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The Effect of the Exchange Rate on the Trade Balance: The Case of the South African Mining Sector

Owen Willcox

Supervisor: Lawrence Edwards

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1. Introduction

Ever since the Hopetown diamond was discovered in 1866, the history of South Africa and her economy have been closely linked to the mining industry. When diamonds were found in what is now Kimberley, the whole structure of South Africa's economy changed from an agrarian economy to one based on resources. The discovery of gold on the Witwatersrand was a major cause of the Second Anglo-Boer South African War, which led to the current shape of South Africa. The need for cheap labour also played a part in the politics of the nascent Union of South Africa. Industrialization during the 20th century was built on the foundation of mining capital thus, the importance of the mining industry in South Africa could hardly be overstated.

The rationale for the study is based on the significance of the mining sector and the recent history of the Rand. During the 1990s and the early part of this century, the Rand has often been the subject of speculative attacks. Added to this is the long-term trend of depreciation against the US Dollar. In a world of infinitely mobile capital and increasing globalization, the possibility of more exchange rate crises is very real. This affects the mining industry more than most other sectors because of the fact that the majority of its production is exported and the majority of the capital inputs are imported. The effect a depreciation will have on the sector is therefore critical.

In terms of exports, depreciation leads to a higher price for exporters. However, it often also leads to an increase in costs. On the import side, higher prices may not lead to higher revenue as consumers may substitute away from imports as their prices rise. In addition, elasticities of demand and supply change over time. Thus, the end result of a depreciation of the currency on the mining sector trade balance is not straightforward. Under certain circumstances it could be positive or negative. This project aims to find what the end result would be but also to find out why such results occur.

To understand any results that one obtains, a theoretical basis is needed. Chapter 2 sets out the various theoretical approaches to the question. In chapter 3, the focus moves to

the empirical support for the positions examined in the previous chapter. This data is examined for developed countries, LDCs, South Africa and the mining sector. Chapter 4 focuses on South Africa and its trade. Specific attention is paid to how the various sectors have contributed to exports and how these shares have changed as economic variables have fluctuated. Chapter 5 explains the econometric technique that was used and the rationale for using it. The results obtained using this technique are also presented. Chapter 6 concludes the thesis and provides some policy recommendations.

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2. Theoretical Background

2.1 Introduction

Studies of the effect of the exchange rate on the current account have often reflected the larger battles between competing macroeconomic theories. The final result has been an amalgamation of some elements of all the approaches. This chapter seeks to place the question of what effect of depreciation of the currency will have on the mining trade balance in a theoretical context. The theories and the empirical data related to the theories have usually been expressed in terms of a depreciation because the IMF used to advocate currency depreciation to increase exports.

2.2 Competing Theories

There are three approaches to studying the trade balance response to an exchange rate devaluation namely the elasticity approach, the absorption approach and the monetarist approach.

The absorption school views the balance of payments as the result of other events in the domestic economy. For a country to move into surplus on the current account, it is necessary for national income to increase faster than total expenditure and thus, the excess production will be exported. Expressed mathematically:

$Y = C + I + G + X - M$, where Y is income, C is consumption, I is investment, G is government expenditure, X is exports and M is imports. Therefore:

$\Delta Y = \Delta C + \Delta I + \Delta G + \Delta X - \Delta M$ where Δ is the change operator. If a devaluation is to lead to an improvement in the trade balance, then $\Delta(X - M) > 0$. Therefore:

$\Delta(X - M) = \Delta Y - (\Delta C + \Delta I + \Delta G) > 0$. This implies that income must grow quicker than expenditure.

In the case of a devaluation, the price of domestic goods relative to foreign will decrease. Foreign and local consumers will substitute towards domestic goods leading to an increase in employment (the absorption approach, being a Keynesian school, assumes

unemployment) and an improvement in the trade balance. However, increased employment and lower prices will lead to an increase in income. The income effect causes greater consumption of all goods and thus the trade balance will decrease slightly but the net effect will be positive (Rincón, 1999).

The monetarist approach views developments in the balance of payments as outcomes of the demand and supply of money. In the short term, a devaluation will increase local prices, which will decrease the value of real cash balances and distort the relative price of tradables and non-tradables in favour of tradables. Thus the short term effect will be positive (Miles, 1979) but in the long term this may not be true. For instance, it would be difficult for a country to maintain a surplus on the balance of trade in the long term as this would lead to an increase in the money supply, which would boost local demand. This would lead to an increase in imports and an increase in inflation making local exports less competitive. Thus the long-term effect of devaluation may well be zero.

2.3 The Elasticity Approach

In this study, the elasticity approach has been used. As (Rincón, 1999) shows algebraically, the three approaches are equivalent; they just view the problem from different starting points. The elasticity approach argues that the response of the current account will be determined by the response in both the export and import markets. The reaction in these markets is a function of the elasticities of supply and demand. In this sense, the elasticity approach does not have as broad a theoretical view as the other schools but merely examines the extant facts.

The one advantage of the elasticity approach is that it allows one to calculate the current account response to a devaluation of the exchange rate algebraically. The reaction can be gauged using the Bickerdike-Robinson-Metzler (BRM) finding, which is merely the exchange rate elasticity of the trade balance. Simple algebra shows this elasticity to be

$$E_{CA} = \frac{V_X}{V_M} \left(\frac{E_{DX} + 1}{(E_{DX} / E_{SX}) - 1} \right) - \frac{E_{SM} + 1}{(E_{SM} / E_{DM}) - 1} \quad \text{where } E_{CA} \text{ is the exchange rate elasticity of}$$

the trade balance, V_X and V_M are the values of exports and imports respectively, E_{DX} and

E_{SX} are the export elasticities of demand and supply respectively, and E_{SM} and E_{DM} are the import elasticities of supply and demand respectively (Vanek, 1962).

Clearly the value of E_{CA} depends on the various elasticities as it is assumed that any change in the exchange rate will lead to a change in prices. Whether the value of imports and exports increases or decreases due to the price change, will be a function of the price elasticities. Price elasticities of demand are themselves determined by other factors. The greater the number of substitutes for a good and the closer the substitutes are, the higher the elasticity of demand will be. The greater the proportion of income spent on a good the more elastic demand will be. Demand elasticities increase over time because in the short run consumers may not substitute to other goods because of high search costs or questions about quality (Sloman, 1994).

The elasticity of demand is important because it partly determines what will happen in the case of a price change. We know that a price change will result in an opposite movement in quantity demanded but without knowing the elasticity of demand it is impossible to know what the ultimate response of total revenue (i.e. the product of price and output) will be. The rule of thumb is that if the price elasticity of demand is less than unity (i.e. demand is relatively inelastic) then revenue will move in the same direction as prices (Sloman, 1994)

The price elasticity of supply has slightly different determinants because it focuses on producers, not consumers. Supply is more elastic the less costs rise with output. Thus if industries face increasing returns to scale, their supply curves will be more elastic than firms with constant returns to scale. The elasticity of supply is also dependent on time. In the very short run, output is unlikely to respond to price changes as the only possible response is to use spare capacity or inventories. In the short run, firms can hire more labour, while in the long run, firms can also respond by changing capital inputs. Thus, over time the price elasticity of supply grows larger (Sloman, 1994).

2.4 Possible Scenarios

Working within the elasticity approach, there are some important variations that will determine the current account response. The first case is shown in Figure 1 below, with the markets being represented in local currency. On the left is the market for exports and the right-hand diagram illustrates the market for imports. In both cases demand is perfectly inelastic (i.e. $E_{DX} = E_{DM} = 0$) and the quantity demanded is not price responsive.

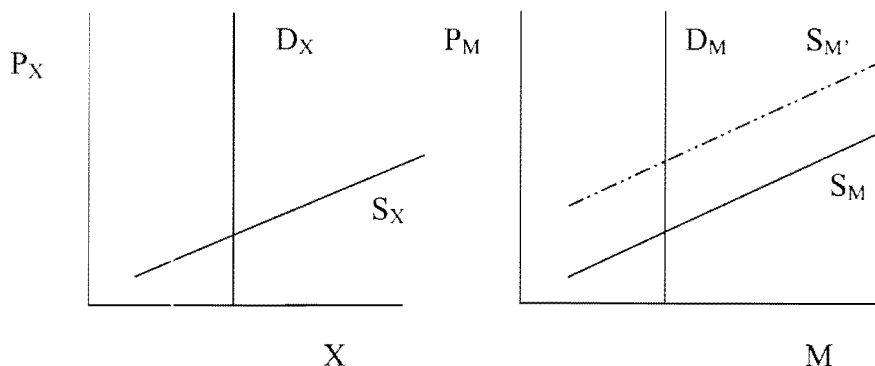


Figure 1: Inelastic Demands

In the case of exports, a devaluation will lead to an upward shift of the demand for exports curve. In figure 1 above, this shift cannot be seen as the new curve is directly on top of the old curve. The vertical distance between similar points on the two demand curves is equal to the percentage value of the depreciation. In the example above, the depreciation has not resulted in a change of the local price. This indicates that the price of the export good in foreign currency has decreased by the full amount of the depreciation. On the import side, the depreciation will lead to an upward shift of the supply curve, again by the amount of the devaluation, from S_M to S_M' . When we apply the case of inelastic demands to the BRM statistic, the formula reduces to

$$E_{CA} = -V_X / V_M < 0.$$

The case of inelastic demands will lead to an unequivocal worsening of the trade balance. The domestic price and quantity of exports will stay exactly the same while the price of imports will increase and the amount of imports does not change. Thus the value of

exports will remain the same but the value of imports will increase leading to a worsening of the trade balance.

The second case is the small country scenario. The main assumption is that the country is

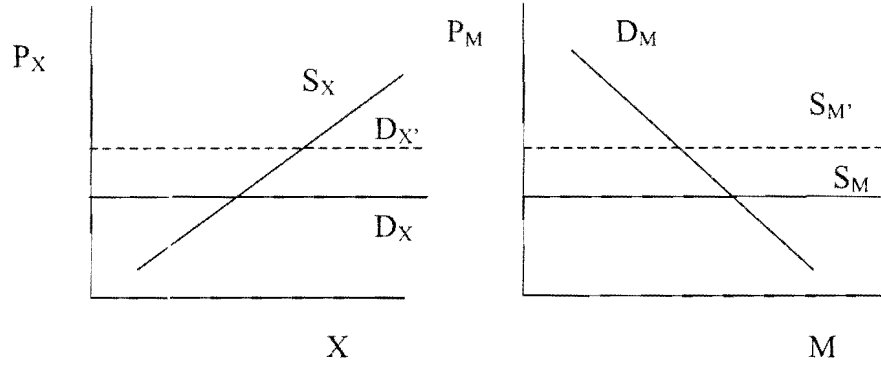


Figure 2: The Small Country Case

a price taker in export and import markets. Therefore the demand for exports curve will be perfectly elastic suggesting that the overseas market can absorb any amount of output that the small country can produce, without there being any effect on the world price. On the supply side, the supply of imports is perfectly elastic meaning that changes in local demand will not influence international prices. Thus, the domestic value of exports will increase while the value of imports may increase or decrease but the increase in the value of exports will always be greater, thus improving the trade balance. As in the earlier example, these effects are illustrated in figure 2 by the shift in the demand for exports curve to D_X' and the shift in the supply of imports curve to S_M' . Substituting these elasticities into BRM, the elasticity becomes

$$E_{CA} = \frac{V_X}{V_M} E_{SX} - E_{DM} > 0. \text{ Thus any depreciation of the exchange rate will lead to an}$$

improvement of the trade balance. The exact effect will depend on the elasticities of export supply and import demand. In this case the more elastic (i.e. the higher the numerical value of the elasticities) the curves are, the greater the improvement in the current account will be.

The third case is that in which prices are set in the buyer's currency. Thus, export markets would face a world price in a foreign currency while imports would be priced in the local currency. This case is more of a theoretical exercise as it unlikely to occur. The demand curves in both markets would be perfectly elastic. Applying this to the BRM equation yields

$$E_{ca} = \frac{V_X}{V_M} E_{sx} + E_{sm} + 1 > 0 \text{ which once again shows that depreciation in this situation}$$

will improve the trade balance as E_{ca} will be greater than zero.

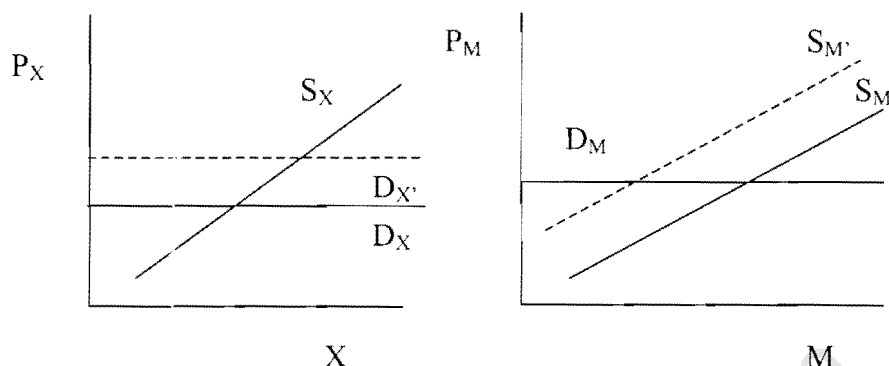


Figure 3: Price fixed in buyer's currency

The implications of the fourth scenario are ambiguous. In this case it is assumed that prices are set in the seller's currency. This may be an accurate representation on the import side for a small country such as South Africa, as one would expect world prices to be set in currencies other than the Rand. For exactly the same reason, this is probably not a good assumption to make on the export side for a small country, as few prices are denominated in the domestic currency. However, perfectly elastic supply curves may also exist when there is excess capacity in an economy¹. This scenario is the basis of the well-known Marshall-Lerner condition which states that if both supply curves are perfectly elastic and the trade balance is zero, then a devaluation of the exchange rate will lead to

¹ This case may be an accurate representation of the late 1980's when local demand was significantly below output, meaning that producers had spare capacity and used export markets to vent this capacity.

an improvement in the trade balance if the sum of the elasticities of the two demand curves is greater than one. More formally, we can use the BRM formula with

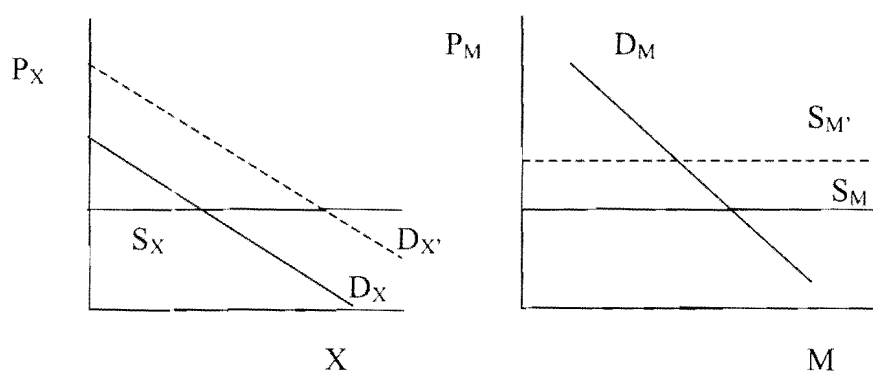


Figure 4: Prices fixed in the seller's currency

$E_{SX}=E_{SM}=\infty$. Therefore:

$$E_{CA} = \frac{V_X}{V_M} (-E_{DX} - 1) - E_{DM} < 0.$$

Thus we may have a deterioration of the trade balance under certain circumstances. Obviously, the deciding factor will be the two elasticities of demand. If the trade balance is zero (i.e. $V_X = V_M$), then the current account will improve so long as the demand for exports is slightly more elastic than the demand for imports ($E_{DX} > 1 + E_{DM}$). On both the export and import side, price is determined by the supply curve, while quantity demanded is determined by the demand curve. The more elastic the curves are, the more quantity demanded will increase in response to a price decrease. The difference is that there will be a price change on the import side while the export price will stay constant, as can be seen in figure 4. Thus, the elasticity of export demand must be slightly larger than the elasticity of import demand because there is no favourable price change on the export side. If the elasticity of export demand is not sufficiently large then the increase in the value of imports will be greater than the increase in exports and the trade balance declines. This scenario is quite important because it has been the basis of many empirical studies (e.g. Smal, 1996; Gafar, 1981) testing what the effects of a devaluation will be. Once the elasticities of demand were estimated, the Marshall-Lerner conditions were applied.

The last case that is left to be considered is one that may arise in an LDC. In this case, it is assumed that an LDC is a small country with underdeveloped local capacity. Thus, we will expect $E_{SM} = E_{DX} = \infty$ as per the normal small country assumptions. The underdeveloped capacity will mean that import demand is highly inelastic². This is because an exogenous increase in national income, local firms will not be able to respond by increasing production. Thus, firms will have to import goods for consumption or import capital goods in order to boost local production, virtually regardless of the cost. This dilemma is typified by the balance of payments constraint on South Africa's growth. In terms of the mining sector, one can also think of non-oil producing countries. Oil has few substitutes so the demand for oil is highly inelastic. Thus, the demand for imports curve may be very inelastic, especially in the short run. This can be seen in Figure 5 below.

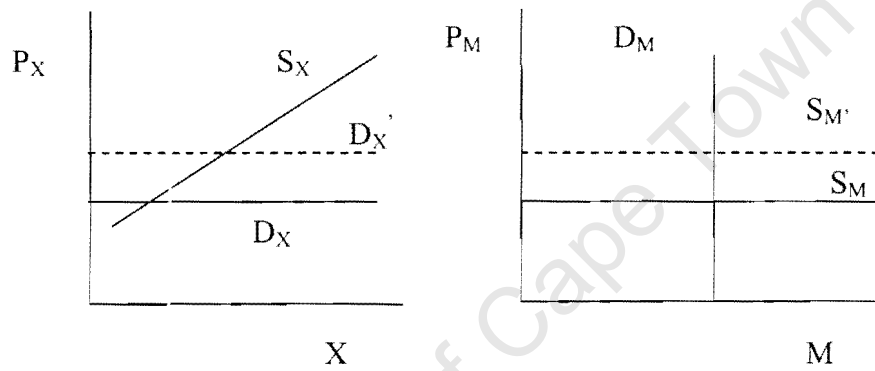


Figure 5: A short run view of an LDC

If we apply these assumptions to the BRM, formula the following result is obtained:

$$E_{CA} = \frac{V_X}{V_M} (E_{SX}) > 0$$

² For the sake of simplicity, we will assume that import demand is perfectly inelastic in this example.

Under this scenario, any devaluation of the currency will lead to an improvement of the current account, as we would always expect the elasticity of supply to be positive. Looking at Figure 5, it is clear that the value of both exports and imports will increase. However, the value of exports will increase by more than the amount of the depreciation but imports will only increase by the amount of the devaluation. Thus, the trade balance will improve. In this case, the more elastic the supply of exports curve is, the bigger the boost to the current account will be.

The above scenarios all employ simplifying assumptions, none of which are probably true. In reality we are very unlikely to see any curve that is infinitely elastic or inelastic. However the assumptions do help to show what the probable effects will be under various conditions. The results are likely to be more complicated.

2.5 The Applicability of the Various Scenarios to South Africa

In the short run, both demand curves may be quite inelastic but will grow more elastic in the long term. This corresponds well with the first case that was examined. The short run may see a deterioration in the trade balance followed by a marked improvement as the elasticities grow over time. This effect has come to be known as the J-curve. In the very short term, goods that have already been purchased or that are in transit when the depreciation occurs will cause a worsening of the trade balance (Bahmani-Oskooee, 1985). Another reason for this could be that exports are sold forward, thus there will be no demand response to lower prices in the short term but there will be a change as time goes on. Magee (1973, 307) observed five different lags, namely “lags in recognition of the changed situation, in the decision to change real variables, in delivery time, in the replacement of inventories and materials, and in production.” Magee (1973) also noted the results of other studies, which showed empirical evidence of lags of up to five years before changes in the exchange rate were reflected in a country’s market share of world trade. These lags refer to the supply side but apply to this situation because there will be lags between a change in the exchange rate and local producers realizing that there are opportunities for import substitution (in terms of retail and inputs). The lack of local substitutes will mean that the demand for imports remains inelastic in the short run.

Consumers may also not respond to the situation immediately because they have to search for substitutes.

The second case is very likely to be applicable to South Africa, due to the fact that the South African local market is not big enough to affect world prices. Thus, South African firms will be price takers in both the export and import markets. The one possible exception to this rule may well be some of the mineral export markets. For example, South Africa mines over half of global platinum group metals (PGM) production and historically, this country has been the world's largest supplier of gold (Chamber of Mines, 2001). This market power may give local mining houses some discretion in setting world prices, thus refuting the small country assumptions. Despite this, this case is the most likely of the five to apply to South Africa in the long term. If this model is accurate then a depreciation of the Rand would lead to an improvement in the trade balance. More data would have to be considered before one could conclude whether this case models South Africa's mining trade.

The third and fourth scenarios are more academic in nature and are unlikely to apply to any country. Prices will be set in the buyer's currency for South Africa's exports but not in the import market. If prices are set in the seller's currency, then South Africa's import market will be well modelled but the same could not be said of the export market. The last case is quite likely in the short term. In terms of manufacturing, South Africa is highly dependent on imported machinery (SARS, 2003). Thus, before an increase in production can be achieved, machinery has to be imported. The demand for mineral imports may be quite inelastic due to oil, even though South Africa has better substitution possibilities than most countries. If the last case were to apply to South Africa then the effect of a depreciation of the currency would be to improve the trade balance.

2.6 Extensions of the Elasticity Approach

2.6.1 Feedback Price Effects

One of the problems with the BRM framework is that it does not account for feedback effects of a depreciation. As was mentioned above, a depreciation of the exchange rate

will lead to an increase in import prices, depending on the elasticity of import demand. In the long term, imported inflation will reduce any competitiveness gain local firms enjoy over foreign exporters. In the export market, rising local prices will reduce the incentive of local firms to export as the domestic market becomes more attractive. Thus, the strength of the feedback price effect will have a significant bearing on what occurs after an exchange rate movement. The elasticity approach does not take this effect into account.

Various studies found that the domestic price feedback effect varied from country to country. The size of the effect depends on the substitutability of domestic goods for imported goods (in both consumption and production), the share of imports in total income, the elasticity of prices with respect to input prices and the elasticity of factor prices with regard to domestic price levels. The larger each of these factors is, the larger the response of domestic prices will be to the increase in import prices (Goldstein & Khan, 1985).

The wage bargaining institutions also play a role. Sachs (1980, quoted in Goldstein & Khan, 1985) found that whenever indexation is common and real wages are sticky downward, domestic prices will be more sensitive to import price rises. This, combined with the fact that South Africa is a relatively open economy, suggests that the domestic price feedback effect may be larger in South Africa than most countries, given trade unions power in domestic wage setting.

Artus & McGuirk (1981) modelled the effects that higher domestic prices would have on the effects of a currency devaluation. They found that if one assumed high feedback the effect on the trade balance was only 60% as high as that when one assumed low feedback. Thus, although a devaluation may lead to a boost in exports and an improvement in the trade balance, in the long term this effect may be much weaker.

2.6.2 Imported Inputs

The discussion above has assumed that exports and imports are independent of one another. However, this is not true, especially in the case of less developed countries (LDCs). Imports are dependent on the amount of foreign exchange that exports generate and very often exports are produced using imported capital goods. As was mentioned above, South African mining is heavily dependent on imported machinery. Thus, the level of exports may be a constraint to imports and vice versa.

Khan & Knight (1988) specify a model incorporating both of the constraints mentioned above. They estimate the model using data from 34 developing countries and find that the coefficients on both the reserves constraint and the imported inputs restraint are significant. They find that the elasticity of imports with respect to changes in official reserves is 0.15 while the elasticity of exports due to a change in imported inputs is 0.52.

Khan & Knight (1988) use their findings to model the effects of a 10% devaluation. The expected result is a temporary worsening of the trade balance followed by a permanent increase (the J-curve effect). However, Khan & Knight (1988) find that the negative portion of the J-curve is less serious but the long run effect may be zero. This is because, as expected, the devaluation leads to an increase in exports and a decrease in imports as import substitution becomes more profitable. However, two effects specific to the Khan & Knight (1988) model now take place. Firstly, the increase in domestic income will lead to an increase in imports. Secondly, the trade surplus causes an increase in reserves which leads to an increase in imports. Thus the long run effect may be negligible. Khan & Knight (1988) do not explain why the amelioration of the short run trade deficit in their model occurs.

Kale (2001) applies Khan & Knight's (1988) insights to Turkey and finds a delayed J-curve effect on the Turkish trade data. He argues that in very short term firms will delay any unnecessary capital expenditure. If the depreciation persists then firms have to buy their capital equipment at the higher prices. Kale (2001) finds that most of the adjustment in exports takes place in the first quarter. Subsequent to that, we see capital imports

increasing again. The net effect may be a W-curve. However, Kale (2001) argues that this response may be peculiar to Turkey.

2.6.3 General Equilibrium Effects

If a depreciation of the exchange rate leads to an improvement of the trade balance, this would affect the rest of the economy. The elasticity approach ignores this because it only examines external trade. One therefore has to use the language of the absorption approach. In the long term, if exports increase more than imports, it will lead to an increase in national income. However, in the long term, exporting firms will spend their profits in the local economy. Thus, consumption and expenditure will rise. This will reduce the gap between income and expenditure so that exports will decline. In addition, some of the new expenditure will be on imports so imports will increase. In the long term, this will reduce any positive effects from a currency depreciation.

2.7 Conclusion

Various theories have been offered as to how the exchange rate will affect the current account and what effect this will have. While the elasticity approach does have the advantage of ease of estimation and interpretation, it does lack the theoretical depth of the other schools. This study follows the elasticity approach but the results must be interpreted with many other factors born in mind. Price feedback effects and the impact of imported inputs will both reduce the effect estimated under the elasticity approach. The increase in income due to exports may also reduce the positive effects of a currency depreciation as this extra income is spent in the local economy. Examining scenarios under the elasticity approach suggests that the long-term effect of a depreciation of the exchange rate may lead to an improvement of the trade balance. The short-term effect is uncertain at this stage.

3. Literature Review

3.1 Introduction

The obvious test for any theory is empirical proof. This chapter seeks to set out the statistical evidence for the competing theories and to find whether there is any consensus about what role the exchange rate will play in determining the trade balance.

3.2 The Elasticity Approach

As mentioned before, the elasticity approach does not try to place the trade balance in context with regard to other aggregate economic measures (e.g. income or the money supply). Instead, it merely studies the outcome of the trade balance as a function of the elasticities of the supply and demand functions. Thus, in the studies stemming from this approach, the main variables used are prices and income. Three main methodologies exist: structural system of equations, non-structural equations and prices studies.

3.2.1 Non-structural Equations

Studies in this vein usually use a reduced form expression for the trade balance and its determinants. A reduced form equation is one where all the explanatory variables are on the right hand side with the single dependent variable on the left. Bahmani-Oskooee (1985), which is typical of this approach estimates:

$$TB_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 YW_t + \alpha_3 M_t + \alpha_4 MW_t + \sum_{i=0}^n \beta_i (E/P)_{t-i} + u_t$$

where TB_t is the trade balance, Y_t is income, YW_t is world income, M_t is high powered money, MW_t is world high powered money, E is the number of domestic currency units per foreign currency and P is local prices. Bahmani-Oskooee (1985) adds the monetary variables to “give some monetary flavour (Bahmani-Oskooee, 1985: 501).” The lag structure is included to determine whether or not a J-curve effect takes place in that country

There are a number of criticisms of this particular methodology. Firstly, there is little link to theory. The equation above offers no consistent explanation as to how the independent variables influence the dependent variable. For instance, one might expect $\alpha_0 < 0$ because as national income grows, so too will demand for imports. However, Magee (1973) points out that income could vary positively with the trade balance because imports are the difference between consumption and production. Thus, as income increases, production may increase quicker than consumption so that imports decline.

Further, the sign of the β coefficient fails to identify whether the impact on the trade balance occurs through a response in imports, exports or both. The coefficient on the exchange rate term is neither a demand nor supply elasticity, but rather a weighted average of the various elasticities of demand and supply of both imports and exports. These dilemmas regarding the theoretical foundations limit the applicability of the findings to policy making.

On the positive side, non-structural equations allow one to estimate the relationship directly. If variables such as the money stock and national income are included in the regression, this method can represent a merger of the elasticity, absorption and monetarist approaches (Rincón, 1999).

3.2.2 Structural System of Equations

The system of equations approach seeks to isolate the different effects on both the demand and supply side of exports and imports. Most of the studies using this methodology have assumed that imports are not perfect substitutes for domestically produced goods. One's assumptions regarding the substitutability of goods determine how to model trade.

The imperfect substitute model assumes that the goods being traded are not totally homogenous (as the name suggests). This may be due to various reasons including product differentiation, quality differences and branding. While this model runs contrary to classical trade theory (which assumes that all goods are homogenous), real world

characteristics clearly vindicate the model. If all goods were homogenous, there would be no intra-industry trade. Countries would either export or import a good but would not do both. In addition, the law of one price does not seem to hold as many studies have shown that there are prices differences both between and within countries (Goldstein & Kahn, 1985). Thus, to study the effect of the exchange rate on trade, one would have to estimate a system of equations such as those below:

$$\begin{aligned} M^D &= f(Y_i, P^M, P_i) & f_1, f_3 > 0, \quad f_2 < 0 \\ M^S &= h(P^M, P^*) & h_1 > 0, \quad h_2 < 0 \\ M^D &= M^S \end{aligned}$$

$$\begin{aligned} X^D &= g(Y^*e, P^X, P^*e) & g_1, g_2 > 0, \quad g_3 < 0 \\ X^S &= j(P^X, P_i) & j_1 > 0, \quad j_2 < 0 \\ X^S &= X^D \end{aligned}$$

where M^D is import demand, Y_i is domestic income, P^M is the price of imports, P_i is a domestic price index, X^D is export demand, e is the real exchange rate, P^X is the price of exports, M^S is import supply and X^S is export supply. Asterisks indicate foreign variables. In a perfect world, one would model bilateral trade for every country in the world. Most studies use the country under study as one data point while the rest of the world is merged into the other country (Goldstein & Kahn, 1985).

In the world of heterogeneous products, the decision to trade is based upon relative prices. On the demand side, consumers decide between a foreign product and a local product based on their relative price. If the price of the foreign good increases while the local good's price remains unchanged, then consumers will buy more of the local good. On the supply side a similar process takes place except firms have to choose between the price that can be obtained through trade versus the price in the local market.

Despite the empirical relevance of the above model, it cannot accurately model the trade of all goods. In some cases, especially commodities, goods from different sources are

perfect or very close substitutes. Thus, the law of one price may well hold in these cases and countries may only export or import the product but not do both. The perfect substitutes model posits that trade does not take place on the basis of price differentials. Rather, there is only one price that clears all domestic markets for the good. The price in local markets will be the world price, adjusted for exchange rate differentials and barriers to trade. Thus, to model the trade in that good we need only model an excess supply or excess demand function depending on whether the country exports or imports the good.

Thus, trade can be modelled as such:

$$D_i = f(P_i, Y_i) \quad f_1 < 0, f_2 > 0$$

$$S_i = n(P_i, F_i) \quad n_1 > 0, n_2 < 0$$

$$M_i = D_i - S_i$$

$$X_i = S_i - D_i$$

$$P_i = P_j = P X_j = e \cdot P_w$$

$$D_w = \sum D_i$$

$$S_w = \sum S_i$$

$$S_w = D_w$$

Even if one decides to merely estimate excess supply or excess demand functions, instead of estimating local supply and demand functions, there would be a difference between the two different models. The difference lies in the price variables. The imperfect substitute model relies on relative prices while its homogenous counterpart has only one price.

Estimation of systems of equations runs into two problems: simultaneity and dynamics. Simultaneity arises because the price and quantity of trade is determined at the same time so that neither variable is exogenous. Thus, an estimation of a single equation with exports as the dependent variable and export prices as an independent variable will suffer from simultaneous equation bias as the error term will be correlated with the price variable (Goldstein & Kahn, 1985). The estimated coefficients will be biased.

The simultaneous determination of prices and outputs (imports or exports) has implications for the estimation procedures followed. Goldstein and Khan (1985) note that there are two ways to deal with the problem of simultaneity. The first method is to assume that the elasticities of supply are infinite, as in Gafar (1981). This effectively means that price is exogenous and thus OLS estimators will be unbiased (if the assumption is correct). The second method is using simultaneous equation methods. These equations should be estimated with maximum likelihood methods or two-stage least squares.

The estimation of lags is also a problem. The Koyck model is commonly used when modelling lags but it has a number of peculiarities that make it unsuitable in this case. The Koyck model assumes that the majority of the adjustment takes place in the first time period. However, exchange rates affect the economy over such a long period of time that it is unjustified to assume that the majority of the adjustment would take place so soon after a shock. In addition, the Koyck model assumes that the effect on the dependent variable will follow the same lag structure for all the explanatory variables. There is no theoretical reason to assume, for example, that income changes will affect the trade balance with exactly the same lags as price changes will (Goldstein and Khan, 1985).

One problem with the Koyck methodology is that it still does not fully solve for the problem of endogeneity as the exchange rate is assumed to be exogenous. This is contrary to both theory and intuition. In addition, Lin (1997) uses the Gweke linear feedback test and finds that there is bidirectional causality between the trade balance and the exchange rate. This criticism applies equally to the non-structural equations methodology.

3.2.3 Price Studies

Price studies focus on the effect of exchange rate changes on the price of products. The important aspect is not the prices themselves but two relative prices. Firstly, the relative price of imports to import substitutes, which is assumed to play a role in the quantity of imports consumed domestically and secondly, the relative price of exports to local prices, which plays a role in firms determining how much of their output should be exported.

When one of the relevant prices changes (due to a real exchange rate movement) then there would be some substitution effect and an effect on the trade balance. The behaviour of prices does allow one to draw inferences about the likely effect on the current account.

For example Swift (1998) tests the assumption that Australia will conform to the small country model (i.e. have perfectly elastic demand for export and supply of imports curves). In a small country, one would expect that the full effect of a depreciated exchange rate would be passed onto domestic consumers, while the foreign price will remain constant. However, Swift (1998) finds that 60% of the devaluation is passed onto the world price. Thus, one has to refute the assumption that Australia is a price taker on world markets and the only conclusion is that the small country characteristics do not describe Australia very well.

3.3 The Absorption Approach

3.3.1 Macroeconomic Studies

In contrast to the structural system of equations methodology, macroeconomic studies methodologies are firmly rooted in studying the whole economy. The difference stems from the fact that the system of equations methodology is usually linked to the elasticity approach while the macroeconomic methodology is part of the absorption approach.

Central to the absorption approach is the income-expenditure identity

$Y \equiv C + I + G + X - M$ which can be expressed as

$$Y - E = TB = X - M$$

where Y is income, C is consumption, I is investment, G is government expenditure, E is total expenditure, TB is the trade balance in local currency, X is exports in the local currency and M is imports in the local currency. The absorption approach studies the left-hand side of this equation while the elasticity approach investigates the right (Rincón, 1999). Gylfason & Radetzki (1991) is a typical example. It is argued that a depreciation will have no real impact unless it lowers real wages. This will feed through to lower

consumption so that imports are lower. In order to test this hypothesis, an intricate model of the economy is constructed. As above, the basis of the model is the identity:

$$TB = Y - E(YP/V, M/V)$$

where total expenditure is a function of the real purchasing power of the gross national product (YP/V) and the real money stock (M/V).

Given that the models estimated are more complex, one would expect that it would be a lot more difficult to determine beforehand what the ultimate effects of an exchange rate depreciation might be. As with the elasticity approach, consumers respond to new prices by substituting away from imports. However, absorption models also take into account the fact that the devaluation will reduce consumer's income so that there will be less consumption of all goods. The effects of this will be larger than most models given that the absorption approach assumes some level of unemployment. Generally it is assumed that a devaluation will lead to a decrease in national income and in the terms of trade. The effect on the trade balance will depend on how much the price of exports drops (Rincón, 1999).

Bahmani-Oskooee (1985) and Rincón (1999) include production and money supply variables into their set of independent variables explaining the trade balance. However, these are largely ad hoc additions and do not capture to the essence of the macroeconomic linkages emphasised in the absorption and monetary approaches. A consistent interpretation of their coefficients is thus not possible. Gylfason & Radetzki (1991) use a general equilibrium model.

3.4 Results

3.4.1 Less Developed Countries

Bahmani-Oskooee (1985) uses a reduced form model (as above) to test for the J-curve effect arising from a devaluation in Greece, Korea, India, and Thailand. He finds that in all four countries there is a short run deterioration of the trade balance followed by a

small improvement. Despite this, the long run effect is only positive in Thailand. However, these results are invalid as the real effective exchange rate was incorrectly defined (Bahmani-Oskooee, 1989).³ In a later paper, corrected for the earlier error, Bahmani-Oskooee (1989) re-estimates the data and finds the exact opposite of a J-curve as the trade balance first improves and then worsens. In the long run, only Thailand's trade balance improved because of the deterioration.

Unfortunately, there were other problems in both the original and the erratum as Bahmani-Oskooee (1985 & 1989) failed to test for the stationarity of the variables. A process is stationary if *"its mean and variance are constant over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods and not the actual time at which the covariance is computed"* (Gujarati, 1995: 713).³ If two non-stationary variables are regressed on one another, the probability is that the relationship will appear to be statistically significant when they are in fact unrelated. One has to conclude that Bahmani-Oskooee's (1985 & 1989) results cannot be relied upon. The test for stationarity was only developed in 1986 by Engle and Granger. Thus, any studies prior to this might face the problem of spurious regressions.

Bahmani-Oskooee (1991) examines the effect of the exchange rate on the trade balance by testing for a cointegrating relationship between the exchange rate and the current account for Greece, India, Korea and Thailand. When tests prove that the variables are cointegrated it is argued that this is proof that there is a long run relationship between the two variables. The test for cointegration is performed twice. In the first instance, the real exchange rate is the dependent variable and in the second it becomes the independent variable. The variables are only cointegrated when the trade balance is the dependent variable. Bahmani-Oskooee (1991) concludes that this shows that causation runs from the real exchange rate to the trade balance and not vice versa. This proposition is not theoretically viable (one would expect the causation to run in both directions as discussed

³ In calculating the foreign price measured in domestic currency, Bahmani-Oskooee (1985) incorrectly multiplied the foreign price by the units of foreign currency per unit of domestic currency.

above) and the peculiar empirical technique is not explained. This methodology is very sensitive to the weaknesses in the Augmented Dickey-Fuller test.

Buluswar, et al. (1996) test for cointegration between the real exchange rate and the trade balance for India. No evidence of cointegration is found meaning that there is no long run relationship between the two variables. However, once the data was first differenced both processes were found to be stationary. The change in the real exchange rate was then regressed on the change in the trade balance and the results were found to be significant indicating that there is a positive short run relationship. Buluswar, et al. (1996) also estimate a function with lags of the first differenced real exchange rate and find results consistent with an M-curve (i.e. after a depreciation, the trade balance first appreciates, then depreciates and then repeats the whole cycle).

Rose (1990) examines the evidence from 30 developing countries. The first finding is that the exchange rate and the current account are not cointegrated. He estimates the equation

$$\Delta BT_{t,j} = \alpha + \sum_{i=0}^p \beta \Delta q_{t-i,j} + \sum_{i=0}^r (\delta_i \Delta Y_{t-i,j} + \delta^* \Delta Y_t) + \tau_i \varepsilon_{t-i,j} + u_{t,j}$$

where BT is the balance of trade, q is the real exchange rate, Y is income and ε denotes the residuals from the cointegrating equation. The subscripts t and j denote time and countries respectively. Rose (1990) estimates the equation using three stage least squares. A Wald test was performed on the estimate of $\Sigma\beta$ for each country. The coefficient was significant in only the cases of Tanzania and Thailand. When the test were repeated with quarterly data, six out of the nineteen coefficients were significant. In most cases, therefore, no relationship between the trade balance and the exchange rate is found. Rose applies the same methodology in Rose (1991) to five OECD countries and in Rose and Yellen (1989, cited in Rose (1990)) to the United States and finds similar results.

Wilson & Choon Tat (2001) apply Rose's (1991) methodology to the analysis of Singapore's trade. As found in Rose (1991), there is no evidence of cointegration between the real exchange rate and the trade balance and hence, no long run relationship. Wilson & Choon Tat (2001) also test for cointegration between national income and the

trade balance and find no relationship. Following Rose (1991), the regression is estimated using first differenced data. The exchange rate was found to have a significant effect on exports only in the fifth, sixth and seventh quarters after an exchange rate movement. Imports and the trade balance were unaffected. It should be noted that Singapore is considered something of an anomaly in terms of the trade response to the exchange rate. Wilson & Choon Tat (2001) report that the correlation coefficient of the real exchange rate and the real trade balance was only 0.04 between 1970 and 1996. Still, the finding that the trade balance and the exchange rate are not cointegrated implies that there is no long run relationship, positive or negative. Any relationship found using first differenced data only applies to the short run relationship.

Upadhyaya & Dhakal (1997) uses a distributed lag model that looks like the non-structural model to test for a relationship between the trade balance and the exchange rate in eight LDCs. However, the only variables used as independent variables are lags of the trade balance and lags of the real effective exchange rate. Moreover, the absence of autocorrelation is merely assumed, it is not tested for. Upadhyaya & Dhakal (1997) still use OLS to estimate the regression. If autocorrelation is present, then the estimated coefficients will be the best linear unbiased estimators but they will not be efficient. This will mean that the goodness of fit (R^2) will be overstated and the tests for significance of the coefficients will be biased towards declaring significant coefficients, insignificant. In addition, the use of an autoregressive model has other shortcomings. The main problem is that the explanatory variables may be correlated with the error term. If this does occur, then OLS estimators will be biased and inconsistent. Thus, autoregressive models should not be estimated using OLS (Gujarati, 1995). Upadhyaya & Dhakal (1997) find that in the long run only Mexico benefits from a currency devaluation. In Cyprus, Greece and Morocco a devaluation will decrease the trade balance in the long run while in Colombia, Guatemala, Singapore and Thailand there will be no effect.

Gafar (1981) uses a system of equation method to estimate export demand and import demand. It is assumed that the elasticities of export and import supply are infinite but no reasons are given for this assumption. Gafar (1981) estimates the elasticities and then

applies them to the simple form of the Marshall-Lerner condition. When he finds that the elasticities sum to 1.27, the conclusion is that a depreciation will lead to a improvement in the trade balance. This finding is correct, so long as the assumption of infinitely elastic supply curves is correct. However, there is no reason why this assumption should be accurate. One would expect Jamaica to fit the small country case, which would mean that the price elasticities of export demand and import supply would be infinite. This does not correspond with Gafar's (1981) assumptions.

Kulkarni (1996) finds that both Egypt and Ghana exhibit symptoms of the J-curve. However, there seems to be little statistical evidence to support this in the paper. Indeed the only test seems to be an inspection of the graph of the trade balance over time.

Rincón (1999) uses a non-structural equation model but estimates it using the Johansen technique. The equation used includes the money stock, income and the exchange rate in analysing the trade balance of Columbia. Rincón (1999) finds that there is a significant positive relationship between the exchange rate and the trade balance. The analysis is extended to include a vector error correction model which shows that there is no J-curve present in the case of Columbia; the effect on the trade balance is positive throughout. Adjustment takes place at the rate of 7% per quarter which implies a very long adjustment process.

Kale (2001) also uses the non-structural approach but does so using Turkish data. The Turkish trade balance responds positively to a depreciation in the long run. However, the short run picture is a lot more complicated. In the very short run the trade balance improves in response to a depreciation. However, in the third period the trade balance deteriorates, possibly reflecting the delayed import of capital inputs. This purchase is delayed until it becomes apparent that the depreciation is not temporary.

3.4.2 Testing the Small Country Assumptions

Small countries will have no effect on the world price of the goods they trade because they do not have any significant market share. Implicitly one can assume that all LDCs

are small countries according to this definition. Riedel (1988) tests whether this assumption is justified in the case of Hong Kong's manufactured exports. Export demand and supply equations are specified. The results show that the export demand curve is infinitely elastic. This confirms the hypothesis that Hong Kong is a small country. The data was not tested for stationarity thus the findings may be spurious.

Muscatelli, et al. (1992) also examine Hong Kong's exports but find different results. A totally different methodology is used as Muscatelli, et al. (1992) use the Phillips-Hansen cointegration estimation method to correct for endogeneity and serial correlation. The systems of equation approach is also used but, whereas Riedel (1988) normalised the demand equation using price and the supply equation using quantity, Muscatelli, et al. (1992) normalise the demand equation with quantity and the supply equation using price. An error correction model is also estimated to determine the short run dynamics. The results on the supply side are similar to Riedel (1988) but Muscatelli, et al. (1992) find an export demand elasticity of -0.594, implying that Hong Kong does not behave as a small country.

Athukorala & Riedel (1994) respond to the findings of Muscatelli, et al. (1992) by re-estimating the data using the Phillips-Hansen technique and imposing conditions that the coefficients on the world income and export quantity variables must be zero. Athukorala & Riedel (1994) argue that this is a formal test of the small country hypothesis. They find that the coefficients are not statistically significantly different from zero and thus conclude that Hong Kong can be defined as a small country.

Muscatelli (1994) responded to the claims in Athukorala & Riedel (1994) by noting that the new specification of the export demand function in Athukorala & Riedel (1994) does not reject the null hypothesis of no cointegration. Thus the results obtained are spurious. Muscatelli (1994) also points to other studies that have found results similar to Muscatelli, et al. (1992), most notably his own.

One such paper is Muscatelli, et al. (1995), which argues that as LDC's economies grow, increasing product differentiation is likely, in terms of a wider range of products (horizontal differentiation) and more technology-intensive products (vertical differentiation). To capture these effects, Muscatelli, et al. (1995) introduce the absolute capital stock into the estimate of export supply. A structural system of equations approach is used and it is found that the new variables reduce the value of the income elasticities.

It is very difficult to come to any conclusion about the effect of the exchange rate on the trade balance from the developing country evidence. Partly this is because the evidence is so conflicting and partly because of the methodological problems with a lot of the studies. Obviously, cointegration is a key issue and any empirical technique that is used must take account of this.

3.4.3 Developed Countries

Goldstein and Khan (1978) use the structural system of equations methodology to estimate the supply and demand for export functions of eight developed countries. Two different specifications were used. In the first, it was assumed that exports respond to price changes within the first quarter after the change. The second specification, termed the disequilibrium model, assumed that there were some lags in the adjustment and used the Koyck transformation for the lag terms. As was pointed out above, the Koyck specification is unsuitable for use in this type of estimation. Goldstein and Khan (1978) also do not test for the stationarity of their data.

Goldstein and Khan (1978) find that their estimates of the price elasticity of demand are higher than those found by other studies. This may be partly because a supply curve is estimated whereas other studies assumed an elastic supply curve. The study was unable to conclude whether the equilibrium or disequilibrium model was superior. When using the disequilibrium model, the lagged effect was found to last less than a year. However, as was mentioned above, this may be because of the use of the Koyck model rather than some other lag specification.

Goldstein, et al. (1980) test whether the price of non-traded goods is a significant determinant of the demand for total imports using the structural system of equations methodology. The price of non-traded goods is found to be insignificant. Using only the price of imported goods did not affect the explanatory power but did yield more significant and larger price elasticities. The price elasticities of import demand varied from -0.036 for Italy to -0.877 for Austria. In both of these countries, a depreciation will increase the total value of imports. The rise in the value of imports will be much higher in Italy.

Miles (1979), a monetarist, uses a non-structural equation but only uses the money stock, the nominal exchange rate and government expenditure as the regressands for ten developed countries. It is argued that one cannot use ordinary least squares (OLS) because it assumes that the errors of the individual country equations are unrelated. However, the world trade balance must be zero therefore the errors may not be independent. Thus, Miles (1979) estimates the equation using seemingly unrelated regressions. Miles (1979) finds that there is no improvement in the trade balance following a devaluation, although the balance of payments does improve but only for two years. The coefficient on the exchange rate variable is insignificant. These results stand, even once leads and lags are introduced into the regressions.

Himarios (1985) provides a strong critique of Miles (1979). The first major point is that there is no theory, which states that the nominal exchange rate has any effect on trade. What is important are the relative prices of tradables to non-tradables and of import substitutes to imports (in both the foreign and the domestic markets). Thus any regression including the nominal exchange rate is misspecified. Himarios (1985) contends that the estimation of seemingly unrelated regressions using OLS is inappropriate. To remedy this situation, the exchange rate variable is changed to the real exchange rate. Domestic and foreign income variables are added. Himarios (1985) estimates the regression and finds that the coefficients on the exchange rate variables are significant and positive in nine out of the ten countries analysed.

Mahdavi (2000) examines the price response to exchange rate changes for the United States, Japan and Germany. Not surprisingly, all of these countries push some of the benefits of a depreciation onto their export price. However, what is interesting is that exporters do not respond to exchange rate fluctuations symmetrically. Japanese firms try to keep their foreign currency price constant during a depreciation of the Yen more than they do if it appreciates. German exporters worked the opposite way around. This means that trade balance responses to Yen fluctuations will be greater for an appreciation than for a depreciation. It also means that *“the role of the exchange rate in determining the size of the trade balance of a country may be less predictable in view of the possibility of asymmetric responses on the part of its major trading partners (Mahdavi, 2000: 75).”* This may have implications for our study.

Shirvani & Wilbratte (1997) estimate a non-structural model using Johansen cointegration for bilateral trade between the U.S. and six other OECD countries. The exchange rate is found to be cointegrated with the trade balance in the long term in every case except for Italy. An error correction model finds that the short run response is quite small. In two cases the effect is positive, in two cases there is no response followed by an improvement and in the last two cases there was a J-curve. However, all of the error correction coefficients were insignificant. For time periods over six months there was a significant effect. Shirvani & Wilbratte (1997) term this effect (i.e. no effect followed by an improvement) the backward L curve. The case of Italy is very interesting. The exchange rate affects the trade balance for time periods between six and twenty four months but not in the long term. Shirvani & Wilbratte (1997) conclude that this is because Italy is a high inflation economy. Thus, a depreciation of the exchange rate would lead to an increase in exports but also an increase in local prices in all of the countries studied. In Italy, the price increase will erode any competitive gain that accrued because of the depreciation, over the long term.

The evidence from developed countries cannot lead to a definitive conclusion regarding the effect of the exchange rate on the trade balance. One possible inference is that the effect varies from country to country. As this project is focussed upon the South African

mining sector, a closer examination of the evidence for South Africa and for the mining industry is necessary.

3.4.4 South African Evidence

Bhorat (1998) uses the structural system of equations method in order to find the income and price elasticities of South African manufactured exports. In order to nullify the problem of simultaneity, it is assumed that the demand for exports curve is perfectly elastic. This assumption is not unwarranted given that South Africa is probably a small country. Bhorat (1998) estimates elasticities using disaggregated manufacturing data for seven industries. The most striking result is that South African exports are negatively correlated with our own national income. This validates the so-called vent for surplus theory of exports put forward by Adam Smith. It is argued that exports occur because local firms have produced too much and are trying to sell the excess in other markets. Bhorat (1998) contends that this means that local firms are not actively targeting export markets.

On the negative side, some of the results are very inconsistent. For example, the elasticities of the local price vary from -7.4 to 4.4 and are not consistent in sign or significance. One would expect this elasticity to be negative because as the price of domestic goods goes up, producers will start shifting some of their export production to local consumption. Bhorat (1998) finds four positive elasticities and three negative. The elasticity for total exports is positive, as expected. The inconsistency regarding signs is a problem but this is exacerbated by the fact that only one of the seven coefficients is insignificant. Significant coefficients with the wrong sign point to either data inconsistencies or econometric misspecifications. The elasticities of the foreign price variable are significant in only four industries. This is consistent with the vent for surplus theory as this predicts that exports are not dependent on price. Bhorat (1998) does acknowledge that the sample size is smaller than the optimal and this probably causes the inconsistency regarding signs. An error correction model is also specified and the results show that exports are generally unresponsive in the short term to changes in price. This confirms the other findings.

Bhorat (1998) does test for cointegration of variables but does this using the Augmented Dickey-Fuller Test. This is inappropriate if the cointegrating relationship contains more than two variables.

Behar & Edwards (2003) repeat the experiment but use the Johansen technique instead of OLS, which was the preferred method of Bhorat (1998). The use of a more sophisticated technique allows Behar & Edwards (2003) to dispense with the assumption that the demand for exports is elastic. The price elasticity of demand is found to range between -3 and -6 , depending on the specification used. These elasticities are large, suggesting that South Africa behaves similar to a small country (case 2 above). A depreciation thus improves export prices measured in domestic currency and thus stimulates export supply. The elasticity of supply is about one. These results indicate that a depreciation of the Rand will boost manufacturing exports and, given the elastic nature of export demand, improve the manufacturing trade balance.

Behar & Edwards (2003) do not find any link between capacity utilisation and export supply. Thus, neither the exports as residuals argument, nor the Keynesian argument that exports are exogenous and serve to generate demand, could be tested. One problem is that the export price index on the supply side of the model is not converted into local currency. This specification error will affect the results obtained and makes interpretation very difficult.

Smal's (1996) findings agree with Bhorat (1998) that South Africa's exports are principally a vent for surplus. In addition, Smal (1996) argues that a depreciation of the exchange rate will lead to an improvement of the current account. However, there are serious methodological problems that Smal (1996) does not account for in coming to this conclusion. Smal (1996) uses the structural system of equations methodology. However, only demand equations are estimated under the assumption that the supply of exports and imports are perfectly elastic. No justification is given for this assumption. According to Goldstein & Khan (1978:275), "*While the assumption of an infinite price elasticity seems*

reasonable a priori in the case of the world supply of imports to a single country, this assumption carries far less intuitive appeal when applied to the supply of exports of an individual country.”

Smal (1996) specifies demand functions for non-oil imports, non-gold merchandise exports, manufactured exports and commodities and minerals exports. It is argued that oil imports in the period under study (1985:1 to 1994:4) were often for strategic purposes rather than market considerations. Oil is therefore excluded from the sample. Similarly, the quantity of gold exported is argued to be dependent on the supply of gold, which is determined by non-market factors such as the grade of ore being mined in that period. Thus, gold is excluded from the data. The demand functions are estimated using OLS. The price elasticity of imports is found to be 0.85 while the export price elasticities range between 0.31 and 1.4.

Because the sum of the prices elasticities (approximately 1.43) estimated by Smal (1996) satisfies the Marshall-Lerner condition, a depreciation of the exchange rate is expected to improve the trade balance. The Marshall-Lerner condition only applies if the supply of exports and the supply of imports curves have an infinite price elasticity. Thus, I would argue that this finding cannot be accepted because it is vitally dependent on the untenable assumption of an infinitely elastic exports supply curve.

Kahn (1987) reinforces the assumption that South Africa is a small, less developed country. The central focus of this paper is import penetration and import demand. In a small country one would expect high levels of capital imports, especially machinery. A structural system of equations method is used but the import supply function is assumed to be perfectly elastic. This is a tenable assumption if South Africa conforms to the small country model, as one would expect it to on the import side. The equations are estimated using Almon lags to avoid the problem associated with the Koyck Model. Import demand and import penetration functions are estimated for manufacturing and agriculture. The import demand elasticity for manufacturing is found to be 1.15 while the elasticity for gross domestic expenditure is much higher at 2.16. This is consistent with our

expectations. Elasticities are lower for agriculture. When the data was examined at the industry level it was found that price elasticities for chemicals and machinery were lower than total manufacturing while the activity elasticities were higher. Again, this points to South Africa being dependent on imports for capital goods. The level of these imports is determined more by the business cycle in South Africa than the price of the goods (and hence the exchange rate). Kahn (1987) unfortunately does not test for the stationarity of the data, which is quite understandable given the age of the study. This means that one must be circumspect in using the results obtained because the regressions may be spurious. Even though income seems more important in determining exports than price, we can still apply this study to the question of the exchange rate effects on the trade balance. This study suggests that import demand is actually quite elastic. Thus, one would expect a depreciation to improve the trade balance.

Naudé (2001) examines the effect of transport costs on South African exports, arguing that transport costs may be so high as to preclude South Africa from using an export dominated development strategy. South African shipping costs are 50% higher than developed countries costs and marginally more than the developing country average. A structural system of equations method is used but only the supply of exports curve is estimated with the implicit assumption of infinite price elasticity of export demand. The margin between the cost-insurance-freight (CIF) and free-on-board (FOB) prices is included as one of the explanatory variables. Tests of cointegration failed to reject the hypothesis of no cointegration, thus all regression were performed in first differences. This suggests that the exchange rate plays no long term role in determining the trade balance.

The results of the regression analysis showed that the real exchange rate, imports and shipping costs all had statistically significant effects on the first difference of export supply. Naudé (2001) included imports on the assumption that South Africa was a capital importer and that these imports are used as inputs in exports. The results confirm this, as the coefficient is negative and significant. Shipping costs do play a role but this is quite small. They are important as shipping costs will incurred in transporting capital inputs

from abroad and in shipping the final goods (Naudé, 2001). Although the impact of shipping costs is small, they may limit the amount that the exchange rate can affect the trade balance because they dampen trade. Thus we may expect South African price elasticities to be lower than those for a similar country which is located closer to the first world countries.

Naudé (2000) focuses on the determinants of export supply in South Africa. Export supply is specified as being a function of the real effective exchange rate, South African GDP, world GDP (US GDP was used as a proxy), imports, labour productivity, capacity utilisation and the share of manufacturing in total output. A Johansen-Juselius test for cointegration is performed but no cointegrating vector is found, meaning that there is no long run relationship between the variables. This is quite surprising and means that any regression used has to be in first differences. Again, this implies that there is no long run relationship between the trade balance and the exchange rate. There can only be a short run relationship. The regression was run but none of the coefficients were found to be significantly different from zero. The Ramsey RESET test was performed and the functional form used was found to be appropriate. Most of the coefficients had the expected sign but this has no real importance because of the lack of significance.

One reason for the lack of significance could be because both Naudé (2000) and Naudé (2001) used the incorrect relative price variable. Both studies used the real effective exchange rate, which measures South African prices against a basket of foreign prices (therefore P^D/P^*). However, the relative price on the supply side should be the price of exported goods compared to the price of domestic goods (therefore P^X/P^D). On the demand side the relative price is the export price divided by foreign prices (P^X / P^*). Therefore the real effective exchange rate does not capture the correct relative price for either the demand or supply side. This is a serious error that will invalidate the results found.

Golub & Ceglowski (2002) make a similar mistake in their effort to study how the exchange rate has affected the competitiveness of South African manufacturing firms.

The real effective exchange rate appears in both the import demand and export demand functions that are estimated. Golub & Ceglowski (2002) use a number of different specifications of the real effective exchange rate. One of them is using unit labour costs as a proxy for prices. Thus,

$$REER = \frac{ULC_{SA}}{eULC_f}$$

where ULC is the unit labour cost and e is the exchange rate. In a small

country one would expect the exchange rate and the export price index to move together as there should be pure pass through. Thus, one could substitute the export price index for the exchange rate. In the event of a depreciation, the price of exports would increase by the amount of the depreciation while unit labour costs would not increase the whole amount due to the fact that labour is a non-tradable. Thus firms would *supply* more to the export market. Thus a demand for exports equation using this form of the real effective exchange rate would be misspecified. In effect, what Golub & Ceglowski (2002) interpret as negative demand coefficients may really be positive export supply coefficients

Golub & Ceglowski (2002) face other methodological problems. No cointegrating relationship is found between the variables they specify and the demand functions. In addition, no supply curve is specified. This may be a valid assumption in the case of import supply but it is not for export supply. The elasticity of the real effective exchange rate varied between -0.78 and 0.78 for export demand and 0.2 and 1.05 for import demand.

Tsikata (1994) also falls prey to the mistake of using the real effective exchange rate. Manufactured trade is modelled using the system of equations approach. However, only the demand for imports and supply of exports functions are estimated. The specification of the supply of exports contains the real effective exchange rate, which invalidates the findings. The coefficient on the REER ranges from -0.32 to -0.43 . In addition, the data is not tested for stationarity, thus any findings may be spurious. Tsikata (1994) find support for the hypothesis that exports are merely a vent for surplus, especially in the early 1980s. On the import side, the significant variables are the real effective exchange rate, the lagged real effective exchange rate and national income.

Tsikata (1999) estimated non-structural expressions for exports of manufactured goods. The real effective exchange rate is highly significant and positive in determining exports. Therefore, a depreciation of the exchange rate will lead to an improvement of the trade balance. However, Tsikata (1999) correctly noted that one cannot interpret the coefficient as an elasticity. Tariff levels are negatively associated with manufactured exports. This could be because of the symmetry between tariff and export taxes described by Lerner or because manufactured exports require imported inputs.

Senhadji (1997) estimates import demand functions for 77 developing countries, including South Africa. The import demand function is specified from utility maximization by consumers. The only significant difference between this function and the normal demand function is that the GDP variable does not include exports. The price elasticity of import demand is found to be -0.44 and this coefficient is highly significant. This indicates that a depreciation will lead to an increase in the value of imports. The estimated income elasticity is 0.30 and is also significant. Again it is assumed that the supply of imports curve is elastic.

Senhadji & Montenegro (1997) is very similar to the paper above in that a demand function is derived from microeconomic principles. The difference is that this demand function is the demand for exports. However, it does make a crucial mistake in that there is no estimate of the supply of exports. One can assume that the supply of imports is elastic (as in Senhadji, 1997) but assuming that export supply is elastic is quite heroic. Thus, the estimators face the problem of simultaneity and the estimates will be biased downwards. Export demand functions are estimated for 53 countries of which South Africa is one. The price elasticity and income elasticity are both highly significant. The values are -0.18 and 0.23 respectively.

If one applies the results from both Senhadji papers to the Marshall-Lerner condition, the result $(|(-0.18) + (-0.44)| < 1)$ would seem to indicate that a depreciation of the Rand would lead to a deterioration of the trade balance. This finding is dependent on the

assumption that the supply of exports curve is perfectly elastic. As mentioned above, this is highly unlikely.

3.4.5 Evidence from the Mining Industry

Selvanathan & Selvanathan (1999) study the effects of prices on the Australian supply of gold. Unit root tests show that there is no long run cointegrating relationship between the price of gold and gold production. Thus, all estimation is carried out in first differences. Granger tests of causality show that changes in price Granger cause changes in production but not vice versa. Intuitively, this is a correct result. An extended adaptive expectations model is used to model the supply relationship. The estimated long-run supply elasticity is 1.237. Interestingly, most of the increase in production comes about after a prolonged lag. Indeed, the elasticity only reaches 1.237 after 12 years. The highest change in production only occurs in the third year after a price change.

Selvanathan & Selvanathan (1999) ascribe this to the fact that a change in the gold price will also change future expectations of the long-run price. Expectations determine whether or not new mines are opened. Only if the discounted costs of production are lower than projected revenue will a new mine be set up. Thus, one would assume that there is little scope to change production within existing mines in Australia.

Rockerbie (1999) models the supply relationship for South Africa. The focus of this paper is on cost considerations, specifically in the milling of ore. Ore mills will only accept ore if it can be milled profitably. The grade of ore accepted will therefore depend on the price of gold and the costs of milling. Mines will respond to higher prices by mining areas of lower grade of ore. Rockerbie (1999) argues that if the decrease in the average grade of ore outweighs the increase in ore mined, the supply of gold curve will be downward sloping.

A system of equations was estimated using the generalised method of moments technique. The hypothesis of a downward sloping supply curve was rejected convincingly. The elasticity was found to be 0.492. If the demand for gold is elastic then

this indicates that a depreciation will boost exports. The speed of adjustment to a change in price was found to be very slow. The full effects of a change in price will only be complete after 8 years. These findings correspond with the observations of Keynes (1936), which noted that in the years following a depreciation of the South African currency, gold production actually fell. However, Keynes (1936:414) argued that “*an increase in output is only a question of time.*”

Mainardi (1999) reviews the determinants of gold supply in South Africa. A Koyck model is used to model gold supply with the independent variables being the gold price in Dollars, the Rand/Dollar exchange rate, the grade of ore, a cost-competitiveness index, the size of the mine and the market structure. Alternative tests use the South African gold price. The regression uses data from 1984 to 1995 for 28 mines. As mentioned above, the Koyck model is unsuitable for this type of modelling because it assumes the majority of the change takes place in the first period. Despite this, some important results found.

For instance, the short run elasticity with regard to the gold price in Rands, is found to be negative. Mainardi (1999) argues that this could be due to the fact that the tax paid by mines is linked to the grade of ore mined. Thus, mines’ first concern when the price changes, is to maximise their after-tax revenue. This response is more significant in smaller companies. Natrass (1995) supports this argument.

Similar tests are carried out for other mining industries. Only coal production is found to be significantly linked to its price. This result seems very unlikely. One possible explanation is the significant length of time that production takes to respond to changes in price. The short sample period may not capture these effects properly.

3.5 Conclusion

The issues of which methodology is correct and which variables to include as explanatory variables have been recurrent themes throughout all the empirical work carried out around this question. In some cases the methodology used has been blatantly wrong, while in other cases small mistakes may jeopardise the findings. Bearing all this in mind,

it is hard to come to any conclusion at all. If one was to conclude that the exchange rate does affect the trade balance, there would have to be convincing arguments to explain the findings of papers such as Rose (1990), Rose (1991), Rose & Yellen (1989) and Wilson & Choon Tat (2001). By the same token, any conclusion opposed to the hypothesis that there is a link would have to explain many of the other papers mentioned in this review. Certainly, the majority of studies have found that there is some link but I would argue that the studies showing no connection cannot merely be dismissed. The conclusion may be that the question can only be answered on a country by country basis.

One issue that has not been considered in the literature is the issue of transfer pricing. Kreinin (2001) reports that one fifth of world trade takes place within multinational corporations. Trade carried out on this basis will be largely independent of the exchange rate. Price is determined in this instance by taxes and tariffs and is thus not related to the value of the local currency.

In terms of the South African evidence, the main strands that seem to come out of the literature is that the demand for imports is quite inelastic, as expected for a small country. The other significant finding is that exports may be determined more by a lack of local demand than any price advantage in local markets. This argument is still very tentative given the enormous methodological problems. Indeed the results that the demand for imports is inelastic are highly dependent on assumptions about the elasticity of import supply. If this is less than infinitely elastic, then these findings are also suspect. The issue of spurious relationships is common in the international and South African literature.

The results from the mining literature indicate that mining production is not very sensitive to price in the short run. This is probably because of technical issues. The studies that used longer samples indicate that production only fully responds to price changes after between 8 and 12 years. Thus, the short run effect of a depreciation of the exchange rate may simply be that profits increase, without production changing much at

all. The recent volatility of the Rand may hinder investment in the mining industry because it is harder to tell if the depreciation (and hence, the price increase) is permanent.

University of Cape Town

4. Data Discussion

4.1 Introduction

South Africa's trade has changed remarkably over the last 30 years. Of note has been the decline of gold exports with manufacturing rising to take its place. The imperfect substitute model argues that these changes will be determined by changes in the relative price between export prices and local prices. This chapter begins to answer the question of whether relative prices do in fact determine the level of trade (specifically in the mining sector) and whether changing relative prices have caused changes in the share of South Africa's trade. Another key question is whether or not South Africa's mining sector trades as a small country would. Finding the answer to this question will help determine what the effects of a depreciation will be on the mining sector trade balance. This chapter provides a preliminary answer to this question. A graphical analysis of the exchange rate effect on the mining trade balance is carried out. This chapter also introduces the data that will be used in the estimation.

4.2 A Description of South Africa's Trade

South Africa has a well diversified range of exports but it still displays some of the characteristics of a middle income country. On the export side, over half of all exports are manufactured. However, a large proportion of these manufactured goods are in fact heavily resource based. On the import side, South Africa is dependent on trade for capital goods and oil. The largest category of imports by far is machinery, contributing 27.85% of total imports (SARS, 2003).

The next largest import is mineral products, which includes crude oil at 13.19%. Chemicals account for 11.13% of all imports. South Africa is relatively independent in terms of food, which is less than 5% of imports (SARS, 2003).

The four largest export classifications are: precious metals (19.57% of total exports), mineral products (13.72%), base metals (13.52%) and unclassified goods, which includes the platinum group of metals (9.23%). These four sectors make up 56.04% of total

exports. Although mineral products, base metals and part of the unclassified group are manufactured exports, these groups are still resource dependent. Other manufactured exports in the form of machinery at 8.81% and vehicles at 8.72% make up the next two biggest sectors. The mining industry is obviously very important with the two largest export sectors (SARS, 2003).

Given this pattern of trade, one might expect that South Africa may face the second case that was put forward above, namely the small country case. As was noted above, this may hold for the manufacturing sector in the short run. However, there is reason to believe that this is not necessarily true for the mining sector. South Africa's two most valuable mineral exports are gold and the platinum group metals. South Africa is the world's largest gold producer at 15.1% of world production. In the platinum metals South Africa holds a 50.5% market share (Chamber of Mines, 2001). These large market shares may allow South Africa some discretion in determining prices through changes in export supply. Swift (1998) refuted the small country argument for Australia based on these exact arguments. Thus, instead of a perfectly elastic demand curve, South African mineral exports may be faced by a downward sloping curve, though the curve will still be quite elastic.

On the import side, the small country case is likely to hold in terms of the fact that the supply of imports will quite likely be close to perfectly elastic as prices are generally fixed in foreign currency. One would expect the demand for imports curve to be quite inelastic as South Africa's main mineral import is crude oil. There are few substitutes for oil (though South Africa is one of the few countries with a viable alternative, in SASOL) thus the price elasticity of demand is likely to be very low. In the long run both the demand and supply of imports is likely to become more elastic, especially demand. Supply would change less because prices would still be determined in world markets, even in the long term.

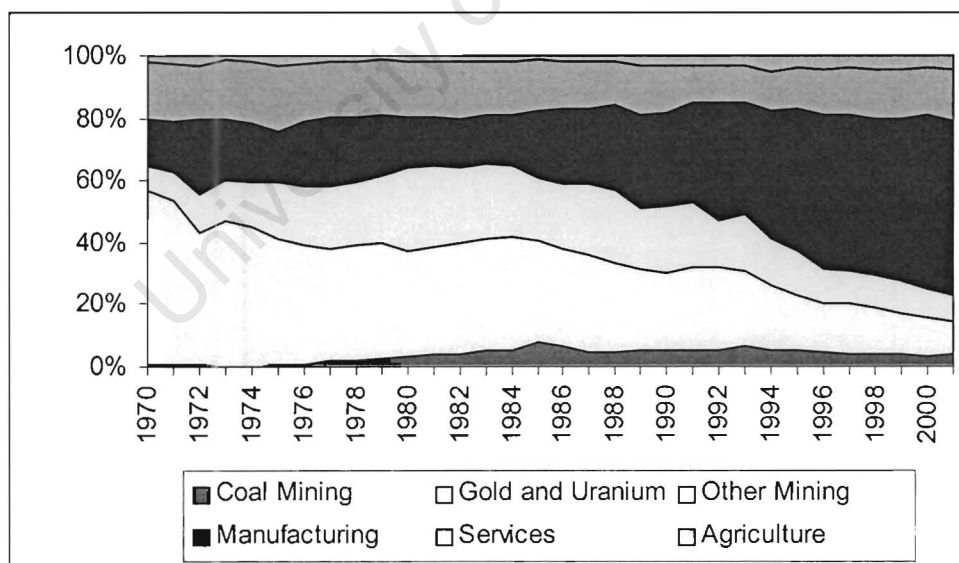
In the long term we may find that the supply of exports becomes more elastic. In the event of local recession, domestic firms may look to foreign markets to sell their surplus

production implying a more elastic export supply curve. Thus, the elasticity of export supply may depend on the state of the business cycle.

4.3 The Changing Nature of South Africa's Exports

South Africa has moved from being a producer of mainly primary goods to being an exporter of manufactured goods. This trend is obvious in Figure 6 below. Mining's share of exports remained virtually constant until the mid-1980s and then declined quite rapidly. Coal mining's share of exports has actually risen from 0.37% of exports in 1970 to 3.8% in 2001. Other mining rose from 7.8% in 1970 to a high of 26.6% in 1980 but fell subsequently. In 2001, other mining's share of exports was 8.76%. The majority of the decline in the importance of the mining sector has been due to the decline of gold exports. In 1970, gold was South Africa's dominant export at 56.5% of total exports but by 2001, gold exports were only 10.6% of total exports. Agriculture's share has increased but still remains small. The importance of services declined slowly over the sample. Most of the slack from the decline in gold exports was taken up by manufacturing which increased its share from 14.9% in 1970 to 56% in 2001.

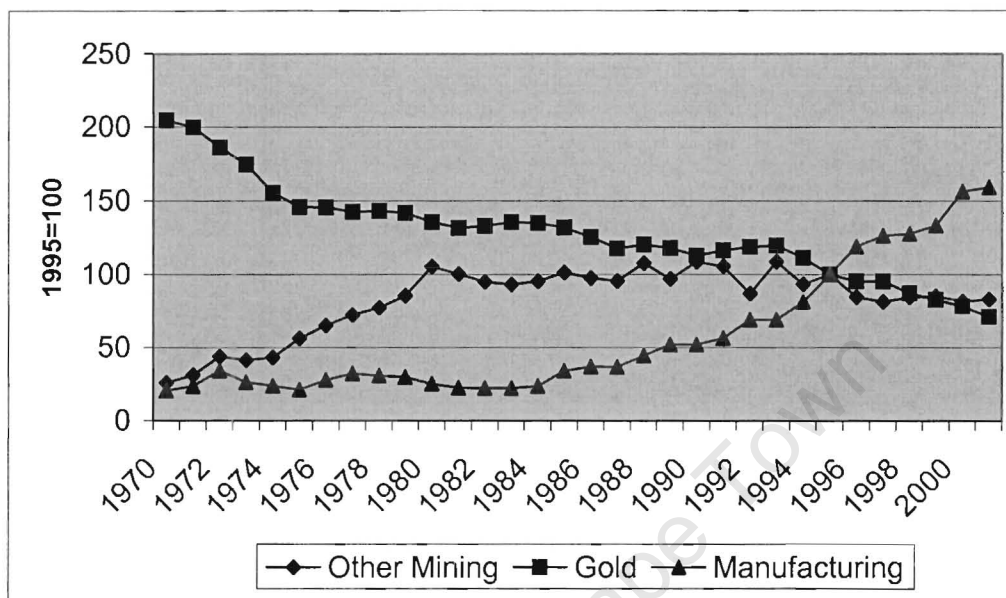
Figure 6: Changing Shares of Real Exports



Source: TIPS

The decline in mining is not only due to faster growth of manufacturing exports. Mining exports have been declining as can be seen in Figure 7 below.

Figure 7: Export Performance



Source: TIPS and the Chamber of Mines

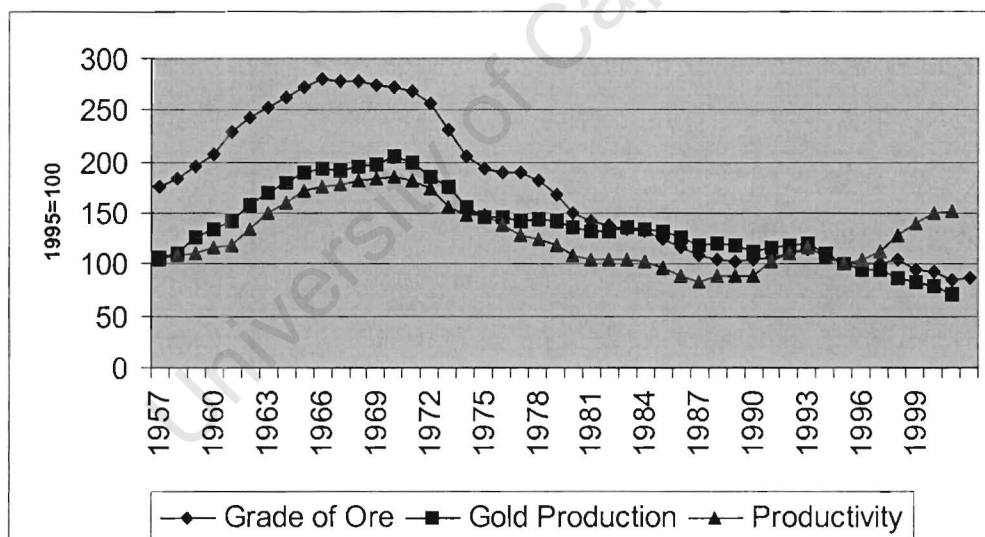
The other mining sector's exports remained more or less constant from 1980 until 1996, when there was a 20% drop in exports. Exports have stabilised at this level again. The quantity of gold exported has been declining since 1970, to just more than a third of their 1970 level. The decline was particularly acute during the early 1970s and the mid-1990s. Gold exports declined by about 4% per annum during the 1990s. In contrast to mining, the quantity of manufactured exports has steadily increased. Since 1983, growth in exports has been negative only once (1987) when there was only a 0.5% decline. The average real growth in manufactured exports since 1983 has been 11% per year. It is the one of the aims of this project to determine whether mining's declining share is because of declining prices or other factors.

Obviously a key part of the answer to this question will involve explaining why gold exports have declined so much. Looking at Figure 8 below, it is quite obvious that the greater part of the reduction in gold exports can be explained by the decline in the grade

of ore mined (where the grade is measured in grams of gold per ton of ore). However, it is important to note that the price of gold will affect the grade of ore that is mined. A higher gold price will lead to a lower ore grade as the higher return allows mines to exploit marginal ore grades. Generally though, the ability of gold mines to respond to the gold price will be determined by the grade of ore available.

Productivity is also clearly linked to the grade of ore mined. However, it is noticeable that productivity breaks away from the downward trend of grade of ore, from 1985 onwards. The most likely explanation for this is the continuous improvement of technology in the gold mining sector, which has allowed mines to extract more gold from the same amount of ore. The effect of this can also be seen in the gold production series, which does not decline as fast as the grade of ore. Employment in the gold sector also declined from a high of 534 255 in 1986 to 197 537 in 2000. This would also lead to productivity increases.

Figure 8: The Grade of Ore Mined, Gold Production and Productivity.

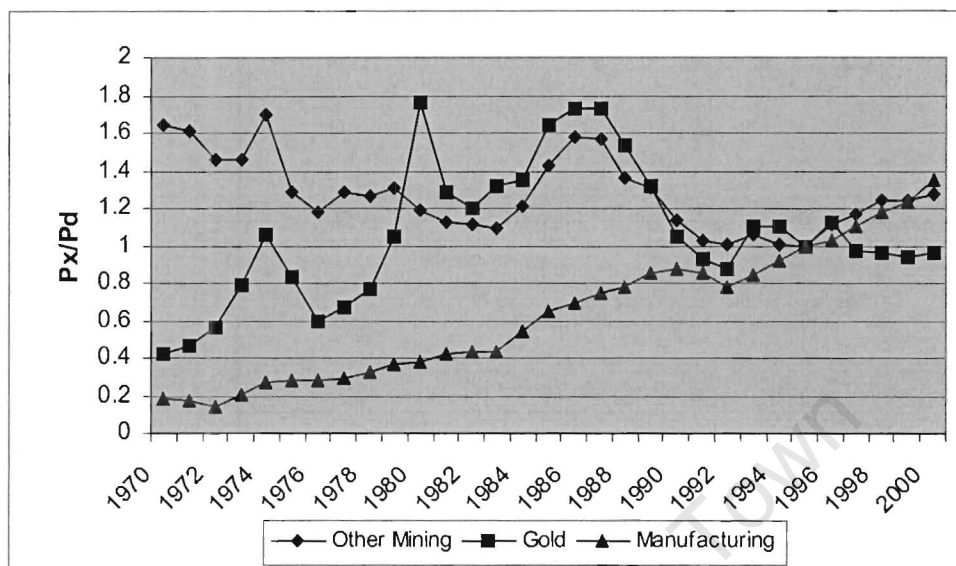


Source: Chamber of Mines

The grade of ore mined will not be the only factor determining gold output. One of the key questions for this project is, does South Africa's mining trade respond to changes in price? We can start examining this question by looking at how relative prices (i.e. the export price divided by PPI, a proxy for local prices) have changed. Exporters will decide whether to supply the local market or the export market based on the ratio of the export

price (in Rands) to domestic prices. If the ratio increases, more production will be sold in overseas markets and obviously, if the relative price decreases, the opposite will occur.

Figure 9: Changes in Relative Prices



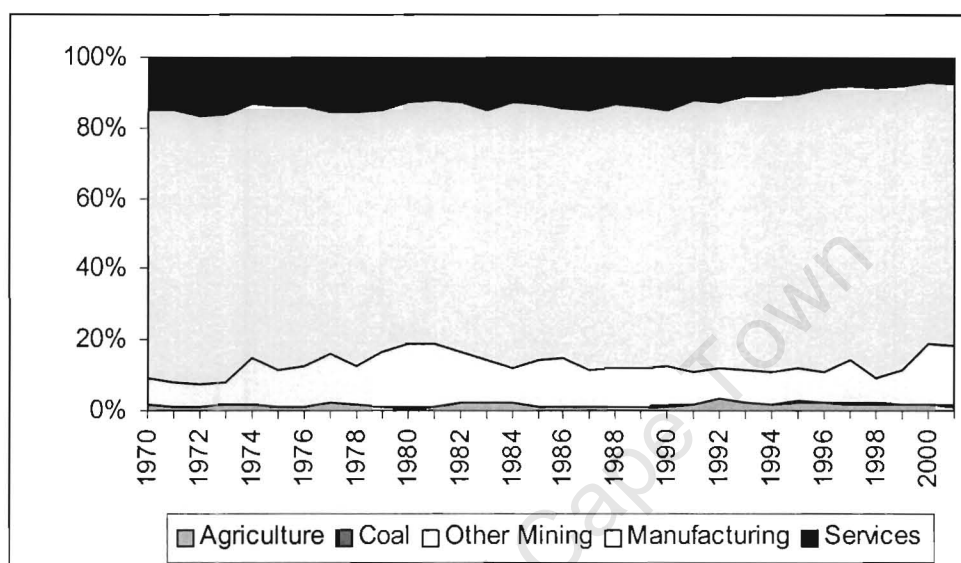
Sources: Statistics SA, Chamber of Mines and TIPS

Figure 9 above illustrates how these relative prices have changed over the last 30 years. It is noticeable that while mining prices have been very volatile, the relative price of manufacturing has been steadily increasing. Since 1970, the relative price of manufactured exports has grown six fold, with average annual growth of over 7.5%. Thus, manufacturers will have a much greater incentive to sell their output on world markets, than locally. Export prices decreased in 1991 and 1992, probably due to the recession in overseas markets. Gold's relative price shows peaks in 1980 (following an 88% increase in the local gold price) and the mid-to-late 1980s as the Rand depreciated. Other mining is very similar except it does not peak in 1980. On the evidence of the graphs, it would appear that the changing shares of total exports are closely related to changes in relative prices.

The shares of total imports, in contrast with exports, have remained fairly constant, as is obvious in Figure 10 below. The one exception to this is the Other Mining category, which includes crude oil. In 1970, its share of total imports was 7.4%. This figure has

increased to nearly 17% in 2001. There are noticeable peaks in the figure due to the oil shocks of 1974 and 1979. There was also a very sharp increase in other mining's share of imports in 2000. Coal imports have increased from virtually nothing in 1970 to 0.4% of imports in 2001. The share of services has decreased slightly over the sample period, while manufactured imports remained fairly constant.

Figure 10: Shares in Imports.



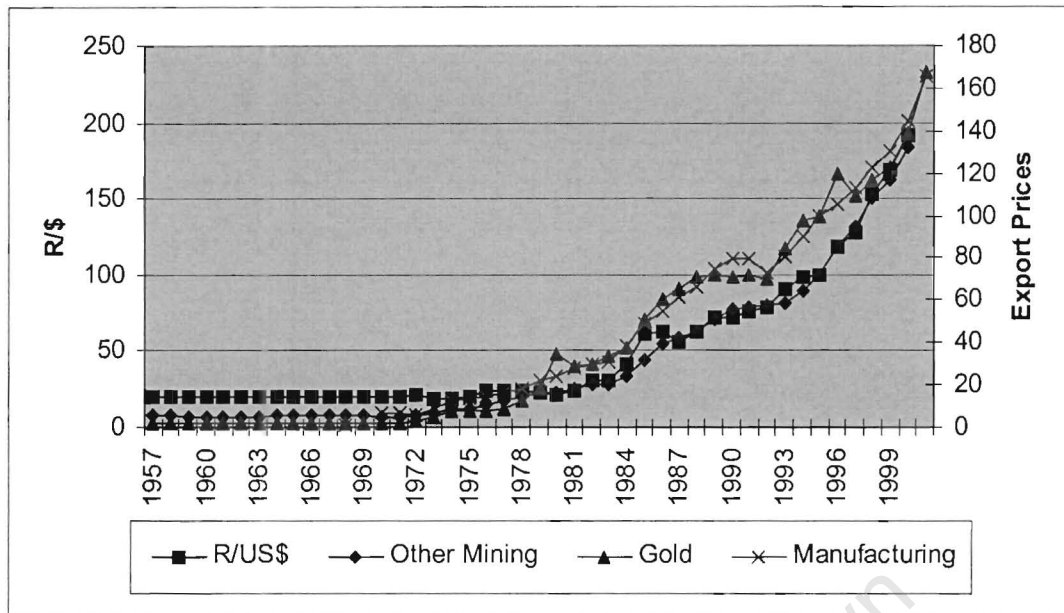
Source: TIPS

4.4 Does South Africa Fit the Small Country Model?

A small country faces perfectly elastic demand for exports and supply of imports curves. Thus, in the event of a depreciation of the currency, the price of imports and exports in the local currency will increase by the amount of the depreciation. If South African mining exports and imports follow the small country model, then one only has to estimate an export supply and an import demand function. Simultaneity will no longer be a problem as prices will be determined exogenously in world markets.

Reviewing the data graphically will start to answer the question of whether South Africa trades as a small country. The question is reviewed more rigorously in the following chapter.

Figure 11: Export Prices and the Exchange Rate



Sources: Chamber of Mines and TIPS

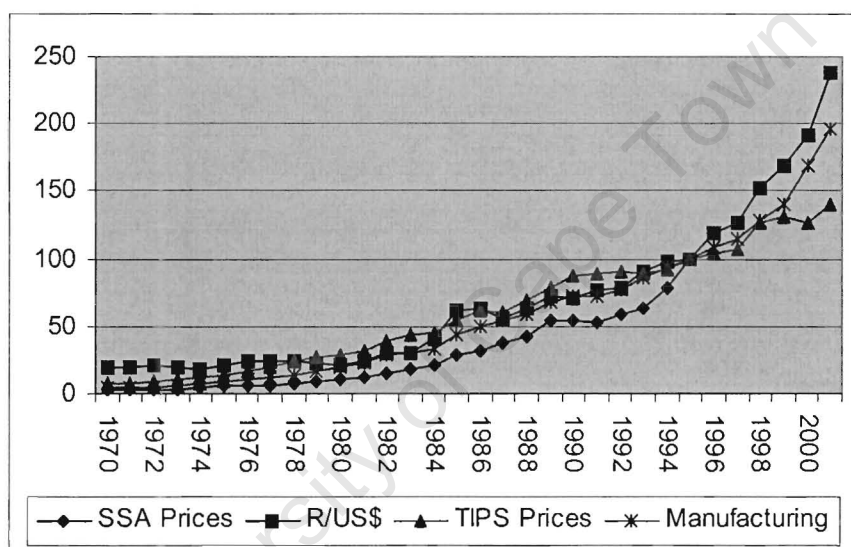
Figure 11 above shows the price that South African exporters received (in Rands) for exports of Gold, other mining and manufacturing. Other mining shows a very clear correlation with the exchange rate, although it does not track the Rand volatility in the early 1980s. The relationship with gold is slightly less clear but the prices of all mining products have clearly increased as the Rand has progressively depreciated. Similarly, there was very little variation in the price of exports while the Rand was set at a fixed value, pre-1971. The price of Gold was fixed by the US Treasury until 1971. Before 1968 the price was quite stable but rising U.S. inflation meant that adjustments were taking place quite often until the end of 1971 when President Nixon abandoned the gold standard and gold was allowed to float (Only Gold, 2003; Botha, 1972). Since then, the price has been quite volatile.

Examining Figure 11 reveals that South African manufactured exports show a strong link to the exchange rate, although not as strong as the other mining sector. It is likely that manufacturing is more independent of the exchange rate than mining products. This could be explained by the fact that there is greater product differentiation in manufacturing than there is in mining where the goods are uniform. Branding allows producers some discretion in setting their own prices as consumers have developed a

taste for the brand as opposed to other similar products. There is still a clear upward trend in the export price as the currency depreciates.

The correlation coefficients confirm the above analysis. They are 0.993, 0.945 and 0.972⁴ for other mining, gold and manufacturing respectively. Thus, one could argue that the price of South Africa's exports is very closely related to the exchange rate. This is exactly what one would expect from a small country. On the import side, a small country would absorb any changes in its exchange rate into import prices (in local currency) without affecting world prices at all, as shown in scenario 2 above.

Figure 12: Import Prices and the Exchange Rate



Source: TIPS and Statistics SA

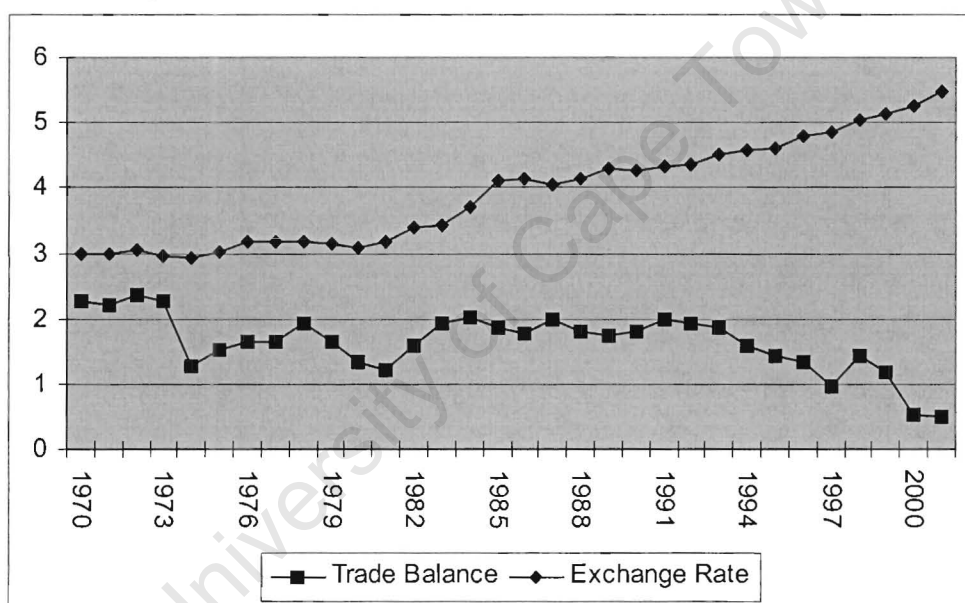
If the currency of a large country depreciated, then the price of imports would increase and this would decrease the quantity of imports (as in a small country). However, because the large country consumes a large portion of world production, this would affect world prices. Exporters from foreign countries would try to limit this effect as much as possible by absorbing some of the price increase. Thus, the full effect of the depreciation is not felt on import prices in the large country.

⁴ These correlation coefficients should be interpreted with caution as there is a strong likelihood that the series are non-stationary.

In Figure 12 above, South Africa once again resembles a small country. All the import prices follow the general upward trend with the Rand's depreciation. The TIPS data shows a big increase in import prices following the devaluation in 1985, which the other data does not chart as well. Manufacturing prices increases are not quite as large as the Rand depreciation. This may be due to import substituting. Import substitution is not as viable in the mining sector because the ability to substitute will depend largely on the availability of mineral reserves. Thus, for example, an increase in the price of crude oil will lead to minor import substitution because of the low availability of substitutes.

4.5 The Exchange Rate and the Mining Trade Balance

Figure 12: The Mining Trade Balance and the Exchange Rate



Source: TIPS and Statistics SA.

The graph above shows the movements of the mining trade balance and the exchange rate. The trade balance is calculated as the natural log of the ratio of exports to imports [i.e. $\ln(X/M)$]. This formulation of the trade balance means that it is independent of the currency that it is expressed in. From the graph above there is no obvious correlation between the trade balance and the exchange rate. If anything, the correlation seems to be negative as seen by the increasing exchange rate and decreasing trade balance. There are two possible explanations for the lack of any visible relationships. Firstly, there may be

no relationship. Secondly, there may be significant lags (as suggested by the previous empirical evidence).

4.6 Data Sources

Table 1 below provides the name, code and source for all the data used in the estimation of the regressions carried out in the next chapter. All data was converted to indices with 1995 as the base year. Natural logs were taken of all series so that the coefficients in the regressions could be interpreted as elasticities.

Table 1: Data Sources

Variable	Description	Source
PG	Price of Gold in Rands.	Chamber of Mines Annual Report 2001
XG	Gold Production. It was assumed that South Africa does not consume any gold so the total output is exported. In reality, about 1% of production is consumed locally.	Chamber of Mines Annual Report 2001
E	Rands per US Dollars. The Rand/Dollar exchange rate was used because resources are priced in Dollars.	South African Reserve Bank (SARB)
GW	Wage per worker in the Gold sector. Calculated as total wage bill divided by employment.	Statistics South Africa (SSA)/ Chamber of Mines Annual Report 2001
GRADE	Grade of ore mined. Grams of gold per ton of ore milled.	Chamber of Mines Annual Report 2001
PPI	Producer Price Index for the mining industry.	Statistics South Africa
GPROD	Gold productivity. Calculated as gold production divided by gold employment.	Chamber of Mines Annual Report 2001
TAR	Tariff collection.	Trade and Industry Policy Strategies (TIPS).
PWG	World Price of Gold in US Dollars.	Unites States Geological Survey statistical database.
PX	Price of exports for non-gold export in Rands. Data merged from two different sources.	Statistics South Africa (1957-1969)/ Trade and Industry Policy Strategies (1970-2001).
X	Non-gold exports.	Statistics South Africa (1957-1969)/ Trade and Industry Policy Strategies (1970-2001).
W	Wage per worker for the non-gold mining sector. Calculated as (Total Mining wages-gold wages)/(Total mining employment-gold employment).	Statistics South Africa/ Chamber of Mines Annual Report 2001
PROD	Productivity in the non-gold sector. Calculated as output/(Total mining employment-gold employment).	Statistics South Africa/ Chamber of Mines Annual Report 2001
PW	World price for non-gold exports, in Dollars. Calculated with weighting based on 2001 exports. As such, the price is biased in favour of platinum, which made a large proportion of exports in 2001 but whose share of exports has increased throughout the sample.	Unites States Geological Survey statistical database / Chamber of Mines Annual Report 2001

M	Imports of mining products.	Statistics South Africa
PM	Price of imports. Calculated by using an import deflator.	Trade and Industry Policy Strategies (TIPS).
GDP	Gross Domestic Product of South Africa.	South African Reserve Bank (SARB)
OILM	Oil consumption. Assumed that all consumption is imported.	BP Statistical Review of World Energy June 2002
OILP	World oil price in dollars (Brent Crude).	International Financial Statistics.
SAOILP	Price of oil converted into Rands.	International Financial Statistics / South African Reserve Bank (SARB)

Vector error correction models require long time series because the technique is relatively intensive in its use of degrees of freedom. This presented a problem as two different data series had to be used for the trade data alone. The Trade and Industrial Policy Strategies (TIPS) database had trade data from 1970 to 2001. It was felt that this time period was too short. Statistics South Africa published trade data from 1922. However, this series was stopped in 1997 with the last observation being 1995. Obviously, the more recent the data is, the more applicable the findings of this study will be. Thus, the idea of using SSA data solely was rejected. Therefore the only viable option was to splice the data to produce long time series, if possible. The overlap of the observations was used to judge how valid the splice was. Obviously the use of a splice means that one must carefully question any results obtained but it was felt to be the only viable option, given the deficiencies in the data. Splicing is not desirable but it is, unfortunately, necessary.

The SSA data was taken from the indices of volume and price for the mining and quarrying sector. The TIPS data consisted of values of trade and unit values for various sectors. The sectors that were used were coal mining and other mining. The main exports included in the other mining category are the platinum group metals, iron ore and copper. Less important minerals include manganese, diamonds, chromite, lead, nickel and silver. The value of trade was deflated using a CPI index. Import prices were calculated by dividing the nominal value by the real value, in effect calculating an import deflator index.

The price data from the two different data sources was very highly similar with correlation coefficients of 0.95 and 0.99 for imports and exports respectively. Export

quantities were also found to be highly similar with a correlation coefficient of 0.92. Imports however, appeared to be almost unrelated. While the peaks and troughs often coincide, the relative size differs. Where the TIPS data shows imports to be relatively constant, the SSA data shows a declining trend. The correlation coefficient was only 0.18. It was decided that it would be unwise to attempt to splice the two series, as they were too dissimilar. When the estimation was attempted, only the SSA series provided plausible results. Thus, it was decided to dispense with the TIPS data and merely estimate using SSA data. Obviously, the results must be interpreted with a great deal of caution because the time series is shorter than optimal.

The source for all the gold data was the Chamber of Mines. This source allowed the use of one continuous series, which was preferable to using spliced data, in addition to being from the horse's mouth, so to speak. The Chamber of Mines data was only for gold sales not exports. It was assumed that local sales would make up a relatively minor part of total production, thus one could equate production with exports. There is some data available for local sales of gold in the last five years. This reveals that local consumption was usually less than 1% of production. Mining wages and a producer's price index for mining were both obtained from SSA.

4.7 Conclusion

South Africa's exports seem to have changed in line with prices. The exception to this is gold whose decline appears to be mainly a function of falling ore grades. Imports have been fairly stable, except for the decline of manufactured imports during the 1980s, most probably due to sanctions and the balance of payments adjustment due to disinvestment. On both the export and import side, the preliminary analysis suggests that South Africa fits the small country predictions. There appears to be no relationship between the mining trade balance and the exchange rate.

5. Results

5.1 Introduction

Examining graphs can provide one with a basic understanding of the dynamics underlying a system. This chapter turns to econometric techniques to confirm or deny hypotheses. The Johansen technique was used because it allows one to estimate systems where all the variables are endogenous. This overcomes the problem of simultaneity that was found in some of the other studies. In addition, this technique overcomes the problem of spurious correlations.

5.2 Estimating Procedure

The Johansen cointegration technique relies on all the variables used being stationary after being first differenced (i.e. all variables had to be an $I(1)$ process). Thus, the first step was to apply the augmented Dickey-Fuller (ADF) Test to all the variables. The results of these tests are recorded in Appendix A.

The next step was to test for the order of the vector autoregressive (VAR) regression. The order of the VAR is selected such that the residuals are normally distributed, show no serial correlation and no heteroscedasticity. Although the Aikake and Schwarz Bayesian Criteria were used in selecting the correct lag length, more emphasis was placed on the results of the log-likelihood ratio test, adjusted for small samples because of the shortness of the data series. In all cases, an order of one was selected (the complete test results can be seen in Appendix B). In addition to being the optimal lag length chosen by the tests, selecting an order of one was beneficial for two reasons. Firstly, there was as little loss of degrees of freedom as possible. Secondly, a higher order of the VAR was almost invariably accompanied by serial correlation of the residuals. Thus, choosing an order of 1 added to the robustness of the results. Dummy variables were sometimes included to deal with heteroscedasticity problems or non-normality of the error terms. A dummy variable, D5772, was also used to proxy for the period of fixed exchange rates.

Once the VAR was specified correctly, the Johansen procedure was applied. The Johansen procedure was used because it allows one to estimate regressions with only endogenous variables. For example, it was expected that South African exports of gold would also determine the price of gold. Thus, both the price of gold and exports would be endogenous and traditional statistical techniques (e.g. OLS) would be invalid.

The starting point of the technique is a VAR of I(1) variables of order k .

$$X_t = \Pi_1 X_{t-1} + \dots + \Pi_k X_{t-k} + \mu + \Phi D + \varepsilon$$

where $T=(1,\dots,t)$. D represents dummy variables. Johansen and Julius (1990) used seasonal dummy variables but this project has used dummies to account for shocks in the data. This system can be represented in an error correction model:

$$\Delta X_t = \Pi X_{t-1} + \Gamma \Delta X_{t-1} + \Psi D + \mu + \varepsilon$$

where Π is a $k \times k$ matrix representing long run effects, while Γ reflects the changes towards an equilibrium after a shock to the system. High values indicate a quick convergence (Johansen, 1988). The main benefit of the reparamaterisation is that it allows one to test for any cointegrating vectors in the system by performing tests on the Π matrix alone.

If Π has full rank, it indicates that the system X is stationary. If the rank of Π is zero, it shows that X is a differenced vector time series model. If neither is the case, then the rank of Π is equal to the number of cointegrating vectors (r) and there are matrices, α and β such that $\Pi = \alpha\beta'$. α and β are both $k \times r$ matrices. α represents the short run moves towards an equilibrium (the coefficients of the VECM) and β is the matrix of long run relationships. Thus, we can rewrite the error correction equation as:

$$\Delta X_t = \alpha\beta' X_{t-1} + \Gamma \Delta X_{t-1} + \Psi D + \mu + \varepsilon$$

Johansen and Juselius (1990) provide two tests to determine r . The maximum eigenvalue statistic tests $H_r: \text{Rank}(\Pi) = r$ versus $H_{r+1}: \text{Rank}(\Pi) = r + 1$. The test statistic is calculated from the eigenvalues of the Π matrix. The trace statistic uses the trace of the same matrix. MicroFit also uses tests based on the log-likelihood function of the Akaike Information Criterion, the Schwarz Bayesian Criterion and the Hannan-Quinn Criterion, based on all possible values of r (Pesaran & Pesaran, 1997). In virtually every case, the tests produced inconsistent answers as to how many cointegrating vectors were present. More emphasis was placed on the Trace statistic and the maximal eigenvalue statistic as these tests were specifically designed for this procedure and gave the most consistent results. If the results were still inconclusive, economic theory was used as the final criterion.

Once r was selected, maximum likelihood estimation was used to find the cointegrating vectors. These results can become clearer if restrictions are placed on the values of some of the β s. Economic relationships allow one to determine which coefficients should be restricted. Thus:

$$\Pi X_{t-1} = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \\ \alpha_{41} & \alpha_{42} \\ \alpha_{51} & \alpha_{52} \end{pmatrix} \begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} \end{pmatrix} \begin{pmatrix} PG \\ XG \\ GRADE \\ GW \\ Trend \end{pmatrix}$$

Just identifying restrictions require that there are r restrictions for every cointegrating vector (i.e. r^2 restrictions in total). However, using economic logic as a base, one can apply over identifying restrictions, as such:

$$\Pi X_{t-1} = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \\ \alpha_{41} & \alpha_{42} \\ \alpha_{51} & \alpha_{52} \end{pmatrix} \begin{pmatrix} \beta_{11} & 1 & \beta_{13} & 0 & \beta_{15} \\ \beta_{21} & \beta_{22} & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} PG \\ XG \\ GRADE \\ GW \\ Trend \end{pmatrix}$$

In the equation above, there is one over-identifying restriction. The log-likelihood ratio test is then used to test whether the restriction is appropriate or not. The test statistic follows the χ^2 distribution. In the case above the restriction was not rejected so the over-identifying restriction remained.

5.3 Gold Exports

Demand for gold was assumed to be perfectly elastic. To test this, a VAR was specified with two variables, the export price of gold (i.e the price obtained by South African exporters) and the world price of gold, converted into Rands. The restriction that the two coefficients were equal could not be rejected. This implies that any changes in the world gold price or the exchange rate are passed through onto the export price of gold (i.e. pass-through is complete). This implies that the export price of gold is statistically the same as the world price and that the demand for gold exports curve is perfectly elastic. Thus, one need only estimate the supply function.

Two supply side variables were felt to be significant. Firstly, the grade of the ore that was mined and secondly, the wage per worker. As was mentioned earlier, the grade of the ore mined almost mirrors gold production exactly. Mainardi (1999) and Rockerbie (1999) both found grade to be a significant supply variable. Gold wages were very stable until 1972 when there was a steep increase, which was sustained for the rest of that decade. It was felt that this must have an effect on the profitability of gold mines, so this variable was included in the regression. The price variable used was the price of exports in Rands (which relates very closely to the world price of gold). Thus, the following export supply function was estimated (the signs above the variables indicate the expected signs of the coefficients):

$$\begin{array}{ccccccc}
 & + & & + & & - & \\
 XG = f(\text{PriceGold}, \text{Grade}, \text{GoldWages}) & \text{so the cointegrated vector would be:} & & & & & \\
 1 & & - & & - & & + \\
 0 = f(XG, \text{PriceGold}, \text{Grade}, \text{GoldWages})
 \end{array}$$

The Maximal Eigenvalue, Trace of the Stochastic Matrix and the Schwarz Bayesian Criterion all indicated that two cointegrating vectors were present. The Akaike Information Criterion and the Hannan-Quinn Criterion both showed three cointegrating relationships. There is no economic rationale for three cointegrating vectors so r was set at 2. This implies the existence of two cointegrating or long run relationships. Various specifications were tried. The most economically sensible results arose when one vector was normalised on exports to yield the export supply relationship, while the other was normalised on wages to yield a wage relationship. The coefficients of the cointegrating vector are presented in Table 2 below.

Table 2: Long Run Relationships in Gold Supply

	Vector 1	Vector 2
Dependent variable	Gold Exports	Gold wages
Export Price of Gold	-0.92495 (-0.23472)	-0.94315 (-0.17851)
Gold Exports		-0.32683 (-0.087380)
GRADE	-2.0884 (-0.41981)	0.000 (NONE)
Gold Wages	0.000 (NONE)	
Trend	0.094197 (0.023591)	0.0000 (NONE)
Just identifying restrictions	a1=1; a4=0;	b4=1;b3=0;
Over identifying restrictions		b5=0;
LR test of restrictions (χ^2) [p-value]		0.47867[0.489]

Because the cointegrating vector is shown, one must bear in mind that the elasticity bears the opposite sign. The results above confirm the preliminary analysis that a large

proportion of the blame for the decline in South Africa’s gold exports must go to the fact that the grade of ore that is being mined is of a lower quality than in previous periods. The elasticity of the grade of ore mined at 2.0884 is more than double the price elasticity at 0.92495. Given the continuing downward trend in the grade of ore, one can only assume that gold exports will continue to decline. Technological advances in mining and milling may delay the inevitable somewhat. The long run price elasticity is roughly one, indicating that a one per cent rise in the price will lead to a one per cent rise in gold supply in the long term. The results confirm the intuition of Smal (1996) who argued that gold exports are mainly determined by supply side factors.

The other vector showed that the price of gold has had a major impact in determining wages in the gold sector, as one would expect. Wages seem to play little role in determining the supply of gold. In earlier versions of the model, gold wages were not restricted to zero but this led to nonsensical results. With the restriction in place, the results are roughly what were expected and all the signs are correct. Wages in the gold industry are closely connected to both the price of gold and gold exports. In the long run, a 1% fall in gold production will lead to a 0.32% reduction in wages. This suggests that falling gold exports have had a negative effect on wages in the sector.

Whilst the results above show long-run trends, using an error correction model allows one to examine the short run dynamics surrounding these functions. The error correction term can be interpreted as how long it would take the system to return to equilibrium after an exogenous shock had taken place. If the coefficient is not significant, it may mean that the variable under consideration is exogenous to the system. The table below shows the results for the error correction terms for the system of equations above.

Table 3: Short Run Relationships in Gold Supply

Dependent Variable	ECM 1 Coefficient	p-ratio	ECM 2 Coefficient	p-ratio	R-Squared
d(Price of Gold)	0.058870	0.72	-0.23137	0.30	0.60
d(Gold Exports)	-0.24314	0.00	0.29883	0.00	0.76

dGRADE	-0.12307	0.02	0.26948	0.00	0.80
d(Gold Wages)	0.048764	0.21	-0.42527	0.00	0.90

Note: There is evidence at the 5% level that the residuals of the PG error correction model were not normally distributed.

The dependent variable in error correction models is always in first differenced form (denoted by the d in this instance, e.g. dGRADE).

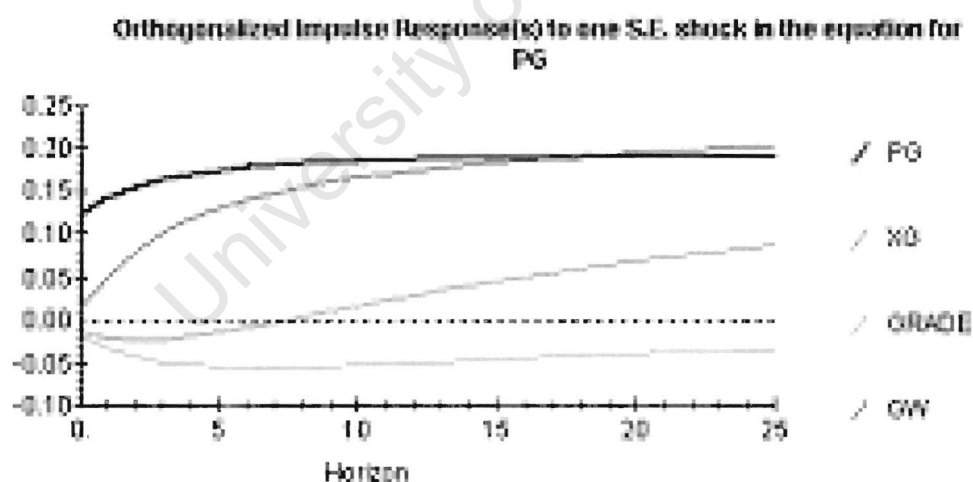
Stability of the system of equations requires that deviations from the long run relationships identified in Table 3 are dissipated over time. The error correction term represents the adjustment back towards equilibrium after an exogenous shock. Of primary importance are the estimates of the ‘own’ error correction coefficients, which need to be negative for convergence to occur. These conditions are satisfied in the above results. The error correction term for the export supply equation is -0.24 , which implies that 24% of disequilibrium in the previous period is corrected for in the current period. The long run wage relationship shows a more rapid convergence towards equilibrium with 42.5 % of the previous period disequilibrium corrected for in the current period.

The positive signs of the coefficient on ECM2 in the equations for gold exports and the grade of ore do however, make sense. If the grade of ore was higher than expected, then gold exports would also be greater than forecast. This would feed back into higher wages in the gold sector as seen in CV2. The negative ECM1 coefficient in the grade equation is also correct. If there is a positive disequilibrium (i.e. excess supply), then mines shift production towards low-grade ore. This is consistent with mining practice, that when the price of gold rises, mines shift towards lower grade ore in order to preserve the long run life of the mine. If the rise in price is assumed to be permanent, then new stopes may be opened up. Thus, the initial response to a price increase may be a decrease in the quantity of gold supplied. This is shown in the Figure 13 below. Interestingly, prices are exogenous, which is consistent with the small country assumption.

The ECM terms suggest very slow movement towards equilibrium. This can also be seen in Figure 13 below. A one unit (one standard error) shock in the price of gold only leads

to an increase in gold exported after 7 years. This could be because there is little scope to increase production, except by opening up new stopes. However, this would require large capital investment so mine owners have to be sure that the shock is permanent before they commit to such an investment. Another reason could be that some gold production is sold forward. This would limit the responsiveness to the price of gold in the short term. This result is not totally surprising given that Rockerbie (1999), Keynes (1936) and Selvanathan & Selvanathan (1999) found a very slow reaction to price changes. Nattrass (1995) mentions that a key determinant of gold exports during the 1980s was mine owners' attempts to reduce their tax burden as much as possible. Tax on mines was based on the grade of ore mined. Thus, management could determine their tax burden through choosing the grade of the ore they mined. This would reduce the responsiveness of gold production to changes in price. As expected, the price of gold had a negative influence on the grade of ore mined. Wages also responded quite slowly to the increase in price, taking 18 years to match the full price increase. This is probably because wages are linked to gold exports and exports themselves take so long to respond to the price change. It could also be because of inconsistencies in the wage data.

Figure 13: Impulse Response to a Shock in the Equation for the Price of Gold



5.4 Non-gold Mining Exports

Unlike the gold sector, there is no data available for grade of ore for the non-gold sector. To replace this data, other supply side data was used. It was assumed that South Africa has no effect on the world price (in Dollars) of these commodities. Thus, instead of using the export price in Rands, the regression used the world price as an exogenous variable.

The coefficient on the world price was restricted to be equal to the coefficient on the exchange rate (expressed in Rands per Dollar). An initial VAR with all variables endogenous was estimated. The error correction coefficients in the exchange rate equation were found to be insignificantly different from zero, implying exogeneity. Subsequent regressions were estimated with the exchange rate exogenous to the system

Alternative models including gross domestic expenditure to test the vent for surplus model (as found in Bhorat, 1998; Smal, 1996; Tsikata, 1994) were also estimated. The results from these regressions were poor with many of the estimated coefficients with the incorrect sign. Consequently, these results are not presented.

Thus, the following export supply function was estimated:

$$\begin{matrix} & - & & - & & + & & & + \\ \text{Exports} = f(\text{PPI, Wages, Productivity, (WorldPrice*ExchangeRate)}) \end{matrix}$$

Thus, the cointegrating vector was expected to show:

$$\begin{matrix} & 1 & & + & & - & & - & & - \\ 0 = f(\text{Exports, PPI, Wages, Productivity, (WorldPrice*ExchangeRate)}) \end{matrix}$$

The order of the VAR was found to be one. The usual tests for heteroscedasticity, autocorrelation and normality of the residuals were carried out. Serial correlation was present in the residuals of the regressions for wages and the producer price index. The addition of dummy variables took care of these problems. The only remaining area of concern was the equat on for exports, which only rejected the assumptions of no serial correlation and normally distributed residuals at the 10% level.

The results of the over-restricted cointegrating vector are printed in the table below.

Table 4: Cointegrating Vector in Non-gold Export Supply

	Vector 1
Dependent Variable	Exports
PPI	+1.7953

	(0.87165)
Productivity	-1.8218 (0.95435)
Wages	0.0000 (NONE)
Exchange Rate	-0.92128 (0.48055)
World Price	-0.92128 (0.48055)
Trend	0.0000 (NONE)
Just identifying restrictions	a1=1;
Over identifying restrictions	a4=0; a7=0; a5=a6;
LR test of restrictions (χ^2) [p-value]	4.9828[0.173]

Once again, it must be pointed out that the elasticities are of opposite signs to the coefficients in the cointegrating vector. The long run coefficients have the correct sign. The similarities to the gold mining sector are quite striking. In both cases, the long run price elasticity is 0.92 while the major determinant of production seems to come from supply-side factors. PPI was used in this regression as a measure of costs. Both productivity and PPI have a greater influence on mining exports than price. A 1% rise in PPI will reduce exports by 1.8% while a similar increase in price would only reduce exports by 0.92%. A likelihood ratio test was used to test for the significance of the individual coefficients. In each case the over-identifying restriction that the relevant coefficient equalled zero was rejected.⁵ The long run coefficients are therefore significantly different from zero.

⁵ The probability statistic for restricting the coefficients on PPI, Prod, (Pw+E) to zero were p=0.000, p=0.008 and p= 0.018, respectively.

Table 5: Short Run Relationships in Non-gold Export Supply

Dependent Variable	ECM 1 Coefficient	p-ratio	R-squared
dExports	-0.090883	0.08	0.26
dPPI	-0.072361	0.00	0.55
dProductivity	0.035488	0.22	0.17
dWages	-0.081419	0.00	0.57

Note: There was evidence of serial correlation and non-normality of the residuals of the exports equation at the 10% level.

The results of the error correction models in the table also correspond with the results of the gold sector. All of the coefficients indicate very slow movement towards equilibrium. If exports are higher than expected, there will only be a 9% move back towards equilibrium in the next year. The speed of convergence is less than half that of gold. One would expect wages to converge slowly. Wages are less fluid than most variables because they are set on a year-by-year basis. Wages are not able to fluctuate as economic circumstances change. In addition, labour will be unlikely to accept reductions in wages in the case that wages are too high. However, rate of convergence is probably too low and is likely caused by problems in the initial data. PPI is likely to also be quite slow to adjust but the values reported here are still surprisingly slow. Part of the explanation could be due to the fact that an increase in PPI would lead to a decrease in exports, as cost competitiveness decreases. The sign on the coefficient for productivity is not what was expected. Once again, this result is probably caused by the low quality of the data.

5.5 Mining Product Imports

As was mentioned earlier, data constraints meant that mining import functions could only be estimated for the period from 1957 to 1995. It is assumed that South Africa is a small country and thus the supply of imports curve is perfectly elastic and equal to the world price. In this model imports are determined by import demand, specified thus:

$$- \quad + \quad -$$

Import Demand = f(Price, GDP, PPI)

Thus, the sign expected in the cointegrating vector were:

$$1 \qquad + \qquad - \qquad +$$

$$0 = f(\text{ImportDemand}, \text{Price}, \text{GDP}, \text{PPI})$$

When specifying the equation, dummies had to be included for the periods 1957 to 1972 and 1994 to 1995. The earlier period represents the end of the Bretton Woods arrangement when the exchange rate was fixed. The second period showed a massive boost in imports due to the end of sanctions against South Africa. This caused the residuals in the imports equation to be non-normally distributed. Using these two dummies took care of this problem satisfactorily. As with all the other estimates, the order of the VAR was found to be 1.

Testing for the number of cointegrating vectors proved to be a slight problem. The trace test, the maximal eigenvalue test and Schwarz Bayesian Criterion all showed one cointegrating vector while the Akaike Information Criterion and the Hannan-Quinn Criterion showed two. On the basis of economic theory one cointegrating relationship for import demand was specified⁶.

The results can be seen in Table 6 below.

Table 6: Long Run Cointegrating Vector in Mining Products Import Demand

	Vector 1
Dependent Variable	Imports
Price of Imports	0.39001 (0.041333)
GDP	-1.3927 (0.14267)
PPI	0.0000 (NONE)
Trend	0.00000

⁶ Two cointegrating vectors were also selected but the error correction models were not robust.

	(NONE)
Just identifying restrictions	$a_1=1$
Over identifying restrictions	$a_4=0; a_5=0;$
LR test of restrictions (χ^2) [p-value]	1.5784 [0.454]

The results are quite interesting. They indicate that the most important determinant of South Africa’s imports is GDP. This may indicate that South Africa faces a balance of payments constraint. Previous episodes of growth have been constrained by a large increase in imports, which lead to the decline of the currency. This has led to increased inflation, which the South African Reserve Bank often responded to with restrictive monetary policy. The price elasticity is quite close to -0.44 , the estimate calculated by Senhadji (1997), for all imports.

The results suggest that import demand is highly inelastic. This, combined with the fact that the restriction of PPI to zero was not rejected, indicates that the majority of South Africa’s mineral imports do not have local substitutes. It also suggests that these results should be interpreted in terms of the perfect substitutes model, not the imperfect substitutes model.

Table 7: Short Run Relationships in Mining Products Import Demand

Dependent Variable	ECM 1 Coefficient	p-ratio	R-squared
dImports	-0.95303	0.00	0.57
dPrice of Imports	0.015303	0.86	0.43
dGDP	-0.018037	0.41	0.28
dPPI	0.16479	0.00	0.56

Note: There is evidence of serial correlation of the residuals at the 10% level for both the imports and GDP regressions. The GDP regression also showed evidence of heteroscedasticity at the 10% level. The PPI regression could not reject the hypothesis of no heteroscedasticity at the 1% level.

The error correction model for imports shows a much quicker adjustment than either of the export equations. The significance of the coefficients shows that both GDP and the price of exports are essentially exogenous. Estimating the regression with the two variables exogenous made little difference to the results. The current results are presented as they are used to estimate the impulse response functions presented later⁷.

The results of the PPI equation in Table 7 are quite surprising but they can be explained. In the aftermath of a shock to the long run relationship (the import demand function), one would find that import demand is higher than predicted. This would cause an increase in imports, which would lead to a depreciation of the currency. This would result in the local price of imported goods increasing, causing inflation. Thus, PPI would increase

To capture the very short run adjustment dynamics, a second error correction regression is specified, with the current period change in the price of imports and change in GDP included as exogenous variables. This allows one to determine the instantaneous change in imports due to changes in GDP and import price. This is only possible because GDP and import price are found to be exogenous in the first VECM. If the variables are endogenous, then there will be other adjustments in the system, including to those variables. The results of the adjusted VECM are listed in the table below. The dependent variable is the change in imports.

Table 8: Very Short Run Relationships in Mining Products Import Demand

Variable	Coefficient	t-ratio [probability]
ECM1	-0.90635	-6.3642[0.000]
dPrice of Imports	-0.046865	-0.15507[0.878]
dGDP	2.6039	2.2148[0.034]

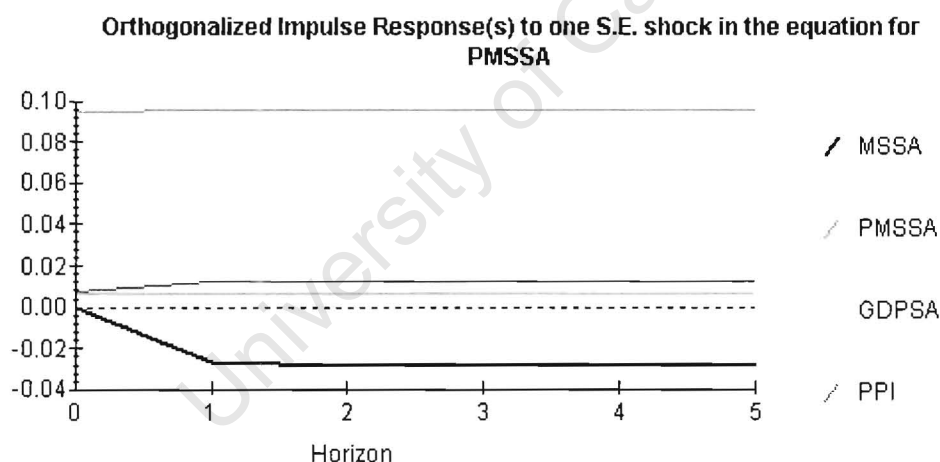
The price and GDP coefficients can be interpreted as elasticities. These results show a very low short run responsiveness of imports to changes in import prices. The estimated

⁷ In Microfit it is not possible to generate impulse response functions for VAR systems with exogenous I(1) variables

short run elasticity is insignificantly different from zero. GDP on the other hand, is more important in the very short term. This is more evidence that South Africa's mineral imports are necessary goods that South Africa does not produce at all or in insufficient quantities.

Figure 13 below shows the result of a shock in the price of imports. The system returns to a state of equilibrium much quicker than the export regressions. The exogeneity of the import price is evident in the way that it does not change at all after the initial shock. The whole response of imports occurs in the first two years. PPI increases but not by much. Surprisingly, the data shows that GDP increases. This may be because a rise in the price of mineral imports is associated with a rise in the price of other commodities. If South Africa exports these other commodities, then a rise in price may affect GDP positively. Alternatively, it could be due to data inconsistencies.

Figure 13: Impulse Response to a Shock in the Equation for the Price of Imports



5.6 Oil Imports

South Africa's major mining import is crude oil. It was decided to have a closer look at how this major component of imports responded to changes in price, assuming that South Africa's entire crude oil consumption was imported. The oil import demand function estimated was:

$$- \quad +$$

$$\text{Oil Import Demand} = f(\text{Price}, \text{GDP})$$

Thus the cointegrating vector was expected to show:

$$0 = f(\text{OilImportDemand}, \text{Price}, \text{GDP})$$

The price variable used was the dollar oil price converted into Rands. No dummies were needed to make the VAR robust. The tests for normality, heteroscedasticity and autocorrelation of the residuals were all passed for all three variables. The only point of concern was the test for the normality of the residuals for the oil imports equation. The hypothesis of normally distributed residuals was rejected at the 10% level, but not at the 5% level. Adding dummy variables for the two oil shocks in the 1970s (1974 and 1979) resulted in an error message from the statistical programme that two or more of the regressors were collinear. Not using the dummies removed this problem. The problem may be caused by inconsistencies in the data set. Once again, testing for the number of cointegrating vectors resulted in conflicting results varying from zero to three. As there was no economic rationale for more than one vector, *r* was set at one. The results can be seen in the table below. None of the coefficients could be restricted to zero.

Table 9: Long Run Cointegrating Vector for Oil Import Demand

	Vector 1
Dependent Variable	Oil Imports
GDP	-1.8723 (0.93603)
South African Oil Price	0.31407 (0.15296)
Trend	0.027906 (0.011274)
Just identifying restriction	a1=1;

As expected, GDP is a significant determinant of oil imports. The price elasticity is quite low, reflecting the fact that there are few substitutes. One would expect this elasticity to

be higher in South Africa than in most other countries, given projects such as MossGas and Sasol. Attempting to restrict the price coefficient to zero was rejected ($p=0.036$) suggesting that in the face of high oil prices consumers take some measures to reduce consumption. As expected the price elasticity is lower than that for total mining imports, again reflecting the lack of substitutes, this time compared to total mining imports. This might also be validation of Smal's (1996) argument that oil purchases during the sanction period were more strategic in nature than motivated by the market. The trend in the cointegrating vector could also not be restricted to zero ($p=0.000$). The sign of the trend may be due to dataset problems or the increasing numbers of vehicles on South Africa's roads (DEAT, 2003). This would indicate that South Africans have experienced an increasing disposition to buying cars besides buying more cars through having greater income.

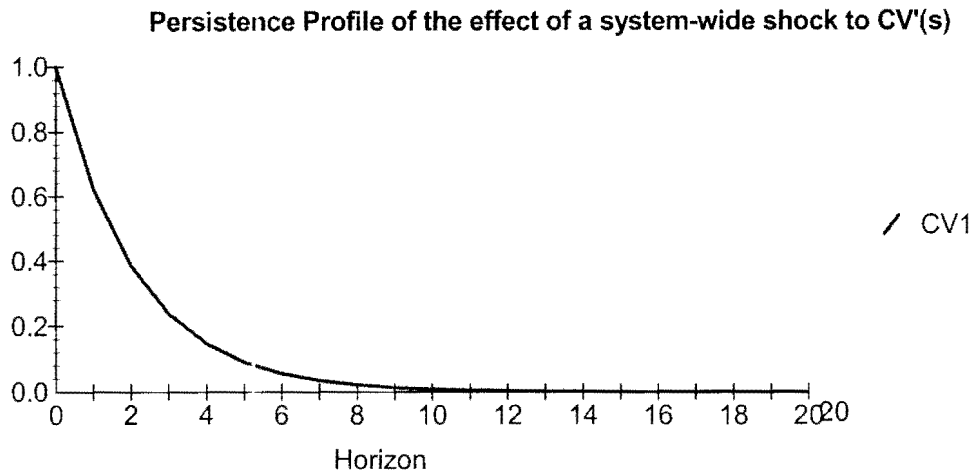
Table 10: Short Run Relationships in Oil Import Demand

Dependent Variable	ECM 1 Coefficient	p-ratio	R-squared
dOil Imports	-0.20746	0.00	0.35
dGDP	-0.078338	0.02	0.15
dSA Oil Price	-0.48304	0.25	0.04

Note: The hypothesis that the residuals of the South African oil price regression were normally distributed can be rejected at the 1% level.

The results in Table 10 above illustrate the importance of oil imports in the South African economy. A 10% rise in the price of oil will reduce GDP by 0.7%. This result is quite significant given the amount of variation in the oil price. As expected, the South African oil price is exogenous, as South Africa will have little impact on the world oil price. Adjustment is slower, at 20% per annum than for total mining imports, which was 95% per annum. This is probably because the adjustment process in this case involves income falling, which will decrease demand for oil. This is obviously a slow process. Income was exogenous in the adjustment process for total mining imports. The slow adjustment in this system can be seen in Figure 14 below. Remnants of an initial shock remain in the system for up to 12 years. Once again, data problems may explain the result.

Figure14: Persistence of a Shock to Oil Import Demand System



5.7 The Effect of a Currency Depreciation on the Trade Balance

The results of the chapter have shown that South Africa conforms to the small country model. Thus, one does not even need to calculate the exchange elasticity of the trade balance (given by the BRM finding) to know that the long run effect of a depreciation will be an improvement in the mining trade balance. Looking more closely at the import side, the low price elasticity of import demand means that the value of imports will increase, even in the long term. However, the long-term response by exports will outweigh the increase in imports.

The major advantage of the elasticity approach to studying the exchange rate effects upon the trade balance is that one can calculate an exchange rate elasticity. This is done using the supply and demand elasticities that have been calculated and substituting them into the Bickerdike-Robinson-Metzler condition. The condition is as follows:

$$E_{CA} = \frac{V_X}{V_M} \left(\frac{E_{DX} + 1}{(E_{DX} / E_{SX}) - 1} \right) - \frac{E_{SM} + 1}{(E_{SM} / E_{DM}) - 1}$$

The above analysis has in part assumed and in part shown that South Africa fits the predictions of the small country. In other words, the supply of imports curve and the demand for exports curve are both perfectly elastic. Thus, the BRM condition reduces to:

$$E_{CA} = \frac{V_X}{V_M} E_{SX} - E_{DM}$$

Using the data from 2001 and the elasticities estimated in this project, E_{CA} is found to be 3.02. This implies that for every percentage depreciation of the exchange rate, the mining trade balance will improve by just over 3%, in the long run.

This finding should be treated with caution. It should be noted firstly, that a large proportion of the gain in exports from the depreciation occurs only after a very long time period, while this figure assumes the adjustment is instantaneous. Thus, the short run effect is more likely to be less positive or even negative, especially given the much quicker response of imports and the inelastic demand for imports. This effect may last for several years. Secondly, this figure does not take into account other processes in the macroeconomy. For instance, the higher price of imports will lead to inflation. Higher costs will reduce the cost advantage that local producers enjoy from the initial depreciation. The criteria supplied by Sachs (1980, in Goldstein & Khan, 1985) suggests that the feedback price effect may be quite strong in South Africa. Thirdly, increased local prices may lead exporters to sell more of their production in local markets, rather than in world markets. This figure also ignores the effect of imported inputs. A depreciation of the currency will make these inputs more expensive, thus reducing the export response. This is a pertinent point for the South African mining sector as many capital inputs are imported. In addition, the increase in exports may add to local income. Thus, the gap between income and output will be reduced and exports will fall. Increased income will lead to greater demand for imports. Finally, the estimates of the elasticities are dependent on the quality of the data used. Limitations in the data set mean that any results obtained must be treated with caution. Thus, the actual exchange rate elasticity of the mining sector trade balance is likely to be lower than 3.02, particularly in the short term.

5.8 Conclusion

The results obtained from the estimation provide a number of insights. South Africa seems to conform to the small country model. The elasticity of export supply for both the

gold and non-gold sectors is about 0.92. Supply-side variables are more important than price in determining output. Adjustment after a price shock is very slow.

The price elasticity of import demand is quite low, especially for the oil sector. GDP plays a large role in import demand, particularly in the very short term, when the price elasticity may well be zero. Calculating the exchange rate elasticity of the trade balance yields a figure of 3.02. However, this finding does not take into account the shortcomings of the elasticity approach.

Some unexpected results may point to either inconsistencies in the data set or functional misspecifications.

University of Cape Town

6. Conclusion

The theoretical literature of the elasticity approach argued that most depreciations will actually lead to an improvement in the trade balance. When the elasticities of supply and demand were estimated for the South African mining sector, it was found that this was the case. Calculating the long-term effect showed that a 1% depreciation of the exchange rate will lead to a 3.02% improvement in the long term. This figure does not take into account other events in the economy and feedback price effects. This figure will also be reduced if inputs are imported.

South African exporters are price takers in world markets, even in the gold market. However, price does not appear to be the most important determinant of exports. The gold sector is heavily dependent on the grade of ore mined. There is little policy makers can do to increase this variable. The only option open to the gold industry and government is to decrease the costs of mining through innovation. Intentional depreciation of the exchange rate may not be a viable option due to the fact that gold production takes over 7 years to respond to an increase in price. The recent experience of depreciation in South Africa has been of increased inflation and contractionary monetary policy. Using the exchange rate as a policy variable is unlikely given the policy of inflation targeting. Depreciation is also not a viable policy choice given the finding that an increased oil price reduces GDP. Thus, industry players will have to look elsewhere to try and improve the long-term outlook of the gold industry.

The non-gold sector is very similar to the gold sector in that the major determinants of exports are non-price variables. Once again, the lag between a price change and a change in output was very long. As above, using the exchange rate to boost exports will probably not work in the long run. Rather, exports could be boosted through wage moderation and improvements in productivity. The results suggest that a low inflation environment would be conducive to greater exports. This could be accomplished through trade liberalisation (as many capital inputs are imported) and through tight monetary policy (as in the current policy). Productivity could be increased through better training of workers. Thus,

government could contribute through providing a well-educated work-force and making sure that Sector Education and Training Authorities (Seta's) are effective.

The level of imports was found to be highly dependent on GDP. The evidence also suggests that most of the imports are commodities not mined in South Africa. Thus, there is little scope to reduce the quantity of imports. In terms of oil, the only option is to increase the production of alternatives such as MossGas and Sasol, if they are able to undercut the price of oil imports.

One interesting result was the much quicker adjustment of imports over exports. This may imply that the short run effect of a depreciation episode may be negative (the so-called J-curve effect). Once again, this implies that using the exchange rate as a means of improving South Africa's mining trade balance is not a viable option as the initial effect could be negative.

Any statistical analysis is only as good as the data used as inputs. This is an area of concern in this study due to issues such as the slicing of data series. Where possible, data from a single source was used, provided that the quality of the data was good enough. The problems with the data mean that one must interpret the results with a degree of caution. Strange results may indicate some functional misspecification.

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Appendix A. Tests for Stationarity

The 95% critical value for the ADF test is dependent on the number of observations used. Data considerations meant that the different data series often had different numbers of observations so the regressions were estimated over differing numbers of observations, hence the varying critical ADF values. Lags were selected using the information provided by MicroFit (namely, the Akaike Information criterion, the Schwarz Bayesian criterion and the Hannan-Quinn criterion). For the sake of brevity, variables that are used in more than one regression are only reported in one table. The test statistics reported below are all for the ADF test of the first difference of the variable concerned.

Gold: 95 % critical value for the Augmented Dickey-Fuller Test: -2.9400

Variable	Name	Lags Used	Test Statistic
PG	Price of Gold (Rands)	0	-4.1133
XG	Gold Exports	0	-3.7974
PPI	PPI	0	-3.3938
E	Exchange Rate (R/\$)	0	-4.4931
TAR	Tariff Collection	2	-2.5218
GPROD	Productivity	0	-3.1693
GRADE	Grade	0	-3.0046
GW	Gold Wage per Worker	0	-3.5796 ⁸
PWG	World Price of Gold (\$)	1	-4.6494
PGOLD	World Price of Gold (Rands)	0	-4.1219

Non-Gold: 95 % critical value for the Augmented Dickey-Fuller Test: -2.9400

⁸ This variable is only stationary in the period 1974 to 2001.

Variable	Name	Lags Used	Test Statistic
Px	Price of Exports (Rands)	0	-4.3238
X	Exports	0	-6.3449
PROD	Productivity	1	-6.3140
W	Wages	1	-4.8734
Pw	World Price (\$)	1	-4.1660

Imports: 95 % critical value for the Augmented Dickey-Fuller Test: -2.9528

Variable	Name	Lags Used	Test Statistic
Mssa	Imports	1	-6.1840
PMssa	Price of Imports	0	-3.2954
GDE	GDE	0	-4.9782
GDPSA	GDP	0	-3.6067

Oil Imports: 95% critical value for the Augmented Dickey-Fuller Test: -2.9591

Variable	Name	Lags Used	Test Statistic
OilP	Oil Price (\$)	0	-5.6350
OilM	Oil Imports	0	-5.2590
SAOilP	Price of Oil (Rands)	0	-6.5616

The only variable that fails the test is tariff collection. Thus, tariffs were left out of the regressions where possible despite their obvious importance economically.

Appendix B. Tests for Cointegrating Vectors

Gold

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix

44 observations from 1959 to 2002. Order of VAR = 1.
List of variables included in the cointegrating vector:
PG XG GRADE GW Trend
List of I(0) variables included in the VAR:
D5769 D81 D80 D77 D96
D74 D2000
List of eigenvalues in descending order:
.87566 .53229 .22028 .057073 0.00

Null Alternative Statistic 95% Critical Value 90% Critical Value
r = 0 r = 1 91.7281 31.7900 29.1300
r <= 1 r = 2 33.4357 25.4200 23.1000
r <= 2 r = 3 10.9482 19.2200 17.1800
r <= 3 r = 4 2.5857 12.3900 10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix

44 observations from 1959 to 2002. Order of VAR = 1.
List of variables included in the cointegrating vector:
PG XG GRADE GW Trend
List of I(0) variables included in the VAR:
D5769 D81 D80 D77 D96
D74 D2000
List of eigenvalues in descending order:
.87566 .53229 .22028 .057073 0.00

Null Alternative Statistic 95% Critical Value 90% Critical Value
r = 0 r >= 1 138.6977 63.0000 59.1600
r <= 1 r >= 2 46.9696 42.3400 39.3400
r <= 2 r >= 3 13.5339 25.7700 23.0800
r <= 3 r = 4 2.5857 12.3900 10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria

44 observations from 1959 to 2002. Order of VAR = 1.
List of variables included in the cointegrating vector:
PG XG GRADE GW Trend
List of I(0) variables included in the VAR:
D5769 D81 D80 D77 D96
D74 D2000
List of eigenvalues in descending order:
.87566 .53229 .22028 .057073 0.00

Rank Maximized LL AIC SBC HQC
r = 0 296.4856 264.4856 235.9386 253.8990
r = 1 342.3496 302.3496 266.6658 289.1164
r = 2 359.0675 313.0675 272.0311 297.8492
r = 3 364.5416 314.5416 269.9368 298.0000

```

r = 4          365.8344          313.8344          267.4455          296.6312
*****
AIC = Akaike Information Criterion      SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

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Non-Gold Exports

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Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test: Based on Maximal Eigenvalue of the Stochastic Matrix
*****
44 observations from 1958 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
X          PPI          W          PROD          E
PW          Trend
List of I(1) exogenous variables included in the VAR:
PW
List of I(0) variables included in the VAR:
D5772      D8485      D73      D2000      D80
List of eigenvalues in descending order:
.67589      .34617      .25607      .11665      .051659      .0000      0.00
*****
Null    Alternative    Statistic    95% Critical Value    90% Critical Valu
r = 0      r = 1      49.5731      40.8900      37.9200
r<= 1      r = 2      18.6958      34.7000      32.1200
r<= 2      r = 3      13.0153      28.7200      26.1000
r<= 3      r = 4      5.4575      22.1600      19.7900
r<= 4      r = 5      2.3338      15.4400      13.3100
*****
Use the above table to determine r (the number of cointegrating vectors).

```

```

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix
*****
44 observations from 1958 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
X          PPI          W          PROD          E
PW          Trend
List of I(1) exogenous variables included in the VAR:
PW
List of I(0) variables included in the VAR:
D5772      D8485      D73      D2000      D80
List of eigenvalues in descending order:
.67589      .34617      .25607      .11665      .051659      .0000      0.00
*****
Null    Alternative    Statistic    95% Critical Value    90% Critical Valu
r = 0      r>= 1      89.0755      97.8300      93.1300
r<= 1      r>= 2      39.5024      72.1000      68.0400
r<= 2      r>= 3      20.8066      49.3600      46.0000
r<= 3      r>= 4      7.7913      30.7700      27.9600
r<= 4      r = 5      2.3338      15.4400      13.3100
*****
Use the above table to determine r (the number of cointegrating vectors).

```

```

Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria
*****
44 observations from 1958 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
X          PPI          W          PROD          E
PW          Trend
List of I(1) exogenous variables included in the VAR:
PW
List of I(0) variables included in the VAR:
D5772      D8485      D73      D2000      D80

```

List of eigenvalues in descending order:
.67589 .34617 .25607 .11665 .051659 .0000 0.00

Rank Maximized LL AIC SBC HQC
r = 0 280.5354 250.5354 223.7726 240.6105
r = 1 305.3220 264.3220 227.7461 250.7579
r = 2 314.6699 264.6699 220.0651 248.1283
r = 3 321.1775 264.1775 213.3281 245.3201
r = 4 323.9063 261.9063 206.5964 241.3947
r = 5 325.0732 260.0732 202.0870 238.5691

AIC = Akaike Information Criterion SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

Mining Product Imports

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix

38 observations from 1958 to 1995. Order of VAR = 1.
List of variables included in the cointegrating vector:
MSSA PMSSA PPI GDPSA Trend
List of I(0) variables included in the VAR:
D5772 D9495
List of eigenvalues in descending order:
.67615 .43220 .14741 .023060 0.00

Null Alternative Statistic 95% Critical Value 90% Critical Valu
r = 0 r = 1 42.8441 31.7900 29.1300
r<= 1 r = 2 21.5071 25.4200 23.1000
r<= 2 r = 3 6.0603 19.2200 17.1800
r<= 3 r = 4 .88655 12.3900 10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix

38 observations from 1958 to 1995. Order of VAR = 1.
List of variables included in the cointegrating vector:
MSSA PMSSA PPI GDPSA Trend
List of I(0) variables included in the VAR:
D5772 D9495
List of eigenvalues in descending order:
.67615 .43220 .14741 .023060 0.00

Null Alternative Statistic 95% Critical Value 90% Critical Valu
r = 0 r>= 1 71.2980 63.0000 59.1600
r<= 1 r>= 2 28.4540 42.3400 39.3400
r<= 2 r>= 3 6.9468 25.7700 23.0800
r<= 3 r = 4 .88655 12.3900 10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria

38 observations from 1958 to 1995. Order of VAR = 1.
List of variables included in the cointegrating vector:
MSSA PMSSA PPI GDPSA Trend
List of I(0) variables included in the VAR:
D5772 D9495
List of eigenvalues in descending order:

```

.67615      .43220      .14741      .023060      0.00
*****
Rank      Maximized LL      AIC      SBC      HQC
r = 0      195.2104      183.2104      173.3849      179.7146
r = 1      216.6324      196.6324      180.2566      190.8060
r = 2      227.3860      201.3860      180.0974      193.8117
r = 3      230.4161      200.4161      175.8524      191.6765
r = 4      230.8594      198.8594      172.6580      189.5372
*****
AIC = Akaike Information Criterion      SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

```

Oil Imports

```

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
*****
36 observations from 1966 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
OILM      GDPSA      SAOILP      Trend
List of eigenvalues in descending order:
.49647      .38859      .16034      0.00
*****
Null      Alternative      Statistic      95% Critical Value      90% Critical Valu
r = 0      r = 1      24.7004      25.4200      23.1000
r<= 1      r = 2      17.7114      19.2200      17.1800
r<= 2      r = 3      6.2913      12.3900      10.5500
*****
Use the above table to determine r (the number of cointegrating vectors).

```

```

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix
*****
36 observations from 1966 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
OILM      GDPSA      SAOILP      Trend
List of eigenvalues in descending order:
.49647      .38859      .16034      0.00
*****
Null      Alternative      Statistic      95% Critical Value      90% Critical Valu
r = 0      r>= 1      48.7030      42.3400      39.3400
r<= 1      r>= 2      24.0026      25.7700      23.0800
r<= 2      r = 3      6.2913      12.3900      10.5500
*****
Use the above table to determine r (the number of cointegrating vectors).

```

```

Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria
*****
36 observations from 1966 to 2001. Order of VAR = 1.
List of variables included in the cointegrating vector:
OILM      GDPSA      SAOILP      Trend
List of eigenvalues in descending order:
.49647      .38859      .16034      0.00
*****
Rank      Maximized LL      AIC      SBC      HQC
r = 0      153.1286      150.1286      147.7533      149.2996
r = 1      165.4788      156.4788      149.3529      153.9917
r = 2      174.3345      161.3345      151.0416      157.7420
r = 3      177.4801      162.4801      150.6037      158.3349
*****
AIC = Akaike Information Criterion      SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

```