A Gravity Model for the Determination and Analysis of Trade Potential for South Africa

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EXECUTIVE SUMMARY

1. The aim and objective of the research

The main objective of the study is to develop a methodology (or working tool) for analysing international trade flows, based on the annual bilateral trade volume for the South African department of trade and industry (the dti). The basic tenet of the gravity model is derived from the gravity theory in physics. A flow is regarded as the resultant of the attraction between two objects. When the flows concern international trade, the objects are the exporting and importing countries. The ‘masses’ of the countries are the sizes of their economies, from which a potential trade flow results. The larger the economies of the relevant countries, the larger the trade among these countries will be. However, the mutual distance causes a resistance to trade, due to factors such as transport costs and times. Other factors that impede trade are import tariffs, border controls and quantity restrictions. Such indirect or artificial transport costs are not related to distance, but to the simple fact that the goods are transported from one country to another.

By measuring the impact of these factors on the bilateral trade between the two countries involved, it is possible to simulate bilateral between them and compare this to their actual bilateral trade. This can be disaggregated per sector providing areas that South Africa could exploit. The reasons why the potential is not realised then have to be investigated. This will assist government in its bilateral trade negotiations and also identify areas of possible government intervention.

The objective of this study is to conduct empirical research and develop an econometric gravity model, specifically for analysing the trade potential of South Africa as a whole, but also at a sectoral level. The specific aims of the project are to:

- Predicts what trade flows ought to be, given certain conditions.
- To determine priority markets, currently marked by underperformance in trade potential.

Allocate resources to areas where the best returns can be achieved in export growth, as well as job creation and SMME development.

- Establish performance measures for individual foreign trade offices in a changing environment.
2. Research methodology

The research is conducted as follows:

- Firstly selecting a sample of countries that have supposedly reached their trade potential. Bilateral trade flows are then considered between these countries, in a symmetric manner.

- A gravity equation explaining bilateral exports within the sample is then estimated.

- This equation is used in simulation exercises to determine natural bilateral trade between any two of countries, given the availability of data on distance; GDP and population numbers.

- Such simulated bilateral exports are compared with the actual exports to assess bilateral export potential.

- This methodology is applied for both the aggregated or total level of exports, as well as on five of the dti’s priority sectors, namely textiles, transport, chemicals, minerals and agriculture.

3. Design of gravity model

Figure 1: The gravity model

The gravity model is presented graphically in Figure 1 showing that potential supply and demand, determined by the sizes of the economies, predict the potential trade flow between the countries of the trading partners. This flow is subject to certain trade
resistance factors that are improved by trade arrangements. Finally, the actual trade flow results.

The basic trade gravity model relates to the measure of bilateral trade to the economic mass of the two countries and the distance between them.

\[
\text{TRADE}_{ijt} = \alpha (Y_{it} Y_{jt}) + \theta (P_{it} P_{jt}) + \beta D_{ij} + \mu_i
\]

where:
- \( \text{TRADE}_{ijt} \) is bilateral trade between country \( i \) and country \( j \)
- \( Y_{it}, Y_{jt} \) is the nominal GDP for country \( i \) and country \( j \)
- \( P_{it}, P_{jt} \) is the population in country \( i \) and country \( j \)
- \( D_{ij} \) is the distance between country \( i \) and country \( j \)

Translating the above into a mathematical expression, the following model arises:

\[
\log X_{ij} = \log \alpha_0 + \alpha_1 \log Y_i + \alpha_2 \log Y_j + \alpha_3 \log\gamma_i + \alpha_4 \log Y_j + \alpha_5 \log D_{ij} + \alpha_6 L_{ij} + \sum \alpha_{2z} P_{ij} + \sum \alpha_{2h} Q_{ij} + u_{ij}
\]

Where:
- \( X_{ij} \) is the total exports from \( i \) to \( j \)
- \( Y_i, Y_j \) are the countries' incomes (characteristics of trading partners)
- \( \gamma_i, \gamma_j \) are the countries' per capita incomes (characteristics of trading partners)
- \( D_{ij} \) is the geographical distance between \( i \) and \( j \) (separation characteristic)
- \( L_{ij} \) is a dummy for common language between the two countries (characteristics of trading partners)
- \( P_{ij} \) is a preferential trade scheme dummy (trade arrangements)
- \( Q_{ij} \) is a trade policy dummy (anti-export bias)
- \( u_{ij} \) is the normal random error term

The sizes of the economies of both the exporting and the importing country are represented by their GDP and population size. The distance between the countries and a dummy for a possible trade arrangement reflects trade resistance. This can be disaggregated per sector, providing the areas that South Africa could exploit. The reasons why the potential is not realised will have to be investigated. This will assist the government in its bilateral trade negotiations and identify areas for government intervention. This can be expanded to analyse sectoral determinants.

The gravity model develops a gravity equation for potential bilateral exports. It determines potential trade through a combination of macroeconomic variables (size,
income, exchange rates, prices etc.) between trade partners. Indicators of transportation costs between countries and more generally, market access variables, are also added. In this case the gravity model is used to explain trade patterns and to determine trade potential.

4. Empirical estimation of total exports of South Africa

A sample of 50 countries was used. The sample consisted of 50 countries to which South Africa has exported most in US dollar terms in 2000. A complete list of countries is included in the Appendix 1. The sample for the aggregate model (i.e. total exports) covers the period from 1980 to 2000. For the individual sectors, the model covers the period from 1988 to 2000.

A general-to-specific approach was used to obtain the final specification given by the following equation:

\[
\log X_{ijt} = C_0 + \beta_1 \log EX_{jt} + \beta_2 Dist_{jt} + \beta_3 PCY_{jt} \\
+ \beta_4 Pr odl_{jt} + \beta_5 Infra_{jt} + \beta_6 ERP_{it} \epsilon_i + \eta_i, \tag{7}
\]

\( X_{ijt} \) = exports from South Africa to country j (where subscript i denotes specific sectoral where applicable).

\( C_0 \) = common intercept

\( EX_{jt} \) = exchange rate between South Africa and country j. The exchange rate is used as a proxy for relative prices.

\( Dist_{jt} \) = the distance in miles between South Africa and country j.

\( PCY_{jt} \) = Per capita GDP of the country j.

\( Pr odl_{jt} \) = GDP of country j divided by the Area of country j. This is a proxy of how well a country uses its land area relative to GDP.

\( Infra_{jt} \) = In index containing a comprehensive rating for the infrastructure of a country. The higher the rating, the greater the infrastructure of the country.

\( ERP_{it} \) = The effective rate of protection for exports of sector i.

\( \epsilon_j \) = The country specific random effect

\( \eta_i \) = The white noise residual
The results of the estimation (See table 1 in chapter 3), show the extent of the effect of each of the variables on the potential levels of exports.

(a) **Exchange rate**: The magnitude of the coefficient is relatively small. Rapid short-run depreciations, nevertheless, will in most instances result in actual exports overshooting the potential level. Over the long run, however, the exchange rate effect becomes less severe.

(b) **Distance**: A country that lies geographically further from South Africa, is expected to attract less exports, especially due to transport cost. The coefficients indicate that this is indeed the case. Although the influence of distance is significant for total exports, it might not be an obstacle for some individual sectors, depending on the goods and services produced in the particular sector. Transport costs for goods to the developed world declined substantially during the last decade compared with the 1980s, and therefore is a less important factor in determining trade.

(c) **Use of Land**: A large country (abundant land) is generally expected to have a greater demand for imports from abroad. The ratio of GDP to land area was used as control for the fact that some countries have large land mass, but a relatively small GDP. This is the case with Canada and Russia. However, the coefficient indicates that as a country’s GDP increases relative to land area, exports to these countries will increase.

(d) **Per capita GDP**: The higher the income per capita for a country, the greater the demand for imports, and thus South Africa’s exports. Table 1 shows that this effect is quite strong. The positive coefficient of 0.62 as is evident from Table 1 indicates that a 1 per cent increase in per capita income of trading partners will lead to a 0.62 per cent increase in exports to the rest of the world.

(e) **Infrastructure**: This is a comprehensive rating of a country’s infrastructure that includes various factors, from roads, telecommunications to institutions. A higher rating indicates a better infrastructure. Better infrastructure should lead to higher trade and therefore more exports from South Africa to this country. The coefficients indicate that this is indeed the case.

(f) **Effective rate of protection.** Table 1 indicates that the effective rate of protection has the strongest effect. Although the effective rate of protection for South Africa has already come down significantly since 1994, the gravity equation still indicates the negative impact that high effective rates have on exports.
Consequently, it would seem that there is potential for further gains in. (The impact of the effective rate of protection on various sectors is measured below for a sample of the priority dti sectors).

The model seems to be well specified and robust in all instances. The factors used in the estimation are the factors used in many previously performed studies, and are considered as the core factors determining trade. Given this model, it is possible to calculate potential exports to an individual country based on the fundamentals. Given potential exports, the policymaker can compare it with actual exports, and determine where and to which country exports are under-performing. Figure 2 in chapter shows the 10 leading countries in terms of potential exports.

5. Sectoral analysis: methodology

The aim of the sectoral analysis (Chapters 5 to 8) is to give an overview of the analysis of each of the five chosen priority sectors of the dti. Apart from the gravity analysis, developed for South Africa’s total export function in chapter 4, the sectoral analysis also measures other indicators of specialisation and competitiveness for each of the sectors.

Not all possible scenarios, policy applications, or simulations will be covered in this report. The main objective is to develop a tool for the dti, whereby various simulations can be done. The data used was obtained from TIPS and the ITPC of the University of Pretoria’s own database.

Each of the sectors are analysed in a static as well as dynamic way. The static analysis consists of a description of the sector in terms of the current world market situation, its export and import performance and contribution to total production. The analysis of each sector only refers to some of the sub sectors and the 50 trading partners but the Annexure at the end of the report contains more detail.

The dynamic analysis measures the Revealed Comparative Advantage (RCA), intra-industry trade, and potential (gravity equation) of each sector. The Revealed Comparative Advantage also covers provincial exports of certain sectors, related to total South African exports. Again, the methodology is outlined. The dti can then use this to test the dynamic effects of trade for each sector and each province.
6. **Textile sector**

The industry is the world’s biggest exporter of sewing thread nylon, and supplies 20 per cent of the world parachute fabrics and more than 10 per cent of apparel and home textiles.

The textile sector in South Africa has undergone significant restructuring during the 1990s (See section 5.3.2 on intra-industry trade), due to increased trade liberalisation. Production has stagnated and employment fallen drastically. More than 30 000 jobs were lost during the period 1996 – 1999. Despite this structural adjustment effects, liberalisation and restructuring have resulted in increased productivity, mainly through cost-minimisation and downsizing measures. Due to the increase in textile exports, the share of exports to total production has also increased substantially since 1990. For the total textile industry the share of exports in total production increased from 8 per cent in 1990, to 13 per cent by 2000. The biggest export market for South African textile products is in leather and leather products. The share of exports in this sector has risen from 11 per cent in 1990, to more than 44 per cent in 2000. Given strong global competition, footwear do not have any comparative advantage in trade and exports, and therefore makes up less than 2 per cent of total production. (See Annexure 9).

The correlation between the decrease in total production, employment (see paragraph 5.2.1) and the Revealed Comparative Advantage (RCA) for the total textile industry is eminent. RCA for the total industry increased strongly from 0.2 in 1980 to 0.59 by 1996, whereas it decreased strongly to 0.35 by 2001. Thus, in total, the textile industry has still not reached a sustainable RCA in world markets.

Three of the sub-sectors experienced positive RCA (RCA>1). Since 1982, textile yarn, has experienced sporadic positive values for its RCA, like in 1984 (1.006) and in 1985 (1.54). The effect of sanctions resulted in a loss in RCA for textile yarn until around 1991 (1.1267). During the rest of the 1990s, this sub-sector battled to regain its international RCA. The textile sub-sector with the best RCA in world markets is Yarn of wool, or animal hair (including wool tops). This sector’s RCA coefficient stayed at levels of 3 for most years since 1981, reaching its best relative advantage of 5.7 in 1985.

Intra-industry trade has dominated the textile industry in South Africa, especially since 1985. The T-index increased from almost zero in the early 1970s, suggesting that most
textiles were imported, to just over 0.5 at the beginning of the 1980s. Since 1982, however, intra-industry trade in textiles has increased dramatically as differentiated imports and exports of textiles accelerated. The T-value for total textile, clothing and leather trade, as well as the two main sub-sectors, namely textiles and wearing apparel amounted to almost 1 by 1985, whereas the T-value for the total textile sector decreased to less than 0.7 by 2000. The T-value for wearing apparel nevertheless stayed high at levels just under 1.

The empirical gravity equation shows that despite the lack of revealed comparative advantage, actual and potential textile export have increased dramatically since the end of the sanction era, and the liberalisation of many of the export destination markets. Annexure 3 shows that apart from the traditional first world markets (the USA, Germany, UK, the Netherlands, etc) textile exports between 1993 and 2000 to emerging economies like China ($36 million to $64 million) and Indonesia ($9 million to $42) had increased substantially, even due to the fact that these two countries are well known as textile exporters. Textile exports to Africa also increased remarkably with increases from $50 million to $70 million to Mauritius between 1993 and 2000 and from only $2.8 million to over $25 million to Nigeria during the same time.

6. Chemicals sector

Despite the lack of employment creation in the chemical sector, the sector not only significantly increased total output in real terms during the 1990s, but also became more export orientated. The share of exports in total output has increased in all the chemical sectors. In basic chemicals the share has been as high as 45 per cent since 1995. In all the other sectors, with the exception of plastic products, the propensity to export exceeded 20 per cent by 2000.

During the 1980s, the export performance of the chemical industries was marked by a limited ability to penetrate into world markets. The RCA coefficient remained around 0.3 for most of the 1980s, with the exception of 1985 (0.7). During the 1990s, just like most other sectors in the South African economy, due to the extended liberalisation programme and the globalisation of the South African economy, the RCA of the total chemical sector more than tripled between 1990 and 1996, when the RCA value index reached 1.215. The RCA value again decreased to only 0.6 by 2001. This suggested that the relative contribution of chemical exports compared to total South Africa exports
decreased in relation to the share of world chemical exports to total world exports. Increased international oil demand from the rest of the world was mostly responsible for this relative increase in world chemical exports.

A few of the sub-sectors in the chemical industry have nevertheless experienced RCA values of more than 1 since 1980, namely Inorganic chemicals; mineral or chemical fertilizer phosphates and the radio–active and associated materials. Almost all the sub-sectors however lost its relative comparative advantages from 1997 to 2001.

The degree of intra-industry trade in the chemical industry is relatively high (product differentiation). This means that the levels of imports and exports are almost equal. The intra-industry coefficient for petroleum products, basic chemicals and the category other chemicals and man-made fibre, has increased significantly since the beginning of the eighties. This indicates that the South-African chemical industry has became product differentiated and that similar categories of products are exported and imported (The role of SASOL, etc). The coefficient for coke and refined petroleum products has decreased substantially since 1995, indicating that imports have increased at a faster rate than exports, for the specific sector.

Table 7 contains the gravity equation estimation results for chemical exports to the 50 countries as identified in Annexure 2.

Distance and the effective rate of protection on chemical products produced in South Africa limit the export performance of South Africa’s chemical products substantially. The coefficients are significant and negative, suggesting that free trade agreements for the chemical industry and more cost effective transport will contribute much towards increasing potential exports in the sector.

Figure 20 shows the ten leading countries with the highest potential export margins for chemical products at the end of 2000 (potential less actual). The Democratic Republic of the Congo (DRC)) shows the highest unrealised potential for chemical exports, with more than 70 per cent difference between actual and potential estimated exports. Portugal, Zambia, Turkey and Ireland follow the DRC with potential export levels of higher than 40 per cent.
7. Transport sector

Between 1991 and 1996 the transport sector’s average output growth rate amounted to 2.5 per cent compared to the national average GDP growth of only 1.5 per cent. However, between 1997 and 2001, the average growth rates of both the real GDP and transport output almost doubled. The latter sector also improved on its level of competitiveness. Average annual real export growth increased from 16.2 per cent between 1991 and 1996, to more than 27 per cent between 1997 and 2001, while import real growth decreased from 11 per cent to 7.4 per cent during the same time. However, despite this significant improvement in the performance of the sector, labour demand remained low, and even decreased from an average of 0.7 per cent between 1991 and 1996, to 0.3 per cent average between 1997 and 2001.

Despite the significant inroads that the transport sector has made into the world export market during the last decade, the sector’s share in total South Africa exports is still lower than the relative share of world exports of transport products. This means that the Revealed Comparative Advantage coefficient is smaller than one (RCA<1, - see Chapter 4 for explanation).

The exceptions are the export market for trailers and other vehicles, not motorised and railway vehicles. The RCA for trailers has increased to levels above 1 since 1992. By 1998, the RCA was over 4.7, meaning that the relative importance of this sector to total exports was almost five times more than the relative importance of this sector in the rest of the world exports. Due to a large export contract for railway carriers, the RAC for railway vehicles also exceeded 1 between 1996 and 1999. However, the relative importance of this sector currently declined to a level of less than 0.5.

Figure 27 portrays the automotive intra-industry trade. It shows that as expected, the volume of intra-industry trade has been increasing since 1985 and is now approaching unity. This is due to both the structure of the MIDP that encourages producers to export in order to import. However, with globalisation and integrated manufacturing rising, this is an international phenomenon. Components are sourced and supplied from the cheapest supplier regardless of location.

All signs are as expected, with the exception of the sign for the exchange rate. It is slightly positive. The coefficient is, however, very small and dominated by the effective
rate of protection (ERP). The very large negative effect of the ERP (coefficient of – 31.335) indicates that the protection on imports in the sector is still very high (especially on parts and accessories, and that this protection causes a strong bias towards exports of transport equipment). It thus seems as if the negotiation of free trade agreements would be far more beneficial for South Africa than a weak currency. In 2000 the average tariff for motor vehicles, parts and accessories, within the tariff-phase down under the WTO, was still the third highest of all sectors in the South African economy, at 25 per cent.

The distance between South Africa and its export markets is also a significant negative determinant of trade potential in this sector. For each 1 per cent increase in distance between South Africa and the potential export market, potential exports of transport equipment is due to decrease by 1.8 per cent.

The gravity equation that measures the potential level of exports shows that the effective rate of protection as well as infrastructure variables only effect transport exports with a lag. This is understandable, given that infrastructure does not erode overnight, and that transport exports are likely to be determined by fixed contracts, which expire only over a period of one to two years.

Figure 28 shows the 10 largest potential destinations for the export of transport equipment. The coefficient (in percentage) measures the level by which potential exports exceeded actual exports in 2000. According to the graph the Congo Democratic Republic has the biggest potential that still has to be exploited, namely 150 per cent. Thereafter follows Saudi Arabia (140 per cent); Israel (130 per cent) and Zambia (118 per cent).

8. Agriculture and Mineral sectors Table 16 shows that both the agricultural and mineral sectors are performing worse than the rest of the economy in terms of output growth, exports, and employment demand. Especially after 1997, the real output growth of the agricultural sector amounted to only 1.6 per cent compared to real GDP growth of 2.9 per cent. In the case of minerals, output growth for the period 1997-2001 was negative (-0.5 per cent).

Despite the low propensity to export in both sectors, growth in real exports relative to total output nevertheless increased substantially since 1990. In the agricultural sector
the share had increased from 7 per cent to 13 per cent by 2000, whereas in the mineral sector the share more than doubled from 4 per cent in 1990, to just less than 11 per cent by 2000. The share of the import of agriculture products, to total imports is small at less than 5 per cent. The import penetration share in the mineral sector, however, more than doubled to 25 per cent between 1990 and 2000 due to a sharp increase in the imports of especially glass and glass products.

Imports as well as exports of differentiated products are eminent in these two sectors. The intra-industry coefficient (T) for the minerals sector has remained relatively constant since the middle of the 1970s. However, the coefficient for the agricultural sector fluctuated widely due to weather conditions, but it is concerning to observe a negative tendency as from 1991. The reason could be an increased demand for cheaper foreign products due to agricultural subsidies in large exporting countries like the US and the European Union.

Despite the relatively poor export performance of both agricultural and minerals sectors (around 12 per cent of total production), the revealed comparative advantage of both sectors recorded a RCA coefficient higher than 1 between 1991 and 2001. This indicates that the relative share of total exports exceeds the share of this sector in world exports.

The empirical estimation of the agricultural and mineral sectors exports potential shows positive results. Once again the long run affect of changes in the exchange rate influences export potential but it is small and insignificant. The distance determinant is highly significant and confirms the importance of transport costs and trade facilitation in improving trade potential.

The results of the gravity equation further show that an improvement in the productivity of soil in a country increases South Africa’s exports of agricultural products to that country.

Lastly, the empirical estimation of the potential for agricultural exports proves that the higher the effective rate of protection, the lesser the level of exports. This is statistically highly significant. Domestic tariff protection on agriculture products contributes considerably to lower potential exports.
The results of the potential trade estimation for mineral exports are also significant. Interestingly, the exchange rate correlation is contrary to expectations and should be investigated. Transport costs (distance away from the destination country), the productivity and the per capita income of the destination country and the effective rate of protection of the mineral sector all affects the potential level of mineral exports significantly. The results of the bi-lateral export potential to the 50 biggest mineral export destination confirm the importance of this sector as an important export industry.

9. Conclusion

The purpose of this research project for the Department of Trade and Industry is to develop a working tool that the Department can use to conduct research and formulate policy. The gravity model will enable users to conduct dynamic analysis of bilateral dynamic trade between South Africa and the 50 biggest export destination countries. The particular agility of the model to determine the revealed comparative advantage coefficient, intra-industry trade level and potential and actual levels of trade for each sector of the economy is the core of the research. Although the research report features only five of the priority sectors of the dti, the model was designed and results were obtained for seventeen sectors. The results of all these sectors will be made available to the dti as a consumer friendly tool on CD-disk. As part of the agreement between the ITPC and the dti annual short courses will be provided to the dti to demonstrate and teach the use of the model. Annual updates of the data and the results, as well as further refining of the model, also will be undertaken.