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# Armington Elasticities for South Africa: Long- and Short-Run Industry Level Estimates

**Katherine Lee Gibson**
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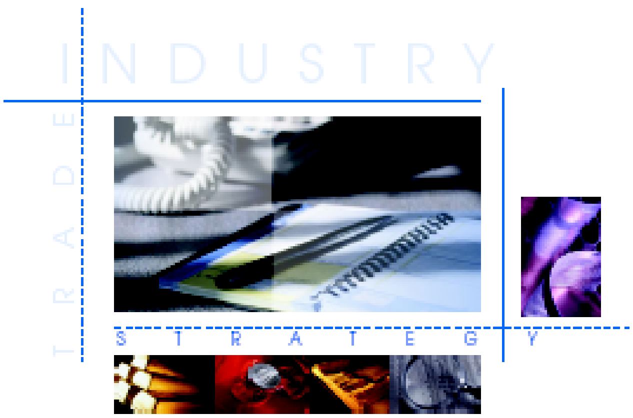


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## CONTENTS

## TABLES

# 1. INTRODUCTION

In economics, the effects of tariff protection and tariff reform remain a contentious, fervently debated issue.[1] In South Africa, decades of high tariff protection, of which domestic manufacturing sectors primarily benefited, are being followed by a period of substantial tariff reform. To this end, endorsement by the South African government of the Uruguay Round of the GATT, in 1994, has manifested itself in the phasing-in of lower tariffs on imported goods, at times at rates accelerated beyond the commitment to GATT (Swanepoel *et al.*, 1997).[2]

In international economic theory, the principal of comparative advantage implies that barriers to trade, for example tariffs, lower the welfare of the protected nation (Mohr *et al.*, 1995: 458). Nevertheless, the 1950s and 1960s saw many developing countries, particularly in Africa, adopt import substitution as a development strategy. But in the period post World War 2, the outward-oriented East Asian economies rapidly outperformed the inwardly focused African countries, a record that sustained through the 1990s, albeit dented by the emerging market crisis of 1997. Indeed, the theoretical literature has increasingly supported the view that countries exhibiting small domestic markets will suffer constrained growth in a closed economy structure (see Ray, 1998). This view recognises the failings of the conventional international economics assumption that imported and domestic goods, in a given sector, are perfect substitutes. When, as Armington (1969: 159) argues, imports and domestic goods are not perfect substitutes in consumption or production, the effects of tariffs, and thus of either an import substitution strategy or subsequent tariff reduction programme, depend critically on the magnitudes of the substitution elasticities estimated (Naude *et al.,* 1999: 42).[3]

Using economic models to evaluate changes in trade policy generally requires, amongst other things, the conversion of policy changes into price effects. Trade policy models use these price shifts to determine how the policy under review is expected to affect output, employment, trade flows, economic welfare and other variables of interest. The direction and magnitude of a trade policy change on individual variables depends on the size of the shock, as well as the behavioural relationships present in the economy (Gallaway *et al.,* 2001: 1). When evaluating policy shifts in an economic model, these behavioural relationships largely take the form of elasticities, which reflect the responsiveness of one set of variables to a change in a second set. For example, trade liberalisation reduces the relative price of imported to domestic goods. This leads to substitution towards imported products, the extent to which is dependent on the degree of substitutability. Subsequently, a key relationship for model analysis is the degree of substitution between imported and domestically produced goods as the relative price of those two goods changes, i.e. the Armington elasticity. This elasticity estimate is derived from the assumption that preferences are well behaved over a weakly separable product category that comprises similar, but not identical products. Crucially, these products are considered imperfect substitutes due to their differing countries of origin (Armington, 1969: 159). In the context of this study, this implies that even though goods produced in South Africa and the rest of the world may fall within the same product category, they are not perfectly substitutable for each other. With this in mind, it is useful, often critical, to ascertain the degree of substitution between foreign and domestically produced goods.

In general, knowledge of elasticities is important for aggregate issues, such as changes in tariffs or taxes. Policy changes of these kinds will effect a country's trade balance, level of income, and employment, the magnitude of the effects depending on the elasticity magnitudes (McDaniel and Balistreri, 2001: 1). Thus, the Armington elasticity forms an essential component of modelling the effects of international trade policy. Furthermore, applied partial and general equilibrium models employed to examine trade policy are almost all sensitive to trade elasticities (McDaniel and Balistreri, 2001: 12). Indeed, the Armington elasticity is a key parameter determining the quantitative, and in some cases qualitative

1 By way of example see Ingham (1995: 333, cited in Naude et al., 1999).

2 The GATT, or 'General Agreement of Trade and Tariffs', has been replaced by the World Trade Organisation (WTO).

3 These substitution elasticities are commonly referred to as 'Armington elasticities', and are introduced in greater depth below.

results that policy makers use.[4] Set against this backdrop, our study attempts to estimate Armington elasticities, at the industry level, for South Africa.

At this stage it is pertinent to establish a framework of model and elasticity estimate assessment. To this end, the analysis that follows has three objectives. First, to determine a suitable method that will, depending on the time series characteristics of the data, allow for the extraction of both short- and long-run Armington elasticity estimates. Second, to apply the method to each of the forty-five sectors under review to estimate the short-run and, where possible, the long-run estimates. Third, in light of the elasticity estimates generated, analyse possible policy effects for South Africa.

The discussion proceeds as follows. Section 2 reviews the literature content of Paul Armington's (1969) original contribution to trade policy analysis, and continues with a synopsis of industry level Armington elasticities estimated over the subsequent three decades, in both the international and domestic context. Next, Section 3 provides the mathematical counterpart to the review of Armington's (1969) exposition, and derives the base equation to be used in estimation. Section 4 examines the four data series required for the estimation procedure, while Section 5 explains the econometric implementation of the method outlined in Section 3. The results obtained from the econometric processes applied are summarised in Section 6. These results are then compared to previous South African and United States industry estimates. In addition, Section 6 highlights problems encountered during estimation that may impair the reliability of results. This relates specifically to weaknesses in data availability, as well as the use of a single equation approach to estimation. Section 7 concludes the study, summarising key results obtained.

[4] By way of example, see Thurlow and Holden (2002).

## 2. A HISTORIC PERSPECTIVE OF THE ARMINGTON ELASTICITY

Any discussion of the Armington literature must comprise two parts, a synopsis of Armington's (1969) original exposition whereby the trade elasticity equation is derived, and a review of subsequent influential studies that, while all employing the Armington equation as defined, estimate it using alternative econometric techniques. In this regard, a relevant concern is the extent to which the elasticity estimates are sensitive to the method used in the estimation procedure, an issue that is addressed in Section 6.3.

### 2.1 The Armington Elasticity Defined

Paul Armington's (1969) exposition presents a general theory of demand for goods, based on a product being distinguished by both its kind, for example textiles or chemicals, and its place of production. Previously, goods of a given kind supplied by sellers in one country were assumed to be perfect substitutes for goods, of the same kind, supplied by any other country, implying that the elasticities of substitution between these supplies are infinite, and that the corresponding price ratios are constants. Such is argued by Armington (1969: 159) to be unrealistic, paving the way for his response whereby at the outset, products of the same kind, but differing in origin, are assumed to be imperfect, rather than perfect, substitutes in demand. Furthermore, the geographic areas that serve as a basis for distinguishing products by origin also serve to identify different sources of demand.

Armington (1969: 160) systematically simplifies the product demand functions introduced above for use in estimation and forecasting. Beginning with the basic Hicksian model, increasingly more restrictive assumptions are applied, leading to the specification of product demand functions, which, while highly simplified, retain the quantitatively significant relationships between demand, income, and prices.[5] The mathematical counterpart to this exposition, as detailed below, follows in Section 3.1.

The fundamental adjustment to the general Hicksian model is to assume independence, implying that buyers' preferences for different products of any given kind, for example South African maize and Zimbabwean maize, are independent of their purchases of any other kind (Armington, 1969: 160). On the basis of this assumption the quantity of each good demanded by each country, for example South African demand for maize in general, can be measured unambiguously (Armington, 1969: 161). Thus, there exist demands for groups of competing products, commonly referred to as markets. Furthermore, Armington (1969: 161) argues that demand for a particular product, for example South African demand for Zimbabwean maize, can be expressed as a function of the size of the corresponding market, for example South African demand for maize in general, and the relative prices of the competing markets.

Alongside the assumption of independence, it is assumed that each country's market share is unaffected by changes in the size of the market, so long as relative prices pertaining to that market remain unchanged (Armington, 1969: 161). Thus, the size of the market is a function of both money income and of the prices of the various goods, for example the price of maize in general, or the price of textiles in general. This price function, combined with the product demand function, yields a function of the demand for any product to be dependent on money income, the price of each good, and the price of that product relative to prices of other products in the same market. To simplify these product demand functions, two additional assumptions are made (Armington, 1969: 161). First, it is assumed that the elasticities of substitution between products competing in any market are constant, implying that they do not depend on market shares. Second, it is assumed that the elasticity of substitution between any two products competing in a market is the same as that between any other pair of products competing in the same market. Subsequently, these assumptions yield a specific form of the relationship between product demand, the size of the corresponding market and relative prices, whereby the only unknown parameter is the elasticity of substitution in the market. Thus, differentiation of the demand functions yields an analysis of changes in demand for a given product, such that the change in the product's market share depends in a specific way on the change in the product's price, relative to the average change in product

[5] For a review of the original Hicksian model see Hicks and Allen (1934: 201-202, 208-211).

prices in the market. It is reminded that these relationships outlined above underpin the mathematical derivation of the Armington elasticity in Section 3.1.

## 2.2 The Armington Equation Employed: A Review of Estimation Procedures and Results

In reviewing previous Armington elasticity estimates, this section revises a selection of international studies, all of United States (US) imports, followed by three studies of South African imports.

*2.2.1 The International Setting*

Four well-known and oft-cited studies available for US imports are Stern, Francis and Schumacher (1976), Shiells, Stern and Deardorff (1986), Reinert and Roland-Holst (1992) and Shiells and Reinert (1993). Each focusing on industry level detail at either the two- or three-digit Standard Industry Classification (SIC) level, a synopsis of each study's method and results are elaborated upon below. Brief comments of related studies are included where relevant.

The first systematic study to provide import-demand elasticities for the United States comes from Stern *et al.* (1976), which determines 'best estimates' of US import-demand elasticities for 28 industries at the three-digit ISIC level. In short, 'extremely import sensitive' industries are predicted as: wearing apparel, rubber products, transport equipment, and metal products excluding machinery. In contrast, 'food', 'beverages', 'tobacco', 'textiles', 'iron and steel', and 'metal including electrical machinery' are categorised as 'moderately import sensitive'. The 'wood' and 'paper' industries are considered 'import inelastic'. While in its time useful, this study, along with others adopting the 'best guess' method, is argued by Shiells *et al.* (1986: 498) to be limited in terms of its theoretical rationale, estimating procedures, and commodity and time coverage.

In the decade after Armington's (1969) paper, Cline *et al.* (1978), Baldwin *et al.* (1980), and Bayard and Orr (1980) assume that changes to imports in response to, for example, changes in tariffs, translate into changes in domestic output on a dollar for dollar basis. However, because this approach neglects to account for variations across industries in the degree of substitutability that may exist between imports and domestic goods, Shiells *et al.* (1986) recognise some uncertainty about the calculation of industry employment and output effects from changes in trade. To partially address this issue, Deardorff and Stern (1986) and Whalley (1984) model the allocation of expenditure between home and domestic goods, for a given industry, in proportions, depending on their relative prices. Notably, price elasticity estimates of import demand used in these studies are drawn from the 'best guess' estimates determined by Stern *et al.* (1976), and are thus subject to the same criticisms of that study. In this regard, one can argue the study to be theoretically weak.

In response to these observed shortcomings in the Armington elasticity estimation procedure, Shiells *et al.* (1986) produces elasticity estimates for 163 US industries at the 3-digit level. Using a simple stock adjustment model, assumed to describe the adjustment of actual import quantity to desired import quantity, the researchers perform two-stage least squares (2SLS), first without, then with, an autoregressive correction, treating the lagged import quantity as a current endogenous variable. This method of estimation is applied to annual data spanning the period 1962 through 1978. Of the 163 sectors estimated, 122 are determined to have statistically significant Armington elasticity estimates. For the most part, results obtained substantiate the findings of Stern *et al.* (1976).

Reinert and Roland-Holst (1992) provide Armington elasticity estimates for 163 mining and manufacturing sectors of the US, using quarterly data from 1980 through 1988. For most of these industries the authors are able to specify an estimating equation that yields statistically significant constant elasticity of substitution (CES) elasticities (Reinert and Roland-Holst, 1992: 631). Indeed, in approximately two-thirds of the cases, positive and statistically significant estimates are obtained. Interestingly, the study observes that a model including a dynamic adjustment process through elaborate lag specifications, as applied in the study by Shiells *et al.* (1986), does not consistently improve the reliability of model estimates (Reinert and Roland-Holst, 1992: 635). Significant elasticity estimates range between a low of 0.14

and a high of 3.49, implying that commodities at the applied level of disaggregation are far from perfect substitutes (Reinert and Roland-Holst, 1992: 635). Reinert and Roland-Holsts' (1992) elasticity estimates are widely cited in related literature.

Also estimating elasticities of substitution for the US, Reinert and Shiells (1993) disaggregate US imports into those from NAFTA members and those from the rest of the world.[6] Using a different method to prior studies, as explained immediately below, the authors use quarterly data from 1980 through 1988 to obtain Armington elasticity estimates for 128 mining and manufacturing sectors. Trade substitution elasticities are estimated using three specifications: 1) generalised least squares (GLS), based on a Cobb-Douglas price aggregator, 2) maximum likelihood estimation using a CES price aggregator and 3) a simultaneous equation estimator using a Cobb-Douglas price aggregator and employing a distributed lag model. Elasticity estimates are observed to be relatively insensitive across the three alternative estimation procedures (Reinert and Shiells, 1993).

The aforementioned papers systematically provide valuable trade substitution elasticity estimates. An evident weakness, however, is the failure of these works to explicitly consider the long-run aspect applicable to applied partial and general equilibrium modelling. In this regard, an additional study is reviewed, that by Gallaway, McDaniel and Rivera (2001).

Gallaway *et al.* (2001) estimate the degree of substitution between imported and domestically produced goods due to changes in the relative prices of those two groups of goods, for 312 industries at the 4-digit SIC level, over the period 1989 to 1995. These results offer the most comprehensive and disaggregated set of Armington elasticities for the US to date. Furthermore, the study is unique as it employs techniques that distinguish between the short- and long-run. Long-run estimates are more appropriate than short-run estimates for most trade policy research. Depending on the time-series characteristics of the data, one of three equation specifications is applied. These are: 1) a geometric lag model, 2) a single equation error correction model, or 3) the variables are first differenced for stationarity and then estimated by ordinary least squares (OLS) (Gallaway *et al.,* 2001: 7).[7] Gallaway *et al.* (2001: 9) report that long-run estimates, when they can be calculated, are on average twice as large as the short-run estimates. Furthermore, statistically significant differences are shown to exist within most 3-digit SIC industries, emphasizing the importance of estimating at a disaggregated level, as policy typically focuses on narrow product definitions (Gallaway *et al.,* 2001: 9). With this in mind, a comparison of the Gallaway *et al.* (2001) 4-digit estimates to Reinert and Roland-Holst (1992) 3-digit estimates provides additional insight to the well-known aggregation bias: the more detailed the commodity level, the greater the ease of product substitution.

A final paper for consideration is that by Hummels (1999, cited in McDaniel and Balistreri, 2002). Hummels (1999, cited in McDaniel and Balistreri, 2002) departs from the literature considered thus far by using a multi-sector model of trade to isolate channels through which trade costs or resistance affect trade volumes across countries. All distance related trade resistance is treated as a freight charge. This model solves for the implied substitution elasticity, generating a range of substitution elasticities of 2 to 5.3. Specifically, average estimates at the 1-digit, 2-digit and 3-digit level are 4.8, 5.6, and 6.9 respectively. Of importance is that the cross-sectional estimates presented are substantially higher than values obtained in comparative time-series studies of US data. Indeed, the average of 6.9 reported at the 3-digit level in the Hummels (1999, cited in McDaniel and Balistreri, 2002) study strongly exceeds the average long-run estimate of 1.6 reported by Gallaway *et al.* (2001) at the 4-digit level. McDaniel and Balistreri (2002:

[6] The anagram 'NAFTA' stands for 'North American Free Trade Agreement'.
[7] These equations, and the procedure used for their selection, are elaborated upon in Section 5.2.

4) suggest that this large divergence indicates misspecification by the single equation methods.

An assessment of the international literature reveals three robust findings. First, long-run estimates are much greater than those for the short-run. Second, the level of aggregation matters as a higher level of disaggregation implies a higher substitution elasticity estimate. Third, model misspecification is of critical concern. A discussion of the implications of these findings, particularly relating to misspecification, continues in Section 2.2.3. Related to the issue of misspecification is that empirical work based on times series data assumes the underlying time series to be stationary. A stationary time series exhibits a constant mean and variance over time. In addition, it shows the value of covariance between two time periods of the series to depend only on the lag between the two time periods, and not on the actual time at which the covariance is computed (Gujarati, 1995: 713). If data series are non-stationary, a high $R^2$ obtained in estimation may reflect a common trend in the variables under review, rather than a true relationship. Such a relationship is said to be 'spurious'. Thus far, the Gallaway *et al.* (2001) approach to elasticity estimation is the only procedure reviewed that accommodates the stationarity aspect. With these comments in mind, three South African studies are reviewed.

### *2.2.2 The Domestic Setting*

Moving to the domestic research, Armington elasticity estimates applied in most trade policy models of South Africa are taken from results obtained by an IDC (1997) research publication. The project employs annual data for 25 manufacturing sectors, for a sample period from 1973 through 1993. Notably, the data is tested for stationarity and cointegration, but in some cases the data is non-stationary after several first-difference transformations, and in other cases no cointegrating relationship can be established (IDC, 1997: 40). With this said, in all cases is the data used in its original form, suggesting that a correlation observed between the demand and price ratio in a given sector may be spurious. Although estimating simply by OLS, as opposed to the selective time-series technique adopted in the Gallaway *et al.* (2001) study, the use of annual data, rather than either monthly or quarterly, is implied to produce long-run elasticity estimates (IDC, 1997: 41).

This issue is readdressed in Section 6.2, where the results yielded by the present study are compared and contrasted to those yielded by the IDC (1997), and again in Section 6.3, which discusses possible remedies to problems encountered in estimation. Two broad results emerge from the IDC (1997) report. First, most Armington elasticities estimated are significant and have the correct sign, i.e. positive. This group includes: processed food (0.74), beverages (2.3), tobacco products (1.87), leather products (4.4), wood and wood products (0.687), printing and publishing (3.192), industrial chemicals (1.528), machinery and equipment (1.092), electrical machinery (0.751) and other manufacturing (0.946). Second, the elasticities of substitution between imported and domestically produced goods cluster around 2 (IDC, 1997: 46). These estimates are argued by the IDC researchers to be of a similar size to those determined by alternative econometric methods applied in studies elsewhere.[8]

Granted that such consistencies across the studies may hold true, the present study contends that the method applied by the IDC, which ignores issues of stationarity associated with time series data, is perhaps less appropriate. If the data series employed are non-stationary, estimates generated may be misleading and unsuitable for use in applied trade policy work. As a final note regarding the estimation procedure, the IDC researchers include a dummy variable for uncertainty, which in most cases is determined to be significant (IDC, 1997: 47).

In a related paper, the researchers that produced the IDC (1997) report contrast the estimates obtained in that report with elasticities previously applied in the IDC general equilibrium model. In doing so, they identify shortcomings in their project, emphasising data limitations that South Africa trade policy researchers are subject to.

[8] Studies cited are Alaouze *et al.* (1977) and Comber (1995).

Akin to the IDC (1997) paper, they imply that the use of annual data *per se* generates long-run estimates (Naude *et al.*, 1999: 45). Lastly, it is noted that the use of a CES specification in the estimation of Armington elasticities may introduce two influences. These are: 1) instability in the estimates with respect to variations in the time period, and 2) bias due to a failure to clearly identify the differences between *ex post* and *ex ante* substitution possibilities (Naude *et al.,* 1999: 49).

In a study severely limited by a lack of data, Le Roux Burrows (1999) estimates Armington elasticities for eleven manufacturing and mining sectors. Consistent with the IDC (1997) approach to estimation, the study applies OLS, and includes a first order autoregressive term to correct for autocorrelation. While more elaborate lag specifications can be used, it is argued that such will not contribute to improved estimates (Le Roux Burrows, 1999: 5; Reinert and Roland-Holst, 1992: 635). Of the eleven industries identified, two cannot be estimated due to insufficient data, and one produces a negative estimate. Of the eight industries remaining with positive estimates, six are significant at the 5 percent level. Furthermore, five sectors have significant serial correlation. A summary of results is as follows: 'motor vehicles, parts and accessories, and other transport equipment' (1.88) exhibit the highest Armington elasticity estimate and 'food, beverages and tobacco' (1.77) the second highest (Le Roux Burrows, 1999: 6). The lowest significant elasticity estimate is exhibited by 'paper, paper-products, printing, and publishing' (0.45). The usefulness of findings in this paper is, for the most part, undermined by the severe shortage in data availability.

### *2.2.3 Remarks on the Current Status of Armington Elasticity Research*

The papers reviewed thus far are useful to trade researchers and policy makers alike as they provide a starting point for specifying key behavioural parameters. However, McDaniel and Balistreri (2002: 6) note 'sensitivity to estimation technique' and 'misspecification', as two key reasons to be wary of adopting either an estimation method, or actual elasticity estimates, from preceding literature. It is imperative that such cautiousness be retained throughout any study on Armington elasticities, and has underpinned the decision-making process, specifically in the choice of estimation technique, throughout this research.

With these arguments in mind, conflicting point estimates of Armington elasticities generated reflect the sensitivity of estimation results to the method employed. Furthermore, the specifications of Stern *et al.* (1976), Shiells *et al.* (1986), Reinert and Roland-Holst (1992), Shiells and Reinert (1993), Gallaway *et al.* (2000), Naude *et al.* (1999) and Le Roux Burrows (1999), may be considered structurally inconsistent with a general equilibrium framework (McDaniel and Balistreri, 2002: 6). Indeed, single equation methods neglect to consider the supply side of the market, relevant as demand for a product and its price level are determined by the interaction between a demand and supply function. Failure to estimate by a simultaneous model, where appropriate, may yield inconsistent and biased elasticity estimates. In most cases, ignoring the supply side causes an underestimation of the Armington elasticity (McDaniel and Balistreri, 2002: 4).

With this said, the Gallaway *et al.* (2001) approach, while suffering these criticisms, uniquely considers the long-run aspect applicable to applied partial and general equilibrium modelling. In addition, Gallaway *et al.* (2001) attempt to overcome the problems associated with time series data, particularly relating to issues of stationarity, an issue ignored by alternative estimating procedures. With these arguments in mind, the Gallaway *et al*. (2001) approach is deemed most appropriate for the intentions of this analysis, and is employed in estimation. As an additional precaution, our study employs a procedure that identifies the long-run forcing variables in the estimating equation. Thus, while short-run simultaneous relationships may still hold, those associated with the long run are resolved.[9] Potential biases emerging through the use of the Gallaway *et al.* (2001) method are considered in Section 6.3.

[9] The ARDL test procedure is explained in Sections 5.1 and 5.2.

## 3. THE MATHEMATICAL MODEL

Examining trade policy commonly requires the building of partial and general equilibrium models. In this regard, of particular importance is the sensitivity of results generated by equilibrium models to the Armington parameters integral to their running, which in turn are conditional upon the structure under which they are estimated (van Heerden *et al.,* 1997). The structure of the Armington model is thus a critical consideration, and is detailed below.

### 3.1 A Mathematical Derivation of the Armington Equation

In trade theory, import behaviour is typically viewed from the perspective of the economy as a whole, which Reinert and Roland-Holst (1992: 632) argue is equivalent to considering an aggregate agent. In modelling trade policy, a standard assumption is that within a product group this representative agent differentiates between domestic and imported goods (Armington, 1969; Shiells *et al.,* 1986). Furthermore, the Armington model assumes that products are differentiated solely by their origin. Thus, it follows that a consumer treats domestic and import goods, of the same product category, as substitutes in consumption. Assuming that this representative consumer has a well-behaved utility function, then the consumption decision is consistent with neoclassical utility maximization, or alternatively, expenditure minimalisation (Reinert and Roland-Holst, 1992: 632).

The hypothetical representative consumer derives utility from a composite ($Q$) of imported ($M$) and domestically produced ($D$) goods. Assuming there to be continuous substitution possibilities between $M$ and $D$, the decision problem is to combine such in a way that minimises expenditure, given the respective prices $p_M$ and $p_D$ and the desired level of $Q$. In this regard, the assumption of weak separability of product categories in the utility function implies that the allocation of expenditures within an industry group is subject to the level of spending on that group (Gallaway *et al.,* 2001: 4). Finally, to model demand for a home and import good in a particular industry, Armington (1969: 167) specifies a CES functional form for $Q$, yielding:

$$Q = [\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)},$$
[Equation 1][10]

Where $M$ = the quantity of the import good;

$D$ = the quantity of the domestic good;

$\sigma$ = the CES between the domestic and imported good;

$\beta$ = a calibrated parameter in the demand function; weights the foreign relative to the home good.

From this, the solution to the consumer's optimisation problem is to choose a combination of imported and domestically produced goods whose ratio satisfy the first-order condition:

$$M/D = [(\beta/(1-\beta))(p_D/p_M)]^{\sigma},$$
[Equation 2][11]

which is the equivalence between the rates of substitution and relative prices and allows the Armington elasticities to be estimated for disaggregated commodity categories.[12, 13] Reinert and Roland-Holst (1992: 632). observe that the parameter $\sigma$ can be interpreted as the compensated price elasticity of import demand. Taking logs of Equation 2 yields the base equation used in the estimations:

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[10] As given by Reinert and Roland-Holst (1992: 632) and Gallaway *et al.* (2001: 3).
[11] The derivation of Equation 2 from Equation 1 is given in Appendix 1.
[12] For an extended treatment of CES import behaviour in a general equilibrium model, see de Melo and Robinson (1989, cited in Blonigen and Wilson, 1999).
[13] Inversion of the price ratio implies that a positive relationship should hold between it and the demand ratio. Thus, elasticity estimates are expected to be positive

$y = a_0 + a_1x$,
[Equation 3] [14]

where: $y = \ln(M/D)$;

$a_0 = \sigma\ln[\beta/1-\beta]$, a calibrated constant;

$a_1$ = the Armington elasticity of substitution between imports and domestic sales ($\sigma$); and

$x = \ln(p_D/p_M)$.

Equation 3 is the base equation used in the econometric estimation of the Armington elasticities in this analysis. Correct specification implies that the data must support a positive relationship between the variables y and x, which are the demand and price ratios respectively. This is observed to hold in most sectors, as reviewed in Section 6.1.

[14] The log-linear equation is a standard specification used in the literature to estimate Armington elasticities. By way of example see: Shiells *et al.* (1986), Reinert and Roland-Holst (1992) and Shiells and Reinert (1993).

# 4. DATA

Four data series are required to apply Equation 3. These are: real imports, domestic sales of domestically produced goods, and the prices of those two groups of goods. Each one of these series is constructed from the Trade and Industrial Policy Strategies (TIPS) South African Standardised Industry Indicator Data Base. The data base offers time series of 46 industries of the South African Economy, for a range of variables at the 2 and 3 SIC digit level, including imports, domestic supply, and their relevant prices. Note that the data series available in the system cannot be obtained 'off-the-shelf' from Statistics South Africa. Indeed, the primary contribution of the TIPS database is that it reconciles a range of inconsistent, and incomplete, industry data series.[15] Data is annual and spans the period 1970 through 2001, implying 31 observations per sector.

## 4.1 Real Import Quantities and Import Prices

These two series are obtained directly from the TIPS South African Standardised Industry Indicator Database.

## 4.2 Real Domestic Sales and Domestic Sales Price Data

The series 'domestic sales of domestically produced goods' is constructed by subtracting 'exports' from 'total output' (both obtained from the TIPS database). Total output comprises the sum of 'intermediate output' and 'final output', whereby the latter is already clean of imports. Therefore, 'total output', as is shown in the TIPS database, can be interpreted as 'total output of domestically produced goods'. To construct the series 'domestically consumed output of domestically produced', 'exports' is subtracted from 'total output'. The series is constructed in current and real terms, and the latter is used as the 'domestic sales' series in estimation. Taking the ratio of constant to current domestically consumed output of domestically produced goods, generates a suitable domestic sales price index for each industry.

Of the 46 industry categories, 42 have sufficient domestic and import price and quantity data for estimation. Those excluded are: gold and uranium ore mining, other mining, water supply, and general government services. With the exception of 'other mining', these categories are omitted owing to South Africa not importing any products classified in these groups, implying no substitutability between imports and domestically produced goods. Multiple missing observations for 'other mining' force the exclusion of this sector.

[15] Primary data sources of the system, as well a brief description of the basic methodology followed in data compilation, can be accessed at: http//www.tips.co.za.

# 5. THE ESTIMATION PROCEDURE

A three-part procedure is used to select a version of the Armington model that generates, where possible, long-run elasticity estimates. These three steps are: 1) identification of the order of integration of each variable series, in a manner described in Section 5.1, 2) identification of a possible cointegrating relationship between each of the two series, a process also explained in Section 5.1, and 3) estimation of the Armington elasticities for each sector using one of three models, as reviewed in Section 5.2.

## 5.1 Determining the Time-Series Properties of Each Variable Series

The concept of stationarity was introduced briefly in Section 2. To remind, a variable is said to be weakly non-stationary if its mean, variance and autocovariance (at different lags) are related to the time at which they are measured. In such cases, regressing a time series variable on another time series variable may yield a very high $R^2$, even if the two variables are not meaningfully correlated. Referred to as a 'spurious' relationship, this problem is associated with time series that exhibit strong trends (sustained upward or downward movements), so that the high $R^2$ observed is due to the presence of the trend, rather than to a true relationship.

In regressions involving time series data, a trend variable may be included as a regressor to avoid the problem of spurious correlation. Indeed, the trend variable has the effect of detrending, or controlling for the influence of the trend on, each time series under focus (Gujarati, 1995: 722). However, this practice is only appropriate if the trend variable is deterministic and not stochastic (see Nelson and Plosser, 1982, and Stock and Watson, 1988).

Broadly speaking, a trend is deterministic if it is perfectly predictable, and not variable. In this case, detrending by a common trend line, as implicated by including a time trend as a regressor, is acceptable, and the time series is referred to as being trend-stationary. If, however, the trend variable is observed to be stochastic, the trend line shifts across the time series, and thus detrending by a common trend line will be misleading. In this case, each time series must be differenced for stationarity. The number of times a variable must be differenced until it is observed stationary is referred to as the order of integration of the variable. By way of example, if a time series is first difference-stationary, it is integrated at the first order, or I(1).

Alternatively, if a time series is second difference-stationary, it is integrated at the second order, or I(2), and so on. Unfortunately, long-run information relevant to trade policy analysis is lost between variables in their difference, rather than their level, form. Thus, this procedure is only applied in cases where statistical tests, as elaborated upon below, find no evidence of a long-run relationship. Furthermore, in no case is a series more than first-differenced, even if determined to be I(2). This is because second differencing a series, while ensuring stationarity, forgoes information on the short-run relationship between the demand and price ratios. Thus, in these cases non-stationarity is simply noted, and the reader can interpret the results obtained accordingly.

Moving on, in an attempt to allow time for adjustment of prices and quantities to some given exogenous change, the estimation technique of Equation 3 is determined by the time-series properties of the quantity and pricing series. The Ljung-Box statistic, based on a correlogram derived from each data series, together with the augmented Dickey-Fuller test, are used to determine the order of integration of the two time series used in estimating Equation 3, the ratio of domestic sales to imported goods, and the corresponding relative prices. In most cases each series is stationary in either log-level or first differenced form. However, in twelve cases one of the series is integrated at a higher order, I(2). With one exception, these cases exhibit no long-run relationship, are reported as non-stationary, and estimated according to the manner described in Section 5.2. The exception is a single case where both series are determined to be I(2) and thus, despite the higher order of integration, it is possible to test for cointegration in the manner outlined below.

Cointegration test results allow one to determine whether an error correction model is an appropriate specification for the sector under analysis. Two non-stationary time series are cointegrated if a linear combination of them is stationary. This implies that the combination of the two series does not have a stochastic trend. Two tests, the Engle-Granger and the ARDL approach, are applied to each industry series to establish the existence, or lack thereof, of a long-run stationary relationship between the demand and price ratios.[16, 17] As the Engle-Granger test is only valid if both variable series are of equal orders of integration, this test is only performed when both the ratio of domestic goods and imports and the relevant price ratio are both either I(1) or I(2). In contrast, the ARDL procedure can be applied irrespective of the order of integration of the regressors, and thus avoids the pre-testing problems associated with standard cointegration analysis (Pesaran and Pesaran, 1997: 303). Furthermore, stability tests associated with this method indicate which of the variables are long-run forcing, thereby ensuring that a simultaneous relationship does not hold between the dependent and explanatory variables, at least over the long-run. In light of these arguments, the ARDL test is applied to all industries, and serves to confirm or dismiss conclusions made regarding cointegration using the Engle-Granger testing technique. Where results conflict, the degree of strength of which each test rejects (or does not reject) the null hypothesis of cointegration, together with a visual inspection of the log-level data series, is used to decide upon the existence of a cointegrating vector.

A final note in this regard is that shift dummy variables are at times included when testing the time-series characteristics of the data. Failure to include appropriate dummy variables in the Engle-Granger testing procedure leads to an under-rejection of the null hypothesis of there being a unit root, which may lead one to conclude a data series is non-stationary, when in fact it is stationary (Pesaran and Pesaran, 1997: 290). However, the choice of appropriate dummy variables to include is a subjective procedure. Accordingly, as unit root tests are sensitive to the nature of variables included, a strict decision procedure is adopted. First, two general dummy variables are applied for structural breaks; one for the Rubicon speech of 1985, after which trade sanctions shortly followed, and the other in 1995, representing the opening of the South African economy with the first democratic elections of 1994 and the phasing in of trade liberalisation. Second, visual inspection of each log-level data series serves to indicate whether an industry specific dummy ought to be included. Where dummy variables are determined insignificant, or fail to improve the overall goodness of fit in the equation underlying the Engle-Granger testing procedure, they are omitted.

## 5.2 Specification of the Model

In generating sector-specific Armington elasticity estimates, the selection procedure used by Gallaway *et al.* (2001) to determine the most appropriate method of estimating the base equation, as given by Equation 3 in Section 3.1, is applied. Gallaway *et al.* (2001) define three models, each of which is described below, where the choice between the models is dependent on the combined time-series properties of the two data series employed per sector.

First, for industries having stationary log-level data, one estimates a geometric lag model that can be used to extract both short- and long-run elasticity estimates with relative ease. In this case, Equation 3 is operationalised as:

$$y_t = a_0 + a_1 x_t + a_2 y_{t-1} + u_t \quad ,$$
[Equation 4]

where $y$ and $x$ are the goods and price ratios respectively at time '$t$', and $u_t$ represents an *iid* error term, also at time '$t$'.[18] Long-run elasticities can be estimated as $a_1/(1-a_2)$, if $0<a_2<1$. Otherwise, the reported elasticities are $a_1$, and notably represent short-run elasticity estimates.

Second, when the data for an industry are both I(1) or I(2) and cointegrated, a single equation error-correction model of the following form is estimated to extract the long-run elasticity estimates:

[16] The theory is outlined in Engle and Granger (1987).
[17] 'ARDL' stands for 'autoregressive-distributed-lag' and is laid out in Peseran and Shin (1995).
[18] *iid*: independently and identically distributed.

$\Delta y_t = a_0 + a_1\Delta x_t + a_2y_{t-1} + a_3x_{t-1} + u_t$,
[Equation 5]

where $\Delta y_t = y_t - y_{t-1}$, $\Delta x_t = x_t - x_{t-1}$, and $u_t$ represents an *iid* error term. Equation 5 is a form of the unrestricted version of the error correction mechanism (ECM) model associated with Hendry, Pagen and Sargan (1984, cited in Gallaway *et al.,* 2001). This model allows the short- and long-run responses of demand with respect to price to be completely determined by the data. Specifically, short-run and long-run estimates are ($a_1$) and ($-a_3/a_2$) respectively.

Equation 5 is estimated using the ARDL procedure. As reported in Section 5.1, the main advantage to this testing and estimation strategy is that it can be applied irrespective of the order of integration of the regressors, thereby avoiding the pre-testing problems typically associated with cointegration analysis. The ARDL procedure comprises two stages. Consistent with the discussion in the previous section, the first stage tests the existence of a long-run relationship between the variables under assessment by computing the error correction form of the underlying ARDL model. The second stage regards the estimation method applied. Here, the coefficients of the long-run relations are estimated employing the single equation error correction model as given by Equation 5, and inferences are made about their long-run values. In this case, the ARDL model is specified (1, 1), which implies a single lag autoregressive explanatory variable ($y_{t-1}$), as well as a single distributed lag explanatory variable ($x_{t-1}$). A possible criticism of estimating Equation 5 by the ARDL technique is that the Johansen maximum likelihood approach is an improved cointegration testing and estimation procedure. However, benefits pertaining to this method are primarily derived when there are more than two variables under consideration, in which case residual based tests, for example the Engle-Granger test, may be inefficient and lead to contradictory results. However, with only two variables per sector under review, the complications introduced by the Johansen technique are believed to more than offset possible improvement in the reliability of cointegration test or estimation results. In any case, the ARDL testing procedure also overcomes problems associated with residual based tests, and so the Johansen procedure is omitted in favour of the ARDL approach. It is noted, however, that the Johansen estimation technique may resolve issues relating to short-run simultaneity, the implications of which are discussed in Section 6.3.

Last, when at least one series does not have log-level data and the $y=M/D$ and $x=p_D/p_M$ variables are not cointegrated, both series are first differenced, and the following model is estimated:

$\Delta y_t = a_0 + a_1\Delta x_t + u_t$,
[Equation 6]

where $a_1$ is the short-run Armington elasticity. In this third and final case, there is no long-run relationship between the goods and price ratio series, and thus it is not possible to extract long-run estimates. As a reminder, while the level of differencing is typically determined by the variable with the highest order of integration, the loss of critical information that second differencing implies, means that non-stationary variables are first-differenced only.

## 5.3 Diagnostic Tests

Before estimation, the following procedure is employed. First, both the level and first differenced log of the goods ratio are plotted against the level and first differenced log of the price ratio respectively, to detect any outliers that may distort the value of coefficient estimates. Any sizable outliers (at most three but in the majority of cases one) are controlled for in estimation through inclusion of a dummy variable for the year(s) of concern. Thus, the added explanatory variable is given as '1' for the problem year, and '0' otherwise. A separate dummy is included for each outlier, unless the outlier years run consecutively. This treatment of outliers is preferred over simply dropping the outlier(s) as it retains the full data series for estimation, crucial given the relatively short time series, and thus low number of observations. In addition, the researcher is able to determine the significance of the distortion of the outlier, as well the exact magnitude of such a distortion, by reading the coefficient on the dummy variable in estimation. As a final note on this point, this process generates equations of a greatly improved fit over those that simply omit the distorting year.

For each regression estimated, a battery of diagnostic tests is performed. This comprises:

- The Shapiro-Wilk *W*-test for normality;
- The Cook-Weisberg test for heteroscedasticity;
- The Durbin-Watson *d*-test for serial correlation;
  - The Geary, nonparametric 'runs' test for serial correlation;
  - The Breusch-Godfrey test of higher-order autocorrelation;
  - The Ramsey RESET test for omitted variables.

Regarding the Shapiro-Wilk test for normality, where the null of the data following a normal distribution is rejected no corrective procedure can be implemented, and so non-normality is noted. Where heteroscedastic errors are observed, the regression is re-estimated taking heteroscedastic errors into account by computing a robust variance estimator, and thereby correcting the standard error. In testing for serial correlation, the 'runs' test is applied following estimation of Equations 4 and 5, and the Durbin-Watson *d*-test is applied following estimation of Equation 6. This difference in testing procedure is because an underlying assumption of the Durbin-Watson test is that the regression model does not include lagged value(s) of the dependent variable as one of its explanatory variables, which is the case in Equations 4 and 5, implying that the test is inappropriate. In the presence of serial residual correlation, the Cochrane-Orcutt iterative procedure is applied in an attempt to remove it. However, this method only corrects for first order autocorrelation. Thus, for cases where either higher order correlation is observed, as tested for by the Breusch-Godfrey test, or the Cochrane-Orcutt procedure is not successful, as tested by the 'runs' test, it is assumed that the autocorrelation cannot be removed, and the presence of such noted.[19] In cases where the null of 'no misspecification' is rejected, as tested for by the Ramsey RESET test, such is indicated by an 'X' in Table 1 in the relevant column. Furthermore, for each industry the sustained presence of either heteroscedasticty or serial correlation is likewise represented. It is reminded that estimation by OLS in the presence of serial correlation and/or heteroscedasticity biases the variances of each parameter estimated, implying that one cannot rely on the standard errors, and subsequently cannot perform hypothesis testing (Gujarati, 1995: 366, 411).

However, the coefficients themselves are unbiased, and thus still useful for inclusion in applied trade policy modelling. Unfortunately, where equations are determined misspecified, the Ramsey RESET test cannot explain the nature of the misspecification, and so it remains unknown whether a problem pertains to the functional form applied in estimation, or omitted explanatory variables.

[19] The transformation of the dependent and explanatory variables in the Cochrane-Orcatt procedure implies that one cannot test whether autocorrelation has been removed by repeating the Durbin-Watson test. Rather, the non-parametric 'runs' test, which makes no assumption about the distribution from which the observations are drawn, is applied.

# 6. ECONOMETRIC RESULTS

## 6.1 An Overview

The estimated Armington elasticities are presented in Table 1, together with certain summary regression statistics. [20] Part A of Table 1 reports short-run and long-run estimates for those sectors in which both price and quantity series are I(0). In other words, Equation 4 is applied to these industry data series, although no industry falls within this estimation category. Alternatively, Part B reports short-run and long-run estimates from Equation 5, the error correction model with specified orders (1, 1), in cases where the series are both I(1) or I(2), and cointegrated. Part C reports estimation results from Equation 6, which is applied when at least one series is non-stationary, or the price or demand series are both I(1) or I(2) and the combined series are not stationary. Most industries fall within this third classification, implying that few industries exhibit a long-run relationship between the change in demand for domestic and import goods, as their relative prices change. It is reminded that a series determined to be I(2) is simply first-differenced and treated as non-stationary.

No industries comply with the time-series property specifications required for the estimation of Equation 4. Of the four industries estimated by Equation 5, all show positive and significant short-run coefficients at the 5 percent level. Three industries exhibit a significant long-run estimate. Thus, in only three (of forty-two) cases is a significant and positive long-run Armington elasticity obtained. Alternatively, of the thirty-eight industries estimated by Equation 6, nineteen show significant and positive short-run coefficients at the 1 percent level of significance, an additional five at the 5 percent level, and another four at the 10 percent level.

Overall, of the forty-two industries for which complete data is available, twenty-two exhibit positive and significant short-run Armington elasticity estimates at the 1 percent level of significance. A further six have estimates that are positive and significant at the 5 percent level, and four have a positive Armington estimate that is significant at the 10 percent level. Thus, a total of thirty-two of the forty-two industries exhibit positive and significant short-run Armington estimates.

Regarding the short-run elasticities estimated from all groups, the five most import sensitive sectors are, in order of sensitivity (from most sensitive): coal mining (2.771), footwear (2.04), beverages (1.57), leather and leather products (1.474) and tobacco (1.35). Three of the least sensitive sectors are, again in order of sensitivity (from least sensitive): catering and accommodation services (0.42), basic chemicals (0.677) and coke and refined petroleum products (0.73).

[20] The Durbin-Watson test is inappropriate for equations that have an autoregressive explanatory variable, and thus no *d*-test statistics are reported for the associated sectors. Section 5.3 explains that this is true of cases in which the error correction model or the Cochrane-Orcutt procedure is applied.

**Table 1: Armington Elasticities of Substitution Between Imported and Domestically Produced Goods**

| | SIC Classification | Armington Elasticity Estimate | | R2 | Adj-R2 | DW stat | I(2) series | Autocor | Hetero-scedastic | Specifica-tion |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Part A: Estimation by Equation 4** | **Short-Run** | **Long-Run** | | | | | | | |
| | - | - | - | - | - | - | | - | - | - |
| | **Part B: Estimation by Equation 5** | **Short-Run** | **Long-Run** | | | | | | | |
| 1 | Tobacco [306] | 1.35 (0.000) | 0.676 (0.000) | 0.58 (0.000) | 0.52 | - | | | | |
| 2 | Motor vehicles, parts and accessories [381-383] | 0.786 (0.002) | 0.638 (0.143) | 0.64 (0.000) | 0.59 | - | | | | |
| 3 | Building construction [51] | 0.584 (0.018) | 2.1 (0.000) | 0.82 (0.000) | 0.8 | - | | | | |
| 4 | Civil engineering and other construction [52-53] | 1.28 (0.001) | 2.688 (0.000) | 0.73 (0.000) | 0.68 | - | *x, y=I(2)* | | | |
| | **Part C: Estimation by Equation 6** | **Short-Run** | **Long-Run** | | | | | | | |
| 5 | Agriculture, forestry and fishing [1] | 1.273 (0.000) | - | 0.63 (0.000) | 0.59 | 2.43 | | | | |
| 6 | Coal mining [2] | 2.771 (0.095) | - | 0.18 (0.068) | 0.12 | 1.75 | | | | |
| 7 | Food [301-304] | 0.937 (0.066) | - | 0.11 (0.066) | 0.08 | 2.24 | | | | |
| 8 | Beverages [305] | 1.57 (0.000) | - | 0.58 (0.000) | 0.55 | 1.72 | | | X | |
| 9 | Textiles [311-312] | 1.262 (0.000) | - | 0.56 (0.000) | 0.51 | 2.93 | | | | |
| 10 | Wearing apparel [313-315] | 1.164 (0.000) | - | 0.37 (0.000) | 0.35 | 1.87 | | | | |
| 11 | Leather and leather products [316] | 1.474 (0.000) | - | 0.57 (0.000) | 0.54 | 2.3 | | | | |
| 12 | Footwear [317] | 2.04 (0.004) | - | 0.54 (0.000) | 0.5 | 1.28 | *x=I(2)* | | | X |
| 13 | Wood and wood products [321-322] | 1.205 (0.000) | - | 0.55 (0.000) | 0.54 | 1.91 | | | | |
| 14 | Paper and paper products [323] | 0.789 (0.000) | - | 0.6 (0.000) | 0.55 | 1.74 | | | | |
| 15 | Printing, publishing and recorded media [324-326] | 0.083 (0.819) | - | 0.27 (0.013) | 0.21 | 2.78 | | | | |
| 16 | Coke and refined petroleum products [331-333] | 0.73 (0.004) | - | 0.69 (0.000) | 0.65 | 2.96 | | | | |
| 17 | Basic chemicals [324] | 0.677 (0.035) | - | 0.52 (0.000) | 0.47 | 2.09 | *x=I(2)* | | | |
| 18 | Other chemicals and man-made fibers [335-336] | 0.792 (0.02) | - | 0.26 (0.015) | 0.2 | 1.98 | | | | |
| 19 | Rubber products [337] | 1.135 (0.000) | - | 0.36 (0.000) | 0.34 | 2.63 | | | | |
| 20 | Plastic products [338] | 0.275 (0.281) | - | 0.43 (0.000) | 0.39 | 2.59 | | | | |
| 21 | Glass and glass products [341] | 0.942 (0.019) | - | 0.27 (0.014) | 0.22 | 2.3 | | | | |
| 22 | Non-metallic minerals [342] | 0.655 (0.207) | - | 0.05 (0.207) | 0.02 | 1.74 | | | | |
| 23 | Basic iron and steel [351] | 0.447 (0.516) | - | 0.02 (0.516) | -0.02 | 1.94 | | | | |
| 24 | Basic non-ferrous metals [352] | 0.595 (0.177) | - | 0.14 (0.267) | 0.04 | 2.41 | | | | |
| 25 | Metal products excluding machinery [353-355] | 0.747 (0.000) | - | 0.55 (0.000) | 0.52 | 2.07 | | | | |
| 26 | Machinery and equipment [356-359] | 0.49 (0.28) | - | 0.13 (0.135) | 0.07 | 2.03 | *x=I(2)* | | | |
| 27 | Electrical machinery and apparatus [361-366] | 0.944 (0.002) | - | 0.28 (0.002) | 0.26 | 2.2 | | | | |
| 28 | Television, radio and comms. Equipment [371-373] | 0.441 (0.502) | - | 0.02 (0.502) | -0.02 | 1.84 | *x=I(2)* | | | |
| 29 | Professional and scientific equipment [374-376] | 0.505 (0.194) | - | 0.4 (0.000) | 0.36 | 2.19 | *x=I(2)* | | | |
| 30 | Other transport equipment [384-387] | 0.932 (0.25) | - | 0.45 (0.000) | 0.41 | 2.26 | *x=I(2)* | | | |
| 31 | Furniture [391] | 1.075 (0.065) | - | 0.36 (0.018) | 0.26 | 2.49 | *x=I(2)* | | | |
| 32 | Other manufacturing [392-393] | 0.417 (0.132) | - | 0.21 (0.035) | 0.16 | 2.64 | *x=I(2)* | | | |
| 33 | Electricity, gas and steam [41] | 1.437 (0.079) | - | 0.63 (0.000) | 0.6 | 1.08 | *x=I(2)* | | | |
| 34 | Wholesale and retail trade [61-63] | 0.603 (0.000) | - | 0.5 (0.000) | 0.47 | 1.7 | | | | |
| 35 | Catering and accommodation services [64] | 0.42 (0.03) | - | 0.43 (0.000) | 0.39 | 1.72 | | | | |
| 36 | Transport and storage [71-74] | 0.861 (0.000) | - | 0.42 (0.000) | 0.38 | 1.27 | *y=I(2)* | | | |
| 37 | Communication [75] | 0.568 (0.012) | - | 0.56 (0.000) | 0.8 | - | | X | | |
| 38 | Finance and insurance [81-82] | 0.616 (0.025) | - | 0.16 (0.03) | 0.13 | 1.25 | | | | |
| 39 | Business services [83-88] | 1.066 (0.000) | - | 0.83 (0.000) | 0.5 | - | | X | | |
| 40 | Medical, dental and veterinary services [93] | 1.135 (0.000) | - | 0.78 (0.000) | 0.77 | 1.53 | | | | |
| 41 | Excl. medical, dental and veterinary services [94-96] | 1.04 (0.000) | - | 0.82 (0.000) | 0.81 | - | | X | | |
| 42 | Other producers [98] | 1.065 (0.000) | - | 0.52 (0.000) | 0.49 | 1.65 | | | | |

Lastly, the significant long-run elasticity estimates are, in order of the size of the elasticity estimates (from largest): civil engineering and other construction (2.688), building construction (2.1), and tobacco (0.676). In the first two cases, 'civil engineering and other construction' and 'building construction', the long-run estimates are 2.1 and 3.6 times larger than the short-run estimates respectively. This is consistent with the Gallaway *et al.* (2001) findings that long-run estimates are, on average, twice as large as those estimated for the short-run, and can be up to five times as large. In the case of 'tobacco', the long-run estimate is uniquely smaller than that determined for the short-run. As a final comment regarding results obtained, it is noted that 'motor vehicles, parts and accessories' yields an insignificant long-run Armington elasticity estimate, even though the short-run estimate is significant at a better than 1 percent level.

### 6.2 A Comparison Between International, IDC and 'New' Estimates

In an effort to establish the degree of consistency of model estimates, it is of interest to model builders to compare results obtained in different research projects, both on the domestic and international front. To this end, consider Table 2. Here, our 'new' estimates are presented alongside those produced by the IDC (1997), in a domestic study, as well as by Shiells *et al.* (1986), an international version. While the latter study is somewhat dated, more recent research assesses industries at a higher level of disaggregation than either the current or IDC (1997) studies, rendering a valid comparison impossible. But, with this said, while the time lapse between the two sets of data employed is substantial, a comparison is still important to determine whether a systematic relationship exists between the three, independent studies. If such a relationship can be identified and explained, trade policy makers and researchers can use Armington estimates of foreign markets, adjusted for systematic differences, to predict domestic industry elasticities.

Comparing results across the three studies is not particularly useful except to clarify that, with one exception, no reliable pattern can be observed between the three sets of elasticities. This 'exception' refers to international estimates appearing consistently higher than estimates produced for the same industries in our and the IDC (1997) reports. While only five elasticity estimates of the Shiells *et al.* (1986) paper are significant, four of these are the highest estimate, relative to the two elasticities produced by the South African studies in the same sector. Indeed, for these five sectors, estimates produced by Shiells *et al.* (1986) are, on average, 8.5 and 5.4 times greater than those produced by the IDC (1997) and our current study respectively. Thus, should one adopt foreign estimates for use in a trade model of the domestic economy, the elasticities taken need to be reduced. By exactly how much is less certain, and would require further analysis into the nature of the relationship between domestic and international Armington estimates.

This 'exception' aside, results generated by the three studies are inconsistent, with elasticity estimates of the same industry differing substantially. In only one case, 'footwear', does the IDC (1997) and current study yield similar estimates, of 2.03 and 2.04 respectively. In a further two sectors, 'plastic products' and 'non-metallic minerals', the three projects agree in finding no significant relationship between the demand and price ratios. But these consistencies are not enough to warrant adopting, without guard, another country's, or even another domestic study's, elasticity estimates. Thus, trade policy researchers are strongly warned against employing foreign determined Armington estimates as proxies for South African elasticities, without first ensuring that a systematic relationship holds between the international and domestically produced estimates.

**Table 2: A Comparison of IDC, International, and 'New' Armington Estimates**[21]

| | | Present Study | | | IDC | | International |
|---|---|---|---|---|---|---|---|
| | SIC Classification | Elasticity Estimate | | $R^2$ | Elasticity Estimate | $R^2$ | Elasticity Estimate |
| | **Part A: Estimation by Equation 4** | **Short-Run** | **Long-Run** | | | | |
| | - | - | - | - | - | - | - |
| | **Part B: Estimation by Equation 5** | | | | | | |
| 1 | Tobacco | 1.35* | 0.676* | 0.58* | -2.681 | 0.93* | -16.19 |
| 2 | Motor vehicles, parts and accessories | 0.786* | 0.638 | 0.64* | 1.87* | 0.85* | - |
| | **Part C: Estimation by Equation 4** | | | | | | |
| 3 | Food | 0.937** | - | 0.11** | 0.74 ** | 0.59* | 0.31 |
| 4 | Beverages | 1.57* | - | 0.58* | 2.33** | 0.66* | 0.46** |
| **5** | Textiles | 1.262* | - | 0.56* | - | - | 2.58 |
| 6 | Wearing apparel | 1.164* | - | 0.37* | -0.465 | 0.6* | 1.62 |
| 7 | Leather and leather products | 1.474* | - | 0.57* | 4.41* | 0.69* | 4.11 |
| 8 | Footwear | 2.04* | - | 0.54* | 2.03* | 0.68* | 3.15 |
| 9 | Wood and wood products | 1.205* | - | 0.55* | .687* | 0.6* | 0.26 |
| 10 | Paper and paper products | 0.789* | - | 0.6* | 3.665* | 0.84* | 1.8 |
| 11 | Printing, publishing and recorded media | 0.083 | - | 0.27* | 3.192* | 0.9* | 2.72 |
| 12 | Basic chemicals | 0.677* | - | 0.52* | 1.528* | 0.72* | 9.85* |
| 13 | Rubber products | 1.135* | - | 0.36* | -0.429 | 0.57* | 2.67** |
| 14 | Plastic products | 0.275 | - | 0.04 | -0.091 | 0.89* | 8.58 |
| 15 | Pottery and Ceramics | - | - | - | 0.174 | 0.74* | 2.11* |
| 16 | Glass and glass products | 0.942* | - | 0.27* | 0.35 | 0.82* | 4.29 |
| 17 | Non-metallic minerals | 0.655 | - | 0.05 | -0.314 | 0.78* | 1.95 |
| 18 | Basic iron and steel | 0.447 | - | 0.02 | 0.693* | 0.85* | 3.05** |
| 19 | Basic non-ferrous metals | 0.595 | - | 0.14 | .57* | 0.76* | 0.81 |
| 20 | Metal products excluding machinery | 0.747* | - | 0.55* | -0.425 | 0.73* | 1.54 |
| 21 | Machinery and equipment | 0.49 | - | 0.13 | 1.092* | 0.52* | 3.34 |
| 22 | Electrical machinery and apparatus | 0.944* | - | 0.28* | 0.751 | 0.44* | 7.46 |
| 23 | Other transport equipment | 0.932 | - | 0.45* | 1.147 | 0.69* | 2.01 |
| 24 | Furniture | 1.075** | - | 0.36* | -0.158 | 0.69* | - |
| 25 | Other manufacturing | 0.417 | - | 0.21** | 0.946* | 0.46* | 3.55 |

It is of no surprise that estimates generated by Shiells *et al.* (1986) compare poorly to those of our study. Besides the markedly different time frame under review and different estimation method applied, one can expect estimates of a foreign country, particularly one which has a very different economy, in both structure and size, to South Africa, to differ considerably. However, the different estimates yielded by the present and IDC (1997) report requires scrutiny, and prompts one to ask the question: 'why?' An obvious response is that the IDC (1997) report estimates Armington elasticities for intermediate goods only, whereas this study

[21] An asterisk (*) or a double asterisk (**) indicates that the concerned parameter is statistically significant at the 5 or 10 percent level respectively.

employs goods and price data for total production, thereby including both intermediate and final goods. Related to this aspect of the nature of data used in estimation, South Africa is historically dogged by unreliable and inconsistent data series. The time series constructed for TIPS and used in our analysis are the product of an attempt to produce a data set that reconciles these previous shortcomings. Thus, one can argue that if the data series employed by the IDC researchers are flawed, results may be distorted and thus unreliable. Furthermore, the TIPS data-series spans a more recent and longer time period, implying greater degrees of freedom in estimation, and more reliable Armington estimates.

An alternative answer may come from differing econometric methodology. Indeed, former research attempts to generate Armington elasticities for South Africa, including the IDC (1997) report, estimate the Armington equation, as given by Equation 3, by OLS, albeit with the inclusion of an autoregressive lag term. In contrast, our study estimates a version of Equation 3 that depends on the time series characteristics of the data. Although IDC (1997) estimates appear to generate an improved fit when compared to current results, the nature of the strong correlation between the industry demand and price ratios is arguably spurious, implying that results obtained using a procedure that ignores non-stationarity in the data series may be misleading.

A final point in this discussion is the substantial difference between the present and the IDC study regarding the detection of a long-run correlation between the goods and price series. As discussed in Section 2.2.2, the IDC (1997) and Naude *et al.* (1999) papers contend that the use of medium- to long-term data, as given by annual data, identifies long-run relationships. Having used annual data in this analysis, similar reasoning implies that the short-run estimates generated are reflecting long-run, rather than short-run, trends, and that the three significant long-run relationships identified, are in fact relationships that hold over the very long-run. Alternatively, it may be the case that most South African markets, while adjusting annually, fail to do so towards any long run value. Section 6.3 returns to this issue.

At any rate, the contrasts between the two studies highlight the sensitivity of Armington elasticity estimations to the quality of data used in the estimation procedure, as well as the estimation method applied. With this in mind, policy makers and academic researchers alike are cautioned against the ready adoption of results obtained by previous studies. Much work is yet to be done to develop a fuller understanding of both data and econometric requirements in this area of trade policy analysis.

## 6.3 A Platform for Future Research

The initial intention of this research paper was to employ the Gallaway *et al.* (2001) approach to Armington estimation to South African industries. Insofar as remaining true to the method, this study has been successful. However, certain factors need to be taken into account when interpreting results obtained. The following discussion addresses these concerns, and where possible suggests remedies to be employed in future research of this subject.

A primary criticism of the Gallaway *et al.* (2001) estimation procedure is that it ignores a possible simultaneous relationship between the demand and price ratios. While the ARDL test for cointegration identifies which variable/s are long-run forcing, thereby enabling one to determine that a long-run simultaneous relationship does not hold, this does not preclude the existence of a short-run simultaneous relationship. In an attempt to deal with the simultaneity issue, two studies reviewed in Section 2.2.1, Shiells *et al.* (1986) and Reinert and Shiells (1993), estimate the Armington equation by two and three stage least squares. Indeed, a crucial assumption underpinning the method of least squares is that the explanatory variable is either non-stochastic or, if stochastic, distributed independently of the stochastic error term (Gujarati, 1995: 636). If neither condition is satisfied, estimates may be biased and inconsistent. But an observed shortcoming of the simultaneous equation models is that they ignore issues relating to the time series properties of the data series, particularly relating to stationarity. In a related aspect, they cannot distinguish between short- and long- run effects, a crucial aspect to this study. In using a multi-sector model of trade solve for the implied substitution elasticity, Hummels (1999, cited in McDaniel and Balistreri, 2002) also neglects to deal with non-stationarity in data series.

Perhaps an answer lies in a version of Sims (1980) vector autoregressive (VAR) model, a response to simultaneity. In this regard, the Johansen testing and estimation procedure referred to in Section 5.2 is a suitable example.[22] The model is based on the principal that true simultaneity among a set of variables implies there should be no distinction between endogenous and explanatory variables. However, this model may be considered *a-theoretic* as, relative to simultaneous equation models, it uses less prior information. Notwithstanding, because of its emphasis on forecasting, VAR models are less suitable for policy analysis (Gujarati, 1995: 749). In any case, the Gallaway *et al.* (2001) application can be defended in light of Reinert and Shiells (1993) findings that elasticity estimates are relatively insensitive across estimation by generalised least squares, maximum likelihood, and simultaneous equation methods. Nonetheless, the reader is urged to reconsider issues of simultaneity when interpreting the results generated. Indeed, McDaniel and Balistreri (2002: 4) observe that simultaneous equation systems typically generate larger elasticity estimates than single equation methods, and thus to the extent that simultaneity holds between the dependent and explanatory variables, the current estimates are biased downwards. Accordingly, further research to ascertain the extent to which simultaneity 1) holds between the demand and price ratio data series for South Africa, and 2) biases Armington estimators, is recommended.

Moving on, the aggregation of products into broad economic sectors at the two- and three-digit SIC level implies that much intra-sector variation is lost. It would be useful to determine the stability of these estimates across sectors by generating coefficients of variation, calculated as the standard error divided by the mean. Furthermore, Gallaway *et al.* (2001) makes the point that aggregated sector estimates are typically lower than those estimated for disaggregated sectors. Indeed, the aggregation process may lead to an underestimation of the 'true' elasticity. This would suggest that the short-term elasticities estimated in this study could be raised upwards if they are to be used in a computable general equilibrium (CGE) model. To this end, additional critical analysis of potential biases that may arise due to the aggregation process is required.

Related to the above point, Armington's (1969) exposition is based on the assumption that products, within the same product class but from different countries, are 'imperfect substitutes due to their differing countries of origin'. This is an important qualification, particularly when dealing with aggregated data, as the aggregation process masks much of the variation in the quality of products. Indeed, quality will differ according to regions. By way of example, South Africa is likely to import low quality textile products from less developed economies, while importing high quality products that fall within the same product group, from developed economies such as Italy. With other middle-income economies, South Africa may import both high and low quality textile products. Within any broad product classification, the elasticity of substitution will thus differ according to region for these high and low quality products. One will expect to find very low elasticities between South Africa and less developed economies if they do not produce high quality products, and South Africa does not produce the low quality products associated with these less developed economies. In other words, countries specialise according to comparative advantage, and trade is completely inter-industry. In this case, relative price shifts will not lead to a change in the demand for imports to domestically produced goods ratio (*M/D*). Also, the responsiveness of this ratio to changes in relative prices will be much stronger between neighbours than between spatially distant economies. Much of these effects are related to transport costs, which economic geography models proxy by proximity (Krugman, 1991). In any case, this will also affect the Armington elasticity, the extent to which requires further attention. While data are not available to estimate country specific Armington elasticities, the problems associated with aggregating imports from all countries, as well as the effect of quality differences on the estimates, should be considered. Subject to data availability, a study alike to Shiells and Reinert (1993), as reviewed in Section 2.2.1, is perhaps required. It is recalled that in Shiells and Reinert (1993), US imports are disaggregated into those from NAFTA members and those from the rest of the world. Similarly, South African imports could be disaggregated into those from SADC and the rest of the world.[23]

An additional concern of estimate reliability relates to the data series employed in estimation. In this regard, Gallaway *et al.* (2001) use monthly data, with considerably more observations. Specifically, the Gallaway *et al.* (2001) study employs monthly data from January 1989 to

[22] An outline of the Johansen procedure is given in Pesaran and Pesaran (1997).
[23] The anagram 'SADC' stands for 'Southern African Development Community'.

December 1995, implying 84 observations per sector, as compared to this study's (at most) 31. With monthly intervals spanning a number of years, one can pick up long-run relationships and the short-run deviations from these. In contrast, it is questionable whether the nature of the data employed in this study, being of annual intervals with (relatively) few observations, can yield the same output, and may explain why so few 'long-run' relationships were identified. This was the issue introduced in Section 6.2 when comparing the IDC (1997) to our 'new' estimates. One solution to this data constraint is to use a dynamic panel model with sectors combined according to some criterion, for example that products should be relatively homogenous, like 'wood and wood products' and 'paper and paper products' (see Baltagi and Griffen, 1995). Alternatively, one could employ a simple fixed effects model, as described in Harrigan (1995) and Bhargava *et al.* (1982).

In light of the above discussion, it is clear that extensive research is still required in the area of Armington elasticity estimation to overcome the difficulties identified. Whatever the response, there are problems inherent to estimating these elasticities in South Africa. Reliable long-term data remains difficult to find, labouring the researcher with severe data constraints.

# 7. CONCLUSION

In light of the importance of appropriate Armington elasticity estimates for trade policy analysis, the intention of this study was twofold:

1. To provide the most comprehensive and disaggregated set of Armington elasticity estimates for South Africa to date. This is important as the level of aggregation of the data used in estimation influences results obtained, and interacts with the Armington specification (McDaniel and Balistreri, 2002). To this end, the study has been successful, deriving significant and positive (short-run) estimates for thirty-two industries, compared to the fifteen produced by the IDC. Furthermore, the data series employed in the estimation procedure spans a longer and more recent time period, respectively implying more degrees of freedom in estimation, and greater relevance to trade policy makers.
2. Because most trade policy analysis attempts to estimate the long-run effects of a policy shock, an attempt is made to extract the long-run relationships from the data. Unfortunately, only three significant long-run estimates are obtained - a somewhat disappointing result, albeit arguably explained by the annual nature of the time series data used in estimation.

In any case, this research paves the way for a new econometric approach to trade data analysis in South Africa, laying the foundation for additional research using improved and updated data series, together with more comprehensive time-series econometric techniques.

# 8. APPENDIX

The derivation of Equation 2 from Equation 1 proceeds below. We start with Equation 1 as:

$$Q(M, D) = [\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}, \qquad \text{[Equation 1]}$$

where
- $M$ = the quantity of the import good;
- $D$ = the quantity of the domestic good;
- $\sigma$ = the CES between the domestic and imported good;
- $\beta$ = a calibrated parameter in the demand function.

Given the respective prices of imports and domestically produced goods as $p_M$ and $p_D$, minimising expenditure requires that the prices be made equal to the marginal utility derived from purchasing the associated products, so that $\delta Q/\delta M=p_M$ and $\delta Q/\delta D=p_D$. Thus, differentiating Equation 1 with respect to $M$ and $D$ yields:

$$\delta Q/\delta M = \sigma/(\sigma-1)[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}.(\sigma-1/\sigma)\beta M^{(-1)/\sigma}$$

$$= \beta M^{(-1)/\sigma}[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}, \qquad \text{[Equation 1a]}$$

and:

$$\delta Q/\delta D = \sigma/(\sigma-1)[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}.(\sigma-1/\sigma)(1-\beta)D^{(-1)/\sigma}$$

$$= (1-\beta)D^{(-1)/\sigma}[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}. \qquad \text{[Equation 1b]}$$

Given that $\delta Q/\delta M$ and $\delta Q/\delta D$ must respectively equal $p_M$ and $p_D$, the price ratio $p_D/p_M$ can be rewritten as:

$$p_D/p_M = (\delta Q/\delta D)/(\delta Q/\delta M)$$

$$= [(1-\beta)D^{(-1)/\sigma}[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}]/[\beta M^{(-1)/\sigma}[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{1/\sigma-1}]$$

$$= [(1-\beta)D^{(-1)/\sigma}] / [\beta M^{(-1)/\sigma}]$$

$$= [(1-\beta)/\beta].[M^{1/\sigma}/D^{1/\sigma}]$$

$$\therefore \quad (p_D/p_M)^{\sigma} = [(1-\beta)/\beta]^{\sigma}.[M/D] \qquad \text{[Equation 1c]}$$

Rearranging Equation 1c and simplifying yields:

$$M/D = (p_D/p_M)^{\sigma} / [(1-\beta)/\beta]^{\sigma}$$

$$= [(p_D/p_M)^{\sigma}].[\beta/(1-\beta)]^{\sigma}$$

$$= [(\beta/(1-\beta))(p_D/p_M)]^{\sigma} \qquad \text{[Equation 2]}$$

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