 in October 2008.	-	-	-	-
AP_t DP_t	- -	*Directional asymmetry:* Appreciation dummy: $AP_t = 1$ when $\Delta lnNEER_t > 0$, and 0 otherwise. Depreciation dummy: $DP_t = 1$ when $\Delta lnNEER_t < 0$, and 0 otherwise.	0.41 0.59	-	-	-
SM_t LG_t	- -	*Size asymmetry:* Small: $SM_t = 1$ when $\lvert \Delta lnNEER_t \rvert < 0.03$, and 0 otherwise. Large: $LG_t = 1$ when $\lvert \Delta lnNEER_t \rvert \geq 0.03$, and 0 otherwise.	0.78 0.22	-	-	-
$LGAP_t$ $SMAP_t$ $LGDP_t$ $SMDP_t$	- - - -	*Directional and size asymmetry:* $LGDP_t = 1$ when $LG_t = 1$ and $DP_t = 1$, and 0 otherwise. $SMDP_t = 1$ when $SM = 1$ and $DP_t = 1$, and 0 otherwise. $LGAP_t = 1$ when $LG_t = 1$ and $AP_t = 1$, and 0 otherwise. $SMAP_t = 1$ when $SM = 1$ and $AP_t = 1$, and 0 otherwise.	0.14 0.45 0.08 0.33	-	-	-

Source: Data from the South African Reserve Bank, Statistics South Africa, and the International Monetary Fund (IFS). Statistics are reported to three significant figures. The sample is 1980:1-2009:12.

Notes: †For a variable X, the augmented Dickey-Fuller (1981) statistic is the t ratio on π from the regression: $\Delta X_t = \pi X_{t-1} + \Sigma_{i=1,k} \theta_i \Delta X_{t-i} + \psi_0 + \psi_1 t + \varepsilon_t$, where k is the number of lags on the dependent variable, ψ_0 is a constant term, and t is a trend. The kth-order augmented Dickey-Fuller statistic is reported, where k is the last significant lag of the lags employed. The trend is included if significant. For null order I(2), ΔX replaces X in the equation above. Critical values are obtained from MacKinnon (1991). Asterisks * and ** denote rejection at 5% and 1% critical values. Stationarity tests are performed for the variables in levels before time-transformation.

TABLE 3

Pass-through after one year for various monthly models and samples

Column	*1*	*2*	*3*	*4*	*5*	*6*
Model	*Differenced only equation: no lagged dependent variable†*	*Differenced only equation with lagged dependent variable at t-12†*	*Campa Goldberg specification †*	*Equilibrium correction model: ECM terms at t-12†*	*ECM with automatic selection‡*	*ECM with automatic selection with outliers‡*
Equation no.	10	10	11	13	13	13
Pass-through coefficient	*Whole sample: 1980:10-2009:12*					
$\sum_{i=0}^{11} \beta_i$	-0.487	-0.499	-0.431	-0.503	-0.464	-0.436
t-ratio	-8.16	-8.36	-7.25	-7.69	-7.16	-7.67
Equation std error	0.01090	0.01070	0.0118	0.0106	0.0105	0.00874
R-squared	0.451	0.492	0.318	0.507	0.462	0.631
	*Sub-sample 1: 1980:10-1995:3**					
$\sum_{i=0}^{11} \beta_i$	-.522	-.542	-0.444	-0.436	-0.475	-0.479
t-ratio	-5.75	-5.44	-4.88	-4.14	-7.10	-7.08
Equation std error	0.0104	0.0106	0.0115	0.0107	0.0105	0.00913
R-squared	0.514	0.545	0.322	0.568	0.429	0.584
	*Sub-sample 2: 1995:4-2009:12**					
$\sum_{i=0}^{11} \beta_i$	-0.415	-0.415	-0.331	-0.458	-0.414	-0.414
t-ratio	-4.99	-4.99	-4.73	-6.08	-6.60	-6.60
Equation std error	0.001000	0.00975	0.01020	0.00981	0.00951	0.00951
R-squared	0.618	0.672	0.541	0.674	0.613	0.613

Notes:

The SA effective exchange rate is defined so that a rise denotes appreciation, see Table 2.

† Outliers are not dealt with by adding dummies. These results refer to fully general models without reduction to more parsimonious models (there is no model selection). We report just the summed coefficients of the twelve differenced exchange rate terms for general models (full model results available on request). All equations pass the CHOW test except the first three models for the full sample. This structural break is rectified through adding the ECM terms.

‡ The ECM result is also reported with automatic selection from the same general model using *Autometrics*, with and without the outlier option. The models are reselected for the sub-samples. The target model size is 0.01, with robust t ratios (HACSE ratios) and without the normality and heteroscedasticity tests. (No outliers were selected in the second sub-sample, Column 6.)

*The sub-samples 1 and 2 are split roughly in the middle, to coincide with the period before and after the substantial opening of the capital account in March 1995.

TABLE 4

One year pass-through equations for monthly equilibrium correction models with interaction terms in openness, regime shifts and volatility, and using automatic model selection

Column no.	*1*	*2*	*3*	*4*	*5*	*6*
Model	*ECM with PLL terms† and interactive effects* in:*					
Interactive effects:	*Capital account openness*	*Trade openness*	*Inflation targeting from 2000*	*Col.3 plus volatility*	*Col.4 plus currency invoicing*	*Col.5 plus asymmetry effect*
Based on equation no.	*14*	*14*	*14*	*14 & 15*	*14 &15*	*14,15,&16*
Pass-through coefficient	*Whole sample: 1980:10-2009:12*					
$\sum_{i=0}^{11} \beta_i$	-0.485	-0.434	-0.448	-0.508	-0.516	-0.453
t-ratio (robust)	(- 6.78)	(-8.02)	(-5.98)	(-8.97)	(-9.56)	(-6.99)
Equation std error	0.00879	0.00888	0.00882	0.00867	0.00870	0.00862
R-squared	0.629	0.618	0.625	0.644	0.635	0.643
Interaction terms						
$\Delta_3 \log NEER_t$ ×*regime change dummy*	-0.0438	-0.00234	-0.0411	-0.0306	-0.0471	-0.0563
t-ratio (robust)	(-2.36)	(-2.32)	(-2.09	(-2.02)	(-3.28)	(-3.38)
$\Delta_3 \log NEER_{t-3}$ ×*regime change dummy*	-0.00438	0.00053	-0.0168	-0.0237	-0.0497	-0.0634
t-ratio (robust)	(-0.307	(0.710)	(-1.22)	(-1.76)	(-3.53)	(-4.11)
$\Delta_6 \log NEER_{t-6}$ ×*regime change dummy*	0.0287	0.00164	0.0266	0.0297	0.0325	0.0298
t-ratio (robust)	(3.40	(3.12)	(2.75)	(3.19)	(3.43)	(3.49)
$\Delta_3 \log NEER_t \times$ $one\ year\ volatility_{t-1}$				0.912	1.03	0.758
t-ratio (robust)				(2.92)	(3.38)	(2.11)
$\Delta_6 \log NEER_t \times$ $invoicing\ dummy$					0.0548	0.0592
t-ratio (robust)					(3.36)	(3.61)
$(\Delta \log NEER_t \times SMAP_t\ )ma4$						-0.440
t-ratio (robust)						(-2.35)
NET pass-through**	-0.457	-0.430	-0.462	-0.469	-0.256	-0.258

Notes:

The SA effective exchange rate is defined so that a rise denotes appreciation, see Table 2.

† Parsimonious longer lags (PLL) are used for all dynamic variables except the exchange rate change. For Z equal to the log of a variable, the terms cover the 12 month period as follows: ΔZ_t , ΔZ_{t-1}, ΔZ_{t-2}, $\Delta_3 Z_{t-3}$, $\Delta_6 Z_{t-6}$, and $\Delta_{12} Z_{t-12}$. For the SA unit labour cost and growth variables, expressed as three month moving averages, the terms enter as: ΔZ_{t-2}, $\Delta_3 Z_{t-3}$, $\Delta_6 Z_{t-6}$, and $\Delta_{12} Z_{t-12}$; and $\Delta_3 Z_{t-1}$, $\Delta_3 Z_{t-4}$, $\Delta_3 Z_{t-7}$, $\Delta_3 Z_{t-10}$, and $\Delta_3 Z_{t-13}$, respectively.

‡*Autometrics* parameters are for a target model size of 0.01, with robust t ratios (HACSE ratios) and switching off the normality and heteroscedasticity tests as a criterion for selection. Outliers are included for the October 2008 financial crisis, the 1985 debt crisis, and Gulf War related outliers in October 1990 and change from December to November 1990.

* The regime change dummies are defined in Table 2. These are: capital account step dummy equal to 1 after March 1995 and zero otherwise; real openness; and inflation targeting step dummies equal to 1 from March, 2000 and 0 otherwise. The currency invoicing dummy and the volatility variable are defined in Table 2. The asymmetry dummies are defined in Table 2: $AP_t = 1$ when $\Delta lnNEER_t > 0$, and 0 otherwise. $SM = 1$ when $|\Delta lnNEER_t| < 0.03$, and 0 otherwise. $SMAP_t = 1$ when $SM = 1$ and $AP_t = 1$, and 0 otherwise.

** Net pass-through is calculated for values prevailing from 2005, and excludes small appreciations in column 6.

TABLE 5

Six month pass-through equations for monthly equilibrium correction models with interaction terms in regime shifts, volatility and asymmetry, and using automatic model selection

Column no.	*1*	*2*	*3*	*4*	*5*
Model	*ECM with PLL terms† and interactive effects* in:*				
Interactive effects:	*Inflation targeting from 2000*	*Col.1 plus volatility*	*Col.2 plus currency invoicing*	*Col.3 plus asymmetry*	*Col.4 without volatility*
Based on equation no.	*14*	*14*	*14& 15*	*14, 15 & 16*	*14 &16*
Pass-through coefficient	*Whole sample: 1980:05-2009:12*				
$\sum_{i=0}^{5} \beta_i$	-0.245	-0.286	-0.280	-0.226	-0.187
t-ratio (robust)	(-4.35)	(-6.32)	(-6.19)	(-3.73)	(-2.95)
Equation std error	0.00900	0.00891	0.00888	0.00873	0.00876
R-squared	0.592	0.602	0.605	0.621	0.617
$\Delta_6 \log NEER_t$ ×*regime change dummy*	-0.0327	-0.0288	-0.0405	-0.0541	-0.0605
t-ratio (robust)	(-2.70)	(-2.78)	(-3.73)	(-3.97)	(-4.40)
$\Delta_3 \log NEER_t \times$ $one\ year\ volatility_{t-1}$	-	0.834	0.772	0.547	-
t-ratio (robust)	-	(2.16)	(1.98)	(1.27)	-
$\Delta_6 \log NEER_t \times$ $invoicing\ dummy$	-	-	0.0247	0.0333	0.0373
t-ratio (robust)	-	-	(1.71)	(2.37)	(2.75)
$(\Delta \log NEER_t \times SMAP_t)ma4$	-	-	-	-0.455	-0.558
t-ratio (robust)	-	-	-	(-2.28)	(-2.95)
NET pass-through**	-0.441	-0.437	-0.355	-0.336	-0.326

Notes:

The SA effective exchange rate is defined so that a rise denotes appreciation, see Table 2.

† Parsimonious longer lags (PLL) are used for all dynamic variables except the exchange rate change. For Z equal to the log of a variable, the terms cover the 12 month period as follows: ΔZ_t , ΔZ_{t-1}, ΔZ_{t-2}, $\Delta_3 Z_{t-3}$ and $\Delta_6 Z_{t-6}$. For the SA unit labour cost and growth variables, expressed as three month moving averages, the terms enter as: ΔZ_{t-2}, $\Delta_3 Z_{t-3}$, and $\Delta_6 Z_{t-6}$; and $\Delta_3 Z_{t-1}$, $\Delta_3 Z_{t-4}$ and $\Delta_3 Z_{t-7}$, respectively.

‡*Autometrics* parameters are for a target model size of 0.01, with robust t ratios (HACSE ratios) and switching off the normality and ARCH tests as a criterion for selection. Outliers are included for the October 2008 financial crisis, the 1985 debt crisis and Gulf War related outliers in October 1990 and change from December to November 1990.

* The regime change dummies, volatility variable and currency invoicing dummy are defined in Table 2 and in footnotes to Table 5. The asymmetry dummies are defined in Table 2 and in footnotes to Table 5.

** Net pass-through is calculated for values prevailing from 2005, and excludes small appreciations in columns 4 and 5.

APPENDIX 1: SA's exchange rate regimes, and trade and capital account liberalisation

Trade liberalisation in SA began in the early 1990s, and opening of the capital account to inflows from 1995. Externally imposed trade and financial sanctions, first applied after 1976, were lifted in the 1990s, mainly after the democratic elections. The increased openness associated with the international reintegration of the democratic SA also influenced the conduct and design of monetary policy in SA (Aron and Muellbauer, 2009b). SA's extensive trade liberalization since 1990 is outlined in Edwards et al. (2009). Conventional measures of openness based on real trade ratios suggest the most trade restrictive period was 1980-85, followed by a substantial liberalisation from the early 1990s beginning with the removal of remaining quotas. The democratic elections heralded several multi-lateral and bilateral trade agreements that instituted tariff reduction for the first time, beginning with the GATT Uruguay round of 1994. Quotas and export subsidies were eventually largely phased out by 1997.

There have been a variety of episodes in the floating period (see Table). SA's exchange rate policy has evolved from fixed rate episodes in the 1970s, through managed floats from mid-1979 to mid-1999, when a dual exchange rate system embodying a more flexible "financial" rand for non-residents operated for all but some eight years, and thereafter to a freely floating unified exchange rate under inflation targeting. The intended impact of the financial rand was to break the direct link between domestic and foreign interest rates, as well as to insulate the capital account from certain categories of capital flows. The financial rand applied to most non-resident portfolio and direct investment. All other transactions were channelled through the official or commercial rand market.

Except for some trade finance, there was little access to international finance in the sanctions era after 1976, especially after the 1985 debt crisis. However, after the 1994 elections capital flows increased strongly. In March 1995, virtually all exchange controls on foreign investors were removed with the abolition of the financial rand mechanism and unification of the exchange rate. Controls were retained for residents and gradually dismantled, hence continuing partly to insulate the unified exchange rate.

The nominal effective exchange rate in the floating regimes from 1980 is shown in Figure 1. Rising commodity prices induced real appreciation before 1985, around 1987 and after 2001. The damaging effects on confidence are apparent from the debt crisis of 1985, the home-grown currency crisis in 1996 and contagious currency crises in 1997 and 1998, and the exchange rate shock of 2001. The figure also illustrates exchange rate volatility measured over the previous 12 months. Exchange rate volatility has been quite high on this measure since the end of 1998, but lower than in the mid-1980s.

TABLE:

Regime Changes in the South African Foreign Exchange Market

Episode	*Dates*	*Exchange Rate Regime*
1†	1961q1-1971q2	Pegged to £
2†	1971q3-1974q2	Pegged in episodes to floating $ or £
3	1974q3-1975q2	"Controlled Independent Float": devaluations every few weeks
4	1975q3-1979q1	Fixed regime: pegged to the $
5	1979q2-1982q4	Dual foreign exchange system: controlled floating commercial rand and floating financial rand
6	1983q1-1985q3	Unification to a controlled floating rand
7	1985q4-1995q1	Return to the dual system
8	1995q2-1999q4	Unification to a controlled floating rand
9	2000q1-	Freely floating rand under inflation targeting

Sources: Detailed parity changes as reported in Aron, Elbadawi and Kahn (2000).

† Note that during episodes 1-4, a securities (or "switch") rand was operative for the purchase of South African securities by non-residents, but not transferable between non-residents. This was then replaced by the financial rand in Episode 5.

APPENDIX 2: Technical details on the Johansen set-up

We impose three fundamental restrictions on the long-run solution for the five I(1) variables. The first is to treat foreign producer and oil prices as strictly exogenous. The second is the currency conversion restriction which implies that foreign producer and oil prices enter the system converted into rand at the exchange rate. This implies that we can think of the long-run solution in terms of four rand variables: import prices, unit labour costs, and rand foreign and oil prices. The third restriction is the homogeneity restriction which implies that doubling unit labour costs and rand foreign and oil prices must double import prices in the long-run.

The implication of these restrictions is that there can be at most two co-integrating vectors. Using Oxmetrics, we find that the data clearly reject a rank of 1. With currency conversion imposed, any co-integrating vector will have the form

$$b_1 \log PIMPORT + b_2 \log ULC + b_3(\log FPRICE - \log NEER) + b_4(logPOIL - \log NEER) \\ = constant + trend/shift$$

Homogeneity implies $b_1 + b_2 + b_3 + b_4 = 0$. A relationship interpretable as an import price equation is obtained by normalising $b_1 = 1$. Then $b_3 + b_4 = -1 - b_2$, and

$$\log PIMPORT = (1 + b_3 + b_4)\log ULC - b_3(\log FPRICE - \log NEER) \\ -b_4(logPOIL - \log NEER) + constant + trend/shift$$

Single equation results suggested that b_2 is around -0.25, implying weights of around 25 percent on log unit labour costs and 75 percent on the combination of log rand foreign prices and log rand oil prices in the long-run solution for log import prices.

The second co-integrating vector could be interpretable either as an equation for unit labour costs or for the exchange rate. Since key drivers of the exchange rate are likely to include I(1) variables such as the commodity terms of trade, omitted from the current model, the former interpretation seems the more plausible. With $b_2 = 1$, this suggests

$$\log ULC = \log PIMPORT + constant + trend/shift$$

It turns out that the hypothesis that rand foreign producer prices and rand oil prices do not enter the second co-integrating vector can be accepted. These two sets of restrictions were imposed on the beta matrix in a rank 2 co-integration model.

The alpha matrix satisfies the restrictions suggested by the above economic interpretations: the speed of adjustment for log import prices to the first co-integration vector is 0.063 (the alpha coefficient is -0.063) and zero to the second co-integration vector. The hypothesis that the speed of adjustment of $\log ULC$ to the first co-integration vector is zero is accepted and imposed. However, the speed of adjustment of $\log ULC$ is 0.013 (t=4.9) to the second vector. This suggests that in the long-run, unit labour costs do adjust to import prices and hence ultimately to foreign prices and the exchange rate, though only very gradually.

The alpha coefficient for the exchange rate to the second vector is close to zero, but -0.147 (t=3.6) to the first vector, which has the form:

$$\log PIMPORT - 0.25 \log ULC - 0.68(\log FPRICE - \log NEER) - 0.07(\log POIL - \log NEER)$$

Since the exchange rate is the most volatile element in this vector, this implies some negative feedback in the exchange rate, tending to correct shocks in the previous period. An economic interpretation is that, for example, exchange rate depreciation in the previous period (a negative shock) is followed by tighter monetary policy, actually implemented or expected, which appreciates the exchange rate. Since unit labour costs and foreign prices appear with negative coefficients in the first vector, inflationary shocks in these variables also tend to be followed by exchange rate appreciation via the same monetary policy reaction.