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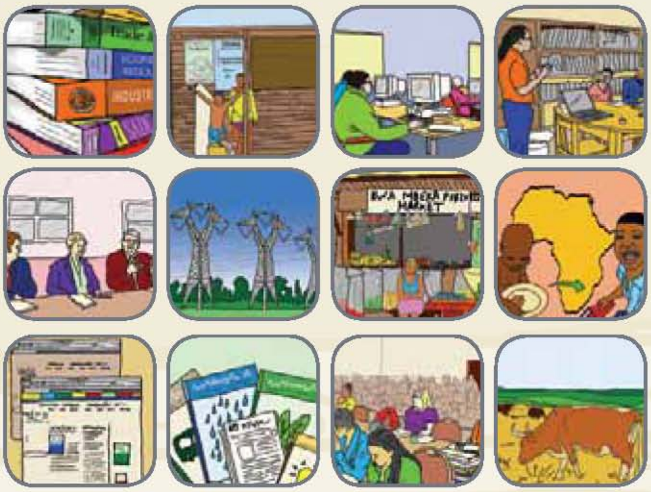

The Impact of SADC Trade on Energy Use

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Acronyms

EIA Energy Information Administration
IEA International Energy Agency
SADC Southern African Development Community

1 Executive Summary

Trade patterns change as a result of the international specialisation of production and the increased integration of world markets. This is especially evident in small open economies such as the countries that make up the SADC region. In 2000, the share of SADC industrial production that was exported stood at 12%; by 2005, this share stood at 17%. A similar yet more pronounced trend applies to the share of domestic final demand for industrial goods imported. For 2000, the share of domestic final demand imported was 13%; this increased to 20% in 2005. The change in trade patterns reflected in these numbers has important implications for the use of resources in the economies of the region. This study focuses on the implications of changes in SADC industry trade patterns on the energy use patterns of the countries within the region.

Trade literature on South Africa and the SADC region as documented by Hayter *et al.* (2001), Nattrass (1998) and IMF (2000) indicates that the region's comparative advantage in international markets is derived from its abundant natural resources rather than other factor inputs such as unskilled labour. As a result, many of SADC's export-oriented industrial sectors are natural resource (and in some cases energy) based. Furthermore it is argued by some – such as by Hayter *et al.* (2001) and Fine & Rustomjee (1996) – that many of SADC's manufacturing and mining sectors which are linked through beneficiation and metals production have benefited substantially from the low industrial energy prices that the region's domestic energy policies have provided. There is thus sufficient reason to believe that SADC's trade in industrial goods has a significant impact on the region's energy requirements. This study adopts a structural input-output approach to test the extent to which this hypothesis is valid. Finally, the effect that the SADC industry trade components have on the region's energy use patterns are decomposed using the refined Laspeyres technique in order to establish the underlying causes of change in the country's energy requirements, such as whether these constitute technology changes, input output changes, and (or) composition changes..

The study finds that the embodied energy intensity of SADC mining and manufacturing exports is a great deal higher than that of imports over the period under consideration. Since the volume of SADC's international trade in these goods increased significantly during this period, the total value of embodied energy in the region's industry trade components followed a similar pattern. These results provide evidence of a significant impact on the region's energy use patterns by its trade in mining and manufacturing products.

2 Introduction

Patterns of energy use in an economy can change substantially over time. In Southern African Development Community (SADC) countries,[11] as in many other countries, changes in the types of fuels used in production and improvements in energy efficiency are major factors driving changes in aggregate energy intensities and energy use patterns by economic activity. Table 1 shows that, by international standards, the SADC economies are extremely energy-intensive; this is true irrespective of the measure of aggregate energy intensity used in the calculations employed for the economies tabulated.

Table 1. Energy Intensity Comparisons

Region	TPES/pop (toe per capita)		TPES/GDP (toe/000 2000 US$)		TPES/GDP(PPP) (toe/000 2000 US$)		Elec Cons/GDP (kWh/2000 US$)	
	2000	2005	2000	2005	2000	2005	2000	2005
SA	2.51	2.70	0.83	0.79	0.02	0.27	1.46	1.38
SADC	0.79	0.83	1.34	1.26	0.37	0.37	0.85	1.05
Africa	0.61	0.65	0.84	0.80	0.29	0.28	0.66	0.68
OECD	4.65	4.68	0.20	0.19	0.19	0.18	0.35	0.34
World	1.65	1.77	0.31	0.31	0.22	0.21	0.44	0.46

Source: IEA (2009).

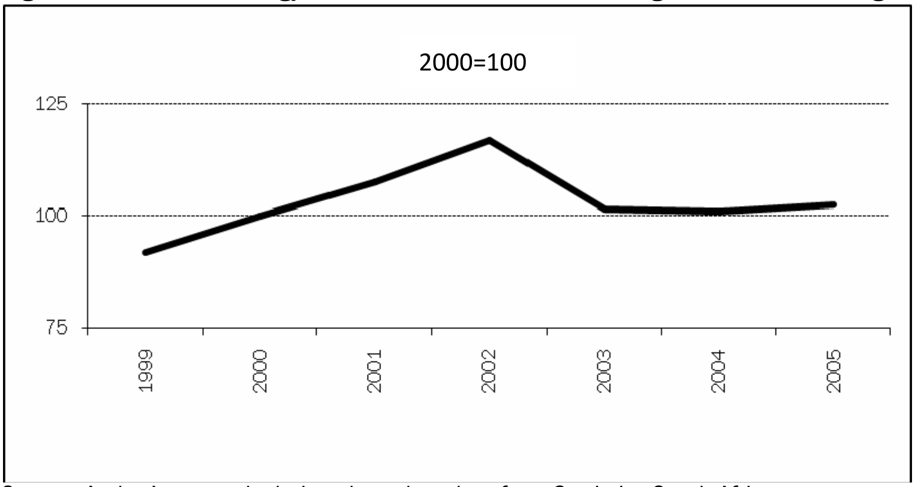
Explanations for changes in industrial energy use and improvements in energy efficiency in industry are numerous and are significant drivers of changes in aggregate economy-wide energy-intensities.

Firstly, given the price and production uncertainty of crude oil in world markets, the price of industrial energy inputs relative to other factor of production inputs can change substantially in a country. Figure 1 provides an indication of the change in the price of energy relative to all other factor of production inputs in the SADC region. More precisely, this figure shows the ratio of the producer price index for energy carriers used by South African[2] industry relative to the mining and manufacturing output deflator over the 1999 to 2005 period. (The limited period under investigation has been dictated by data considerations, in particular the availability of a set of sufficiently detailed and comparable supply-use tables as published by Statistics South Africa. Such tables are central to the calculation and determination of the energy input requirements of the South African economy and the SADC region for the purposes of this study.)

1 Since 1992, SADC members are Angola, Botswana, the DRC, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Swaziland, South Africa, Tanzania, Zimbabwe and Zambia.

2 The South African share of SADC industrial output amounts to 71% for 1999 and 43% for 2005. All data reported in the study relating to industrial output and energy input requirements by economic activity are thus for South Africa. This is due to the lack of sufficiently detailed data for the SADC region as a whole.

Figure 1. Industrial Energy Price Deflator relative to mining and manufacturing output deflator



Source: Author's own calculations based on data from Statistics South Africa.

Figure 1 depicts a fairly significant rise in the relative price of energy inputs for the period 1999 to 2002. Such changes are expected to act as a catalyst for energy saving technological progress in the mining and manufacturing sectors. The changes in industrial energy use brought about by an increase in relative energy prices are commonly referred to in the energy literature as intensity (or technology) effect changes.

Secondly, the price of industrial energy inputs can vary substantially across countries because of differences in government policies in respect of energy. Countries throughout the world have different energy taxation or even subsidisation policies. Such differences have a dramatic impact on industrial energy price differentials between countries. SADC's regional energy policies have a substantial impact on lowering the cost of the region's industrial energy inputs.

Table 2 compares the industrial energy input prices of South Africa, the most significant by industrial output of the SADC producing nations, with that of other countries. Coal as an energy input is responsible for 75% of South Africa's energy requirements (DME, 2006) and 41% of the combined SADC regional energy requirements (IEA, 2009). Fine & Rustomjee (1996) report that on a global scale, the South African economy in particular is uniquely dependent on the electricity derived from this coal. They suggest that this is primarily due to the extensive use of electricity in mining and mineral processing, including manufacturing industries closely related to the minerals energy complex (MEC). These are: the iron & steel, base metals and chemicals industries. The low prices in South Africa for industrial energy inputs, in respect of coal and electricity, highlighted in Table 2, are evidence of the South African government's efforts to subsidise energy-intensive economic activities. Energy use patterns resulting from these domestic policies are commonly analysed as input-output effect changes in the literature.

Table 2. Industrial Energy Price Comparisons using PPP as US$2000

Country	Heavy Fuel Oil For industry (tons)	Natural Gas for industry (10^7 Kcal GCV)	Steam Coal For industry (tons)	Electricity for industry (kWh)
China	n.a.	n.a.	27.28	n.a.
Germany	167.28	187.90	n.a.	0.045
India	280.96	n.a.	24.38	0.080
Japan	156.10	315.00	25.31	0.100
South Africa	**203.84**	**237.06**	**14.21**	**0.017**
South Korea	413.80	n.a.	82.60	0.077

United Kingdom	200.10	109.30	55.50	0.058
United States	168.80	171.00	34.97	0.046

Source: Energy Information Administration, (EIA) various years.

Thirdly, changes in the structure and composition of production in an economy have important implications for energy productivity and hence energy-intensity within the economy. If SADC manufactures proportionally more goods that require large amounts of energy to produce, then the amount of energy that SADC uses per dollar of its GDP will likely increase. Part of the movement toward the production of energy-intensive products when countries have high growth requirements may be explained by the concept of materials, affluence and industrial energy use as proposed in Williams et al. (1987). They argue that when an economy is at a low level of income, economic growth brings with it increases in the capital-labour ratio, but at some income level the economy reaches a steady state equilibrium at which the capital-labour ratio remains constant. At the steady-state, current capital expenditures are only for replacement of depreciated capital. For example, when a country begins to develop it has a large need for infrastructural development which is highly resource and energy-intensive in its requirements. Once the infrastructure is in place it simply needs to be maintained and, as a result, the energy and resource needs of the economy are much lower. Changes in energy use patterns encouraged by changes in the structure of a country's production are referred to as composition effect changes as in other decomposition studies.

Fourthly, changes in international trade patterns associated with changes in a country's specialisation and liberalisation in trade and financial markets are likely to have important implications for energy use patterns in that country. This fourth point is the focal point of this research. It could be that SADC countries have gained competitiveness in the production of energy-intensive goods in world markets, and that a large part of the changes in energy intensity in the SADC mining and manufacturing sectors may be due to a movement towards the production of energy-intensive products for export.

It is clear from this discussion that the price of major industrial energy inputs varies across countries for several reasons. While many types of energy inputs are traded on the world market, they have positive transportation costs and are often subject to trade barriers. In addition, some forms of energy inputs such as electricity are difficult at best to export, suggesting that the process of arbitrage and the law of one price are unlikely to hold for them. For the reasons discussed above, it is an understandable hypothesis that patterns of international trade in energy-intensive goods are influenced by a country's endowments in primary energy inputs and by domestic policies that affect both the explicit and implicit industrial costs of energy inputs.

Understanding changes in the patterns of SADC's energy use in industry will not be complete without an analysis of the impact of international trade on the energy requirements of the region. Unfortunately, undertaking such an analysis is not as straightforward as it would seem. The problem is that, when trade patterns in a country or region change, it is not just a single aspect of production in an economy that changes. Changes brought about by a country's participation in international trade cannot be analysed in terms of a single component of change but rather are embodied in all components related to a country's economic activities. These changes include input-output changes in intermediate goods traded, compositional changes in final goods traded, intensity changes due to changes in technologies employed in both intermediate and final goods traded and additionally changes in the scale of economic activity due to the country's changing specialisation and liberalisation efforts. It is for these reasons, that this study adopts an input-output structural analysis approach to establish the impact of SADC's international trade in mining and manufacturing goods on the region's domestic energy resource requirements.

3 The Energy Content of International Trade

Factor content studies of international trade are an empirical extension of the Heckscher-Ohlin-Vanek (HOV) theory of international trade. The HOV theorem maintains that a country will export the services of relatively abundant factors and import the services of relatively scarce factors [Vanek (1968) and Leamer (1980)]. Leontief, a pioneer in factor-content studies of international trade, employed input-output tables to study the factor contents of US trade flows. Leontief discovered what came to be known as the *Leontief Paradox* of USA' international trade when he observed paradoxically that the US specialised in exporting the services of labour rather than the services of capital. According to Leamer (1980), the Leontief Paradox rests on a simple conceptual misunderstanding. It makes use of the intuitively appealing but nonetheless false proposition that if capital "per man" embodied in exports is less than the capital per man embodied in imports, the country is revealed to be poorly endowed in capital relative to labour. This is a true proposition if the net export of labour services is of the opposite sign of the net export of capital services, but when both are positive, as in Leontief's data, the proper comparison is between the capital per man embodied in net exports and the capital per man embodied in consumption (Leamer, 1980). Using Leontief's figures, Leamer (1980) proves that there is no paradox if one compares the factor content ratios in US net trade with that of US consumption.

A factor content study of South Africa's international trade, SADC's largest producer, as undertaken by Tsikata (1999) using Leamer's approach observed that South Africa exports the services of capital rather than those of labour. In similar research undertaken by Hayter *et al.* (2001) it is found that natural resources, rather than unskilled labour, is the factor that Southern African countries are the most abundant in. A study by the IMF (2000) concurs with these findings, stating that the bulk of Southern Africa's trade is characterised by large exports of natural resource commodities and, at the same time, the country is a net exporter of capital-intensive goods to high and middle income countries in apparent contradiction of the HOV theorem. As a result, many of South Africa's and indeed SADC's export-oriented industrial sectors are natural resource (and, as in many cases, energy-) -based. Furthermore, these industrial sectors – in particular those associated with mining and minerals processing, iron and steel, base metals and chemicals – have benefited from an industrialisation strategy that has subsidised capital-intensive production techniques where the monetary authorities favoured negative real interest rates in an attempt to overcome the problems associated with South Africa's rigid labour markets and through the states' investment in the provision of cheap and plentiful energy (Fine & Rustomjee, 1996). As a result of the region's vast endowment of natural resources and the policy distortions introduced by the state in the countries that comprise SADC, SADC's international trade reveals the region to be relatively well endowed in the factors capital and energy.

Production inputs such as energy have also been the subject of factor content studies; for instance those of Battjes *et al.* (1998), Fujimagari (1989), Roop (1987) and Jacobsen (2000). These studies of the energy content of trade look at the effective embodiment of energy in terms of joules over various time periods for various countries. In our study, the energy content embodied in trade is calculated in terms of real expenditures on energy, that is, in constant price monetary units, rather than in joules. Embodied energy calculated in this manner lends itself well to the discussion of competitiveness in energy-intensive industries. In this study of the energy content of SADC's trade we use an approach, as set out below, similar to that of Roop (1987) but calculate embodied energy in real rands spent on energy rather than in joules.

In order to correctly calculate the value of energy inputs that is effectively embodied in SADC's exported and imported goods, an input-output approach is required. The value of energy that it takes to assemble a finished product is different from the value of energy that is embodied in the finished product itself. In other words, there is energy effectively embodied in all of the intermediate goods that go into producing the finished product in addition to the value of energy that it takes to actually assemble the finished product. Therefore, to determine whether SADC countries are net exporters or importers of energy services via their traded goods, it is important to correctly account for the value of energy that is effectively embodied in the intermediate goods and the extent that these inputs are produced within the region or whether they are imported.

Input-output analysis, which extends back to the pioneering work of Leontief (1951), recognises that industries are interdependent, meaning that production by one industry is most often dependent on the output of other industries as inputs. Input-output tables seek to tackle the problem of simultaneously solving for the amount of output needed in the economy to exactly meet the intermediate needs of each industry and final demands of consumers. Input-output models typically deal with a large number of industries, making them quite complex, and so the simplifying assumptions which we set out next are often adopted in order to make the calculations tractable.

The most common assumptions for input-output models are: (1) one homogeneous good is produced by each industry; (2) each industry uses a fixed proportion of inputs for production, and (3) all production exhibits constant returns to scale. In other words, it is assumed that a technical relationship exists between all inputs and outputs. In order to produce a unit of commodity (j), a fixed amount (a_{ij}) is required of commodity (i). The amount that is required of commodity (i), (a_{ij}) is called the input-coefficient. In practice, (a_{ij}) is assumed to be the rand value of the units of commodity (i) that are required to make one rand's worth of commodity (j). It follows that the input-coefficients must sum to less than one since, in addition to these intermediate industrial goods, primary factors such as labour and capital are also required. The contribution of labour and capital is traditionally termed value-added.

With the additional assumption of perfect-competition, the value of output must equal the value of all of the primary-inputs plus value-added. It follows then that if industry (i) is going to exactly meet its intermediate requirements for each of the n-industries as well as meet its final demand of consumers, the output that is needed to be produced for industry (i) is exactly:

$$y_i = a_{i1} y_1 + a_{i2} y_2 + \ldots + a_{in} y_n + d_i \qquad (1)$$

where (d), is the demand of industry i's output by consumers.

Writing equation (1) in terms of final demand for industry 1, we get:

$$d_1 = (1 - a_{11}) y_1 - a_{12} y_2 - \ldots - a_{in} y_n \qquad (2)$$

Since there are n equations for final demand, one for each of the (n)-industries, these equations can be written in matrix-notation as follows:

$$(I - A) y = d \qquad (3)$$

where (I) is the identity matrix, (A) is the input-coefficient matrix, (y) is a vector of industry outputs, and (d) is a vector of industry final demands. The matrix (I - A) is called the technology matrix. It is possible, provided the technology matrix is non-singular, to simultaneously solve for the levels of output in each industry that exactly satisfies all of the intermediate and final demand requirements for each industry in the economy.

This can be written as:

$$y = (I - A)^{-1} \cdot d \qquad (4)$$

where (y) is a vector of industry outputs that satisfies the system of equations for the economy and $(I\text{-}A)^{-1}$ is the inverse of the technology matrix.

Through the use of input-output tables, it is possible to determine the amount of each good needed domestically to meet all of the intermediate and final demand requirements of an economy. By taking the Leontief inverse of the supply-use table we are presented with four possible technology matrices with which to determine the vector of industry outputs that satisfies the final demand requirements of the economy. These versions differ depending on whether we adopt a commodity or industry (activity) approach in analysing the economy's output. Since, the main focus of this research is the calculation of the energy content of SADC's trade in mining and manufacturing goods and since exports and imports are treated as commodities in the supply-use tables, this study uses the commodity-by-commodity Leontief inverse of South Africa's technology matrix to calculate SADC's output in these sectors. [Note, using this version of the Leontief inverse of the technology matrix it is possible to establish the total effect on both domestic and imported (foreign) commodities used associated with an increase of one currency units worth of final demand for both domestic (regional) and foreign commodities.]

Using equation (4) combined with a vector of industry energy intensities, it is possible to sum over all industries to obtain an estimate of the value of energy that is embodied in the production of all (n)-

industries. This can be written in matrix notation as:

$$\Sigma e_{i,t}^{d} = \Sigma(c_{it}\, y_{it}) = \Sigma[c_{i,t}\, (I - A)^{-1} (d_{i,t})] \qquad (5)$$

where ($\Sigma e_{i,t}^{d}$) is the value of energy embodied in the vector of outputs of all the (i)-industries 1 through (n) at time (t) and (c_{it}) is a vector of industry energy intensities (e_i/y_i) at time (t). In order to calculate the vector of industry energy intensities (i.e., the direct energy coefficients (c_{it})) of the major energy producing industries in the South African economy - namely the coal, the petroleum and the electricity industries - input requirements at time (t) are summed together and treated as value added in the production of the remaining industries recorded in the country's supply-use tables. The technology matrix (A) that is constructed from South Africa's supply-use table for a particular year thus includes the input coefficient requirements of all the sectors of the South African economy excluding those of the coal, petroleum and electricity sub-sectors. In this manner we overcome the problem of double counting the primary energy supplying industries in the calculation of the direct energy coefficients.

It is important to note that equation (5) calculates the total value of energy inputs utilised to produce all of the output and required intermediate goods employed to produce the country's output, on the assumption that all of these goods are produced by these industries with the reported energy-intensities. In reality, this is not guaranteed since many intermediate and final goods are imported and, as such, are not subject to the same energy-intensities as the domestically produced goods. Battjes *et al.* (1998) suggests estimating the energy intensities of imports by means of the average energy intensities of the region in which the country is situated when information relating to the energy intensity of imports is unknown. In view of the fact that regional data on input-output linkages per specific economic activity are unavailable, and since South Africa imports most industrial goods from outside of the SADC region, this approach is deemed inappropriate. Recall that because of the data constraints we use South Africa's supply use tables to construct the SADC technology matrix. The study therefore assumes that SADC's imports are produced with the same energy intensities as South Africa's industrial goods which in turn are assumed to be the same as that of foreign economies goods. This is the standard HOV assumption whose validity has been the subject of much debate in the trade literature.[3]

Despite the limitations of the standard HOV assumptions, the data constraints pertaining to the energy intensity of imports at the industrial level for the SADC region mean that this assumption is nevertheless applied in the present study. This may well introduce an upward bias in terms of the energy intensity in production of SADC's imports.In particular, the bias relates to the fact that both South Africa's and indeed SADC's imports are largely sourced from economies that adopt more advanced production techniques and therefore the direct input-output coefficients which constitute the technology matrix employed will (for most sectors) almost certainly be higher than that of South Africa's and SADC's more advanced trading partners. The difference between the respective countries technologies reflects a lower productivity on the part of local economic activities and substituting a local technology matrix for that of foreign trading countries will almost certainly exaggerate the energy content of imports into the SADC region. The

[3] In this regard see Trefler (1995), Davis & Weinstein (2001) and Fisher & Marshall (2007) among others.

calculated embodied energy in SADC industry imports as well as in SADC output is therefore at best an over-estimate of the energy embodied in these activities. The differences between the embodied energy intensity of SADC's exports and imports will indeed be understated by our calculations providing a strengthened case for the belief that SADC's trade in industrial goods has a significant impact on the region's energy resource requirements.

It is possible, given the data on the value of each industry's exports and imports, to estimate the value of energy in essence embodied in SADC's net exports at time (t). This can be estimated by replacing total final demand in equation (5) with an industry vector of the SADC countries' net export portion of final demand. This is written in matrix notation as:

$$\Sigma(e_{i,t}^{nx}) = \Sigma[c_{i,t}\,(I - A)^{-1}\,(nx_{i,t})] \qquad (6)$$

where $\Sigma(e_{i,t}^{nx})$ is the net exported embodied energy for all (i) industries at time (t) as a result of trade in industries 1 through (n), the vector ($c_{i,t}$) is the energy intensity of industry (i) at time (t) and ($nx_{i,t}$) is a vector of net-exports for each of the (i)-industries at time (t). If $\Sigma(e_{i,t}^{nx})$ is positive then the region is a net exporter of energy services as embodied in its trade components, and if it is negative then the region is a net importer.

The value of energy embodied in the region's exports and imports could respectively be calculated as:

$$\Sigma e_{i,t}^{x} = \Sigma[c_{i,t}\,(I - A)^{-1}\,(x_{i,t})] \qquad (7)$$

$$\Sigma e_{i,t}^{m} = \Sigma[c_{i,t}\,(I - A)^{-1}\,(m_{i,t})] \qquad (8)$$

where ($x_{i,t}$) is a vector of exports and ($m_{i,t}$) is a vector of imports of each of the (i) industries at time (t).

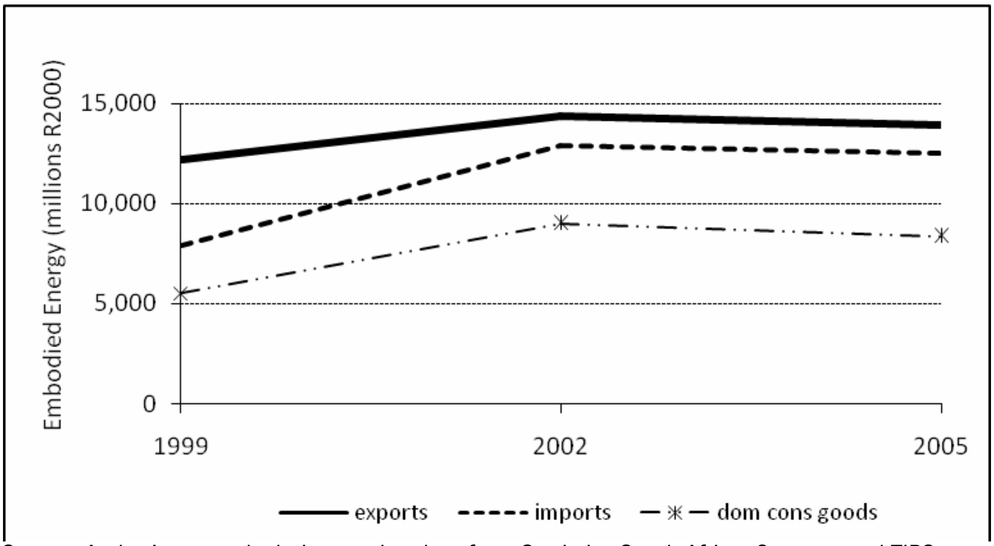
It is also interesting to note that, instead of summing embodied energy over all industries, one can simply have an estimate by industry (i), calculated simply as ($e_{i,t}^{nx}$) in equation (6), of the value of energy embodied in net exports to determine the industries that contribute most significantly in the overall calculation of embodied energy in net exports.

While an input-output table is essentially a detailed "snapshot" of an economy, showing the situation in the economy at a given point in time, structural input-output analysis can nonetheless be used to explore changes in the embodied energy intensities of traded goods over time provided that comparisons are undertaken at constant prices. A time series investigation of embodied energy estimates for SADC's trade components as calculated using equations (5) to (8) above can be undertaken on the assumption that the input-output (I-O) structure of the SADC economies remains unchanged over the years in between published input-output tables. This assumption is without doubt an oversimplification of the real world scenario where structural changes to the SADC economies brought about by their trade liberalisation efforts and other economic policy changes will, amongst other factors, affect both the factor proportions and production processes used in the region's production.

4 Results on the Energy Content of SADC Trade

Using equations (6), (7) and (8) and the data described in the Data Appendix, the value of energy that is effectively embodied in SADC's Mining and Manufacturing exports and imports and regionally consumed goods can be calculated. Figure 2 gives a graphical representation of the results using data from Statistics South Africa, Quantec and TIPS.

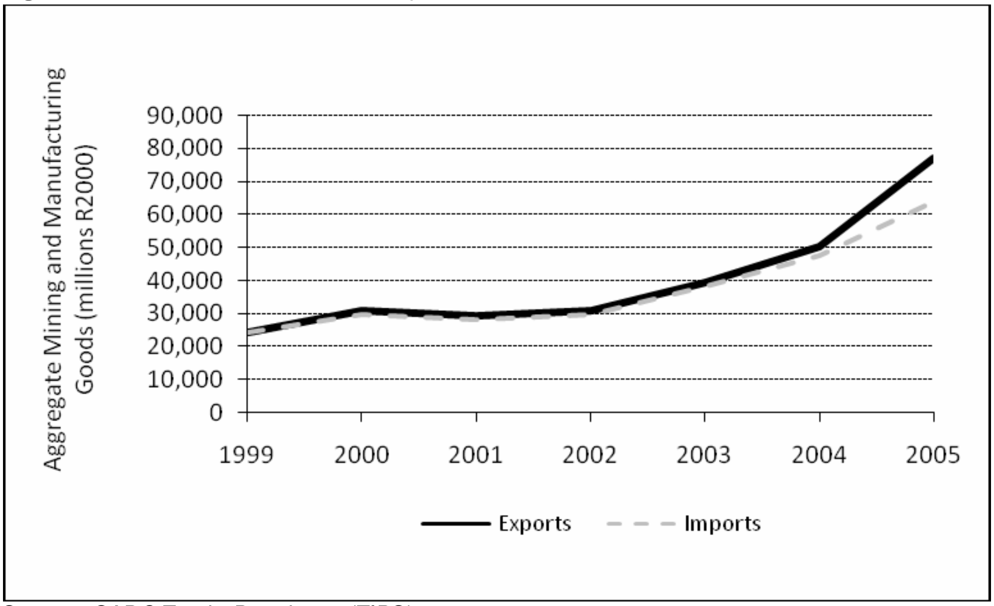
Figure 2. Embodied Energy of SADC Industry Exports, Imports and Domestically Produced Goods, 1993-2005



Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS.

Figure 3 on the other hand shows the real value of SADC's Mining and Manufacturing exports and imports for the same time period.

Figure 3. Real value of SADC Industry Exports and Imports, 199902995



Source: SADC Trade Database (TIPS).

The figures show that the levels of exports and imports are important determinants of the respective embodied energy value of these goods. Note that the difference between the embodied energy in exports and imports is referred to as the embodied energy of net exports. During the period of analysis, 1999 to 2005, energy is being exported via trade in mining and manufacturing goods. Over this period, SADC trade in aggregate mining and manufacturing goods is reasonably well balanced. However, from 2004 onwards, SADC runs a rising trade surplus in aggregate mining and manufacturing goods, confirming its position as a net exporter of embodied services of energy.

Figure 2 and Figure 3 together indicate that SADC countries are adding significantly to their local energy consumption by being net exporters of energy via their trade in industrial goods. These two figures, however, do not provide a complete picture of the role that international trade plays in the implicit exportation of energy services. A better indication of this is provided through an examination of the value of embodied energy per unit of industry exports or imports and in comparing these to the value obtained for the embodied energy per unit of locally consumed goods. The embodied energy intensity values show the energy content of industrial exports, imports and regionally consumed goods in constant (2000) SA rand values. In other words, the embodied energy intensities show the value per rand of energy inputs in the production costs of both intermediate and final industrial goods, whether traded or locally consumed, under the assumption that all the goods are produced in the SADC region. This calculation can be interpreted as an approximation of the average value of mining and manufacturing exports, imports and locally consumed goods that would be required to purchase the energy inputs needed to produce these products along with their intermediate inputs within the SADC region.

This is calculated by dividing equations (6), (7) and (8) by the total regional consumption of mining and manufacturing goods (D), exports of mining and manufacturing goods (X) and imports of mining and manufacturing goods (M) at time (t) respectively:

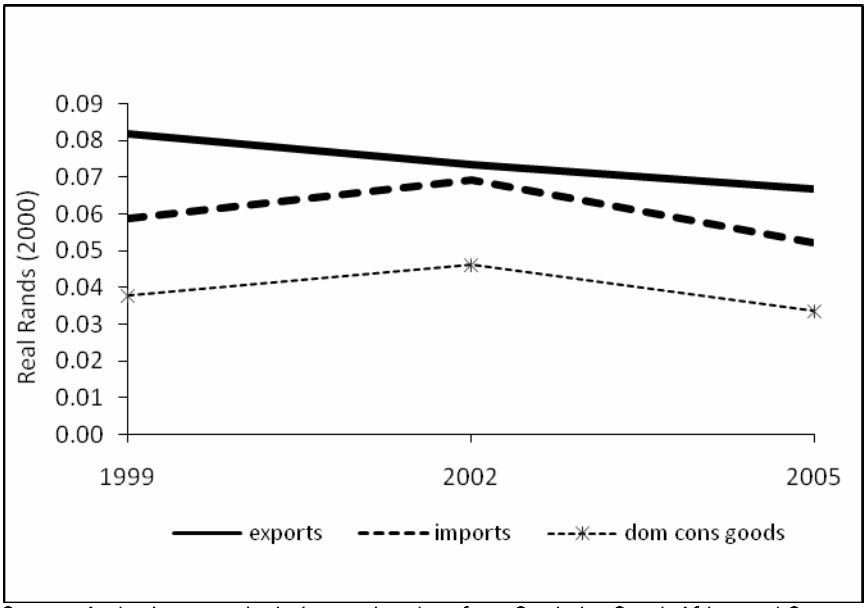
$$\frac{\Sigma(e_{i,t}^{nx})}{D_t} = \frac{\Sigma[c_{i,t}\,(I - A)^{-1}(nx_{i,t})]}{D_t} \tag{9}$$

$$\frac{\Sigma\, e_{i,t}^{x}}{X_t} = \frac{\Sigma[c_{i,t}\,(I - A)^{-1}(x_{i,t})]}{X_t} \tag{10}$$

$$\frac{\Sigma e_{i,t}^{m}}{M_t} = \frac{\Sigma[c_{i,t}\,(I - A)^{-1}(m_{i,t})]}{M_t} \tag{11}$$

The graphical representation of the embodied energy intensities of SADC's regionally consumed industry output and SADC's industry trade components for the period 1999 to 2005 is shown in Figure 4 in constant (2000) SA rand values.

Figure 4. Embodied Energy Intensity of SADC industry Exports, Imports and Domestically Consumed Goods, 1999-2005



Source: Author's own calculations using data from Statistics South Africa and Quantec.

Throughout the period under investigation, the embodied energy intensity of mining and manufacturing exports is higher than that of imports or locally consumed portions of these goods. Note that there is a slight convergence in the embodied energy intensity of mining and manufacturing exports with that of imports and regionally consumed goods for the period 1999 to 2002. This convergence is, however, negated during the period 2002 to 2005 when, despite falling embodied energy intensities, the differences in the intensities increase again.

A closer inspection of the energy intensities (as illustrated in Table 3) reveals that the amount of energy relative to other factors of production embodied in SADC's net exports of mining and manufacturing goods exceeds that of the regional production and consumption of these goods. Table 3 indicates this for 1999 and 2002. The ratio for the year 2005 has not been computed since the embodied energy content of net trade is registered as being positive at a time when the result obtained for the other factors embodied in net trade is negative.

Table 3. Factor Intensity of SADC Consumption, Production and Trade and Industrial Goods for 1999, 2002 and 2005 (Rm at 2000 constant prices)

	Production	Net Exports	Consumption*
	(millions of constant 2000 rands)		
1999			
Energy	R 9,797	R 4,287	5,510
Value added#	R 90,434	R 23,779	R 66,655
Energy/Value Added	0.1083	0.1803	0.0827
2002			
Energy	R 10,441	R 1,454	R 8,987
Value added#	R 103,338	R 12,522	R 90,816
Energy/Value added	0.1010	**0.1161**	0.0990
2005			
Energy	R 9,763	R 1,390	R 8,373
Value added#	R 76,798	-R 18,874	R 95,673
Energy/Value added[1]	0.1271		

*Uses the identity, Consumption = Production - Net Exports

#Value added consists primarily of compensation to emplyees and gross operation surplus

1. Ratio not required since net trade in energy is positive and value added factors is negative

Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS.

What does all of this imply? It must be, given that the same vector of industry energy intensities (c) and input-output tables are used to calculate the embodied energy estimates, that the composition of the SADC region's mining and manufacturing industries are substantially more energy-intensive for exports than for imports and locally consumed goods. These findings suggest not only that energy inputs play an important role in the international trade of SADC goods, but that SADC countries are adding significantly to their regional energy resource requirements through the exportation of their energy services implicitly embodied in the region's traded goods, whether mined or manufactured.

Table 4, although not for the entire SADC region, shows the energy intensities (c) for the traditionally most energy-intensive South African industries in the years for which supply-use tables are available.

Table 4. Energy Intensity of South African Manufacturing Industries, 1999, 2002, 2005 and average over the period (1999 to 2005 shown as the value per SA rand of energy inputs in the production costs of both intermediate and final industrial goods)

	1999	2002	2005	Avg
	Industry Energy Intensity (e_{it}/y_{it})			
Non-ferrous metals	0.1374	0.1799	0.1216	0.1463
Iron & steel	0.1547	0.1238	0.1132	0.1305
Chemicals	0.0576	0.0796	0.0500	0.0655
Mining	0.0664	0.0443	0.0417	0.0537
Non metals	0.0595	0.0435	0.0399	0.0502
Metal Products	0.0398	0.0565	0.0376	0.0466
Electrical machinery	0.0310	0.0422	0.0310	0.0367
Machinery	0.0396	0.0276	0.0350	0.0350
Food, Bev & Tobacco	0.0252	0.0326	0.0302	0.0291
Paper & Printing	0.0339	0.0211	0.0283	0.0283
Wood	0.0175	0.0353	0.0146	0.0219
Textiles	0.0151	0.0264	0.0160	0.0211
Other Manufacturing	0.0148	0.0262	0.0146	0.0183
Radio & Scientific	0.0159	0.0190	0.0124	0.0176
Transport Equipment	0.0043	0.0054	0.0044	0.0061
All Manufactures	**0.0415**	**0.0395**	**0.0328**	**0.0379**

Source: Author's own calculations using data from Statistics South Africa and Quantec.

Table 4 reveals several interesting features. Firstly, all of the energy-intensive industries, namely non-ferrous metals, iron & steel, chemicals, mining and non metals, show a decrease in their energy intensity over the full time period of analysis 1999 to 2005, with ten of the fifteen industries recording a slight increase in energy intensity for the period 1999 to 2002. A somewhat substantial drop in energy intensity is experienced in most South African industries in the 2002 to 2005 period. This is consistent with the results reported in Figure 2 and the drop in the embodied energy intensity of exports and imports recorded for this period. Note the industry energy intensities shown in Table 4 are the value per rand of output that the industry has spent on energy inputs.

In this section I have undertaken a calculation of the effective energy content of SADC's industry trade components over the period 1999 to 2005 to determine whether there is any evidence of SADC adding to its regional energy consumption requirements by effectively exporting large amounts of its energy in the form of energy-intensive exports. The results reported provide sufficient evidence to suggest that SADC's trade in mining and manufacturing goods has a significant impact on the region's energy using patterns. More specifically, it is found that the embodied energy intensity of mining and manufacturing exports is a great deal higher than that of imports of these goods over the entire analysis period. Furthermore, together with a significant increase in the volume of international trade over the period under investigation, we observe a marked increase in the total value of embodied energy in South Africa's trade components.

As far as the embodied energy intensity of SADC's industrial exports is concerned, this decreases throughout the period under investigation. For SADC's imports of mining and manufacturing goods, embodied energy intensity is also somewhat lower in 2005 than in 1999 although the registered decrease in energy intensity occurs only after 2002. The underlying cause of the changes in the energy intensity of both exports and imports is the subject of the next section.

Since the same structural input-output framework and the same industry energy-intensities were used in calculating the embodied energy intensity of exports and imports, it follows that the composition of SADC's industrial exports relative to imports is more energy-intensive throughout the period of analysis. This is an interesting conclusion as it suggests that, given the SADC countries' vast endowment of natural resources and the policy of subsidising industrial energy prices within the region, SADC countries end up with a comparative advantage in energy-intensive mining and manufacturing goods as well as capital-intensive ones.

5 The Decomposition of Changes in Embodied Energy Intensity of SADC Industrial Trade Components

The purpose of the previous section was to calculate and analyse the value of energy effectively embodied in SADC industrial exports and imports and locally consumed goods. This section undertakes to decompose the changes in the embodied energy intensity of SADC's mining and manufacturing exports and imports to better understand the changes that occurred.

The embodied energy intensity of exports and imports can change for three reasons: individual industry energy intensities can change, the composition of the types of manufactured goods exported and imported can change, and the intermediate goods used to produce the traded goods can change. These effects can respectively be called intensity, composition and input-output effects. Traditionally, the intensity effect has been viewed as energy-saving technological progress. In the research undertaken here, where embodied energy intensity is a measure of the cost shares of energy, the intensity effect in addition to capturing technological progress likely includes substitution effects between energy and other production inputs. It is therefore reasonable to expect that the intensity effect leads to both increases and decreases in embodied energy intensity.

In order to understand why the embodied energy intensities of exports and imports have changed through time, a decomposition analysis is undertaken for the purposes of determining the role of the intensity, composition and input-output effects on these energy intensities. Since supply-use tables are not provided by Statistics South Africa every year, the decomposition is carried out for the years such data have been published. Table 5 reports embodied energy intensities for these years as shown in Figure 4.

Table 5. Changes in Embodied Energy of SADC Exports and Imports across main periods, 1999 to 2002 and 2002 to 2005 in SA Rand.

	Exports	Imports
1999-2002	-0.00823	0.0103
2002-2005	-0.00672	-0.0171

Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS.

Table 5 indicates that the value of embodied energy per unit of both SADC industrial exports and imports decreased from 1999 to 2005. Essentially, this section attempts to provide a better understanding of the factors responsible for the changes in the energy intensity of SADC's mining and manufacturing exports and imports as reported here.

5.1 Energy Intensity Decomposition Literature

Changes in the composition of economic activities and its impact on measures of energy intensity have been the subject of empirical analysis since Myers and Nakamura (1978).[4] As far as the decomposition technique is concerned many possibilities exist. The decomposition of energy intensity is undertaken using a variety of techniques in the energy literature. The decomposition of energy intensity can be done over a specific time period, or by using a time series approach and doing a decomposition analysis for each year. Decompositions are typically undertaken by employing either a Divisia or a Laspeyres index.

The Divisia index approach has the advantage that it is not weighted to either the beginning or ending year whereas the Laspeyres index is base-weighted in the initial year. The Divisia index does, however, have some drawbacks. The Divisia index assumes that the decomposition is taking place over an infinitesimally small interval and that the interaction terms between the composition and intensity effects go to zero in the limit. The Laspeyres approach does not make this assumption and, as a result, has a larger residual term – as explained below - than the Divisia index approach. The Divisia index, unfortunately, must arbitrarily assign the residual to either the composition or to the intensity effect. The Laspeyres index approach while less tidy than the Divisia index produces results that are easier to interpret.

Many studies discuss the problem of the residual term, or perfect decomposition. In decomposition analyses which report a residual term, which is the portion of the change in energy intensity from the base period to the analysis period that remains unassigned, i.e., it remains "unexplained". The Laspeyres index approach and most applications of the Divisia index approach suffer from this problem. If the residual term is large, relative to the individual effects being measured the empirical exercise may have little meaning. Ang & Zhang (2000) report that the size of the residual in empirical studies varies dramatically, sometimes overshadowing the portion of the change that is explained. Ang & Liu (2001), Sun (1998) and Boyd & Roop (2004) offer alternative approaches to address this problem; the Log Mean Divisia method I and II, the refined Laspeyres Index Approach and the Fisher ideal index approach, respectively. This paper employs a variant of the refined Laspeyres index approach, commonly referred to as a complete (or perfect) decomposition technique developed by Sun (1996). The purpose of employing the complete decomposition technique as from Sun (1996) is to improve the reliability and accuracy of the decomposition procedure. The basic idea is to decompose and distribute the residual according to the principle of "jointly created and equally distributed".

As an illustration, assume a two-factor model $V = x \cdot y$, (i.e., variable V is determined by factor x and y). In the time period [0, t], the change of variable V can be calculated by

[4] See Ang & Zhang (2000), for a comprehensive review of the decomposition literature as applicable to energy and environmental studies.

$\Delta V = V^t - V^0 = x^t \cdot y^t - x^0 \cdot y^0$

$= (x^t - x^0)\, y^0 + (y^t - y^0)\, x^0 + (x^t - x^0)(y^t - y^0)$

$= y^0 \cdot \Delta x + x^0 \cdot \Delta y + \Delta x \cdot \Delta y$

where, $y^0 \cdot \Delta x$ and $x^0 \cdot \Delta y$ are the contributions of the change of factors x and y to the total change of the variable V, respectively since time 0.. The third term $\Delta x \cdot \Delta y$ is the residual in general decomposition analysis. This third term can, in essence, be assigned equally to x and to y. The contribution is effectively dependent on both of the changes and only if one of them goes to zero does the other effect disappear. In instances where there is no reason to assume otherwise, the third (or residual) term is divided and assigned equally to x's contribution and y's contribution.

In a three factors model: $V = x \cdot y \cdot z$, , the contribution of factor x , y and z to the total change of variable V are decomposed employing the complete decomposition technique by the following formulas, respectively:

$X_{effect} = y^0 \cdot z^0 \cdot \Delta x + 1/2\Delta x(z^0 \cdot \Delta y + y^0 \cdot \Delta z) + 1/3(\Delta x \cdot \Delta y \cdot \Delta z)$

$Y_{effect} = x^0 \cdot z^0 \cdot \Delta y + 1/2\Delta x(z^0 \cdot \Delta x + x^0 \cdot \Delta z) + 1/3(\Delta x \cdot \Delta y \cdot \Delta z)$

$Z_{effect} = x^0 \cdot y^0 \cdot \Delta z + 1/2\Delta x(y^0 \cdot \Delta x + x^0 \cdot \Delta y) + 1/3(\Delta x \cdot \Delta y \cdot \Delta z)$

And

$\Delta V = X_{effect} + Y_{effect} + Z_{effect}$

Many energy intensity studies – see Ang and Lee (1994; 1996); Sun (1998); Boyd & Roop (2004) - do not take into account the value of energy that goes into the preparation of intermediate goods when analysing and decomposing energy intensities. Often, as is the case in these studies, aggregate energy intensities, calculated as the amount of energy used by a country divided by its GDP, are the subject of the decomposition. These studies decompose the changes in energy intensity into an intensity effect and a compositional effect. There is no input-output effect in these studies because intermediate products are not involved in the calculation of the energy intensity.

Since the value of the energy effectively embedded in the intermediate inputs that are required to produce the final exported and imported goods is very important for the correct calculation of the energy content of South Africa's international trade components, the energy intensities decomposed in this study are embodied energy intensities. The calculation of embodied energy intensities, as undertaken and discussed in the previous section, relies on an input-output approach. This method, made popular by Roop (1987), Betts (1989), Fujimagari (1989) and Rose & Calser (1996), is known as Input-Output Structural Decomposition Analysis (IO SDA), otherwise referred to as Direct Decomposition Analysis, and is a popular decomposition method used in energy and environmental studies.

It should be emphasised that even domestically assembled products, in most cases make use of some proportion of intermediate products that may have been produced abroad. As indicated, the decomposition of embodied energy intensity is undertaken by employing a Direct Approach that is similar to the structural decomposition method used in Roop (1987) and the refined Laspeyres index calculation technique as developed by Sun (1996).[5] Since input-output tables are only reported every few years, the decomposition must take place over three to five year intervals. It is therefore unreasonable to assume that the interaction terms between the intensity, composition and input-output effects would reduce to zero.

5.2 The Complete (Perfect) Direct Decomposition Methodology

Decomposing changes in energy intensity essentially means looking at the effect of the changes in each variable while keeping the others constant. Embodied energy intensity is calculated using equations 12 and 13. Substituting industry shares of exports and imports and rewriting these equations slightly, the embodied energy intensity can be calculated as follows:

$$\varepsilon^{x} = c \forall \chi \qquad (12)$$

$$\varepsilon^{m} = c \forall \mu \qquad (13)$$

where ε^x is the matrix of the embodied energy intensity for mining and manufacturing exports, ε^m is that for imports, χ is a vector of industry shares of SADC mining and manufacturing exports (x_i/X), μ is a vector of industry shares of SADC mining and manufacturing imports (m_i/M), **c** is a vector of energy intensities by industry, and $\forall$ is the inverse of the technology matrix.

The decomposition can be viewed as the total derivative of the embodied energy intensity equation. The total derivative by definition shows the effect of a change in one variable while the other variables remain constant. Changes in the embodied energy intensity do not occur instantaneously in the data. Since the changes in embodied energy intensity can only be calculated over three to five year intervals, the interaction terms that would normally converge to zero can not be ignored.

The discrete analog to the total derivative for changes in the embodied energy intensity of exports and imports is given as follows:

$$\Delta\varepsilon^{x} = (\Delta c)\forall\chi + c(\Delta\forall)\chi + c\forall(\Delta\chi) + (\Delta c)(\Delta\forall)\chi + (\Delta c)\forall(\Delta\chi) + c(\Delta\forall)(\Delta\chi) + (\Delta c)(\Delta\forall)(\Delta\chi) \qquad (14)$$

$$\Delta\varepsilon^{m} = (\Delta c)\forall\mu + c(\Delta\forall)\mu + c\forall(\Delta\mu) + (\Delta c)(\Delta\forall)\mu + (\Delta c)\forall(\Delta\mu) + c(\Delta\forall)(\Delta\mu) + (\Delta c)(\Delta\forall)(\Delta\mu) \qquad (15)$$

This decomposes changes in the embodied energy intensity of SADC industrial exports and imports into: a component due to changes in mining and manufacturing industry energy intensities holding constant both the input-output structure and the composition of exports; a component due to changes in the input-output structure holding constant both the energy intensities and the composition of exports; a component due to changes in the composition of exports holding both energy intensities and the input-output structure constant; and four interaction terms.

Each of the effects has one term that is uniquely its own and three interaction terms with the other variables. The following equations thus represent the complete (or perfect) decomposition of the total effect for each of the components on changes in the embodied energy intensity of exports using the idea of

[5] The assumptions by the Divisia index calculation technique are not applicable to this study.

distributing the residual (or interaction terms) according to the principle of jointly created and equally distributed, as suggested by Sun (1996):

$$I^x = (\Delta c)\forall\chi + (1/2)(\Delta c)(\Delta\forall)\chi + (1/2)(\Delta c)\forall(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \qquad (16)$$

$$IO^x = c(\Delta\forall)\chi + (1/2)(\Delta c)(\Delta\forall)\chi + (1/2)c(\Delta\forall)(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \qquad (17)$$

$$C^x = c\forall(\Delta\chi) + (1/2)(\Delta c)\forall(\Delta\chi) + (1/2)c(\Delta\forall)(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \qquad (18)$$

where I^x is the total intensity effect, IO^x is the total input-output effect and C^x is the total compositional effect. There exist identical equations for the decomposition of embodied energy intensity of imports.

5.3 The Decomposition Results

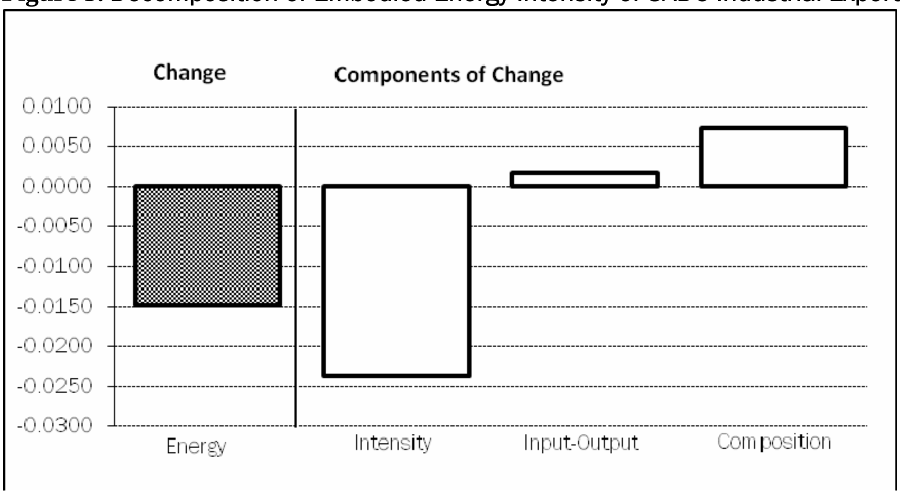
The decomposition investigates the reasons for differences in embodied energy intensity from one reporting period to the next. Table 5 shows the differences in embodied energy intensity over each of the time periods under investigation. On first examination, the results may seem very small. The changes are, however, not as insignificant as would appear on first inspection.

In particular, Table 5 shows that for the period 1999 to 2005 that for a rand's worth of SADC industry exports, the expenditure on energy went down by 1.5 cents and that for a rand's worth of SADC industry imports, the energy expenditure went down by 0.7 cents. The rest of this section presents the results from the decomposition to help identify and explain why these changes in embodied energy intensity took place.

Together Figure 5, Figure 6, Figure 7 and Figure 8 present the results of the complete direct decomposition of the embodied energy intensity of SADC's traded mining and manufacturing goods. The Intensity, the Input-Output, and the compositional effects for the embodied energy intensity of exports and imports are calculated using equations 16, 17 and 18 respectively.

Figure 5 and Figure 6 present the results of the decomposition of SADC's traded mining and manufacturing goods for the entire period under investigation, namely: 1999 to 2005.

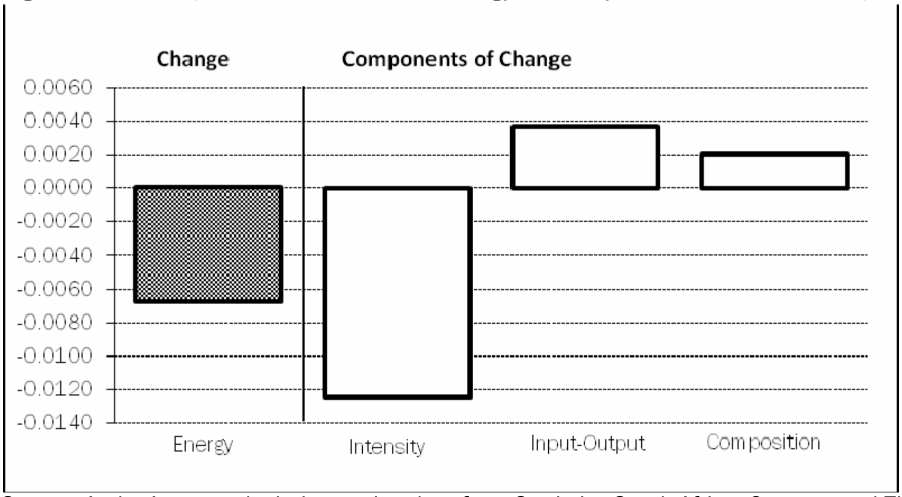
Figure 5. Decomposition of Embodied Energy Intensity of SADC Industrial Exports, 1999 – 2005 (in %)



Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS

The results show that the changes recorded in the embodied energy intensity of both exports and imports are due largely to the intensity (also known as the technology) effect. This in turn suggests that the rising price of energy inputs, relative to other factor of production inputs as identified in Figure 1, has acted as a significant catalyst for the adoption and implementation of energy saving technologies in the industrial goods that SADC exports and imports. The virtual absence of an input-output effect suggests that the decreases recorded in the embodied energy intensity of exports and imports are not driven by a substitution towards intermediate goods that use less energy to produce, but rather a decrease in the energy usage of the final traded goods themselves. This is a significant finding of this research, since it is recognised that it is not as easy for producers to change the assembly methods used in the production of final goods as it is to rely on purchases of less energy-intensive intermediate products to bring about a decrease in the overall energy intensity of finished traded goods.

Figure 6. Decomposition of Embodied Energy Intensity of SADC Industrial Imports, 1999 – 2005 (in %)



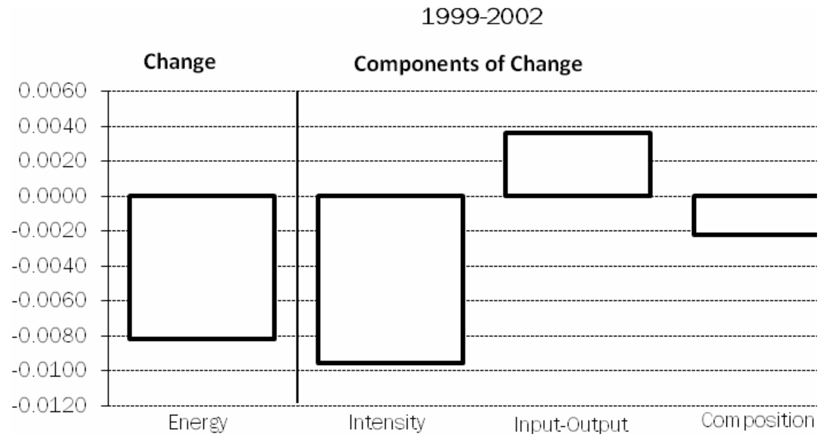
Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS

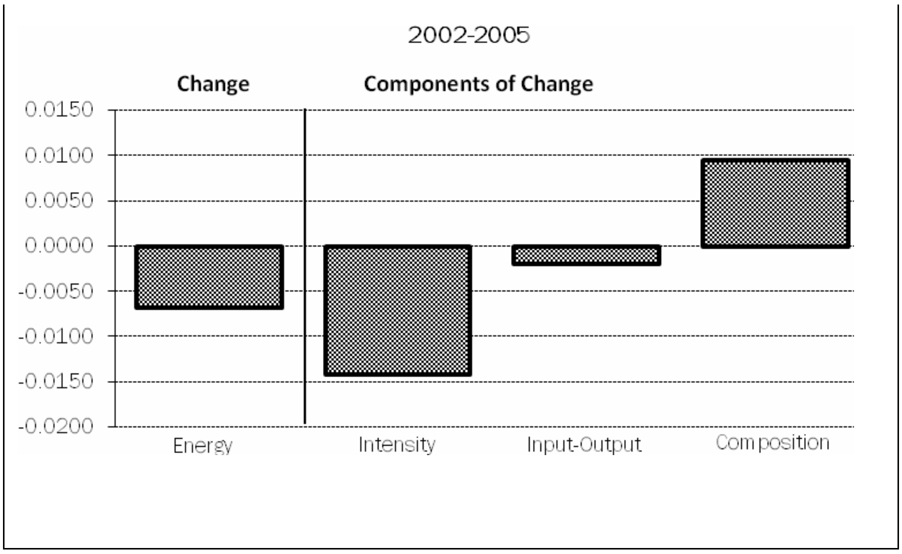
Focusing on the results for exports over the years 1999 to 2005, it appears that embodied energy per rand worth of exports is 2.4 cents lower due to the use of energy saving technologies (i.e., the intensity effect). Similar although somewhat smaller changes are recorded in the case of the embodied energy intensity of imports. Explanations for these changes are fairly similar across exports and imports even though the magnitudes are slightly different. In the case of imports, the embodied energy intensity of goods would be substantially lower at 1.2 cents due the use of energy saving technologies. This effect is, however, somewhat negated by the combination of the input-output and composition effects, leaving the total embodied energy intensity of imports only 0.7 cents lower in 2005 than in 1999.

Clearly the composition of mining and manufacturing goods that SADC exports has changed somewhat to goods that are, on average, more energy intensive. This can be taken as evidence of a slight shift in the competitiveness of SADC's trading partners into industrial goods that are more energy efficient (in other words less energy intensive) for the period under investigation. Finally, given the changes recorded in SADC in the prices of energy inputs during the six years under investigation (highlighted in Figure 1), it is not surprising that the 2005 embodied energy intensity of South African industry exports and imports are lower than the levels recorded in 1999.

Figure 7and Figure 8 examine the decomposition results of the embodied energy intensity of SADC industrial exports and imports for each of the separate reporting periods.

Figure 7. Decomposition of Embodied Energy Intensity of SADC Industrial Exports: 1999-2002 and 2002-2005



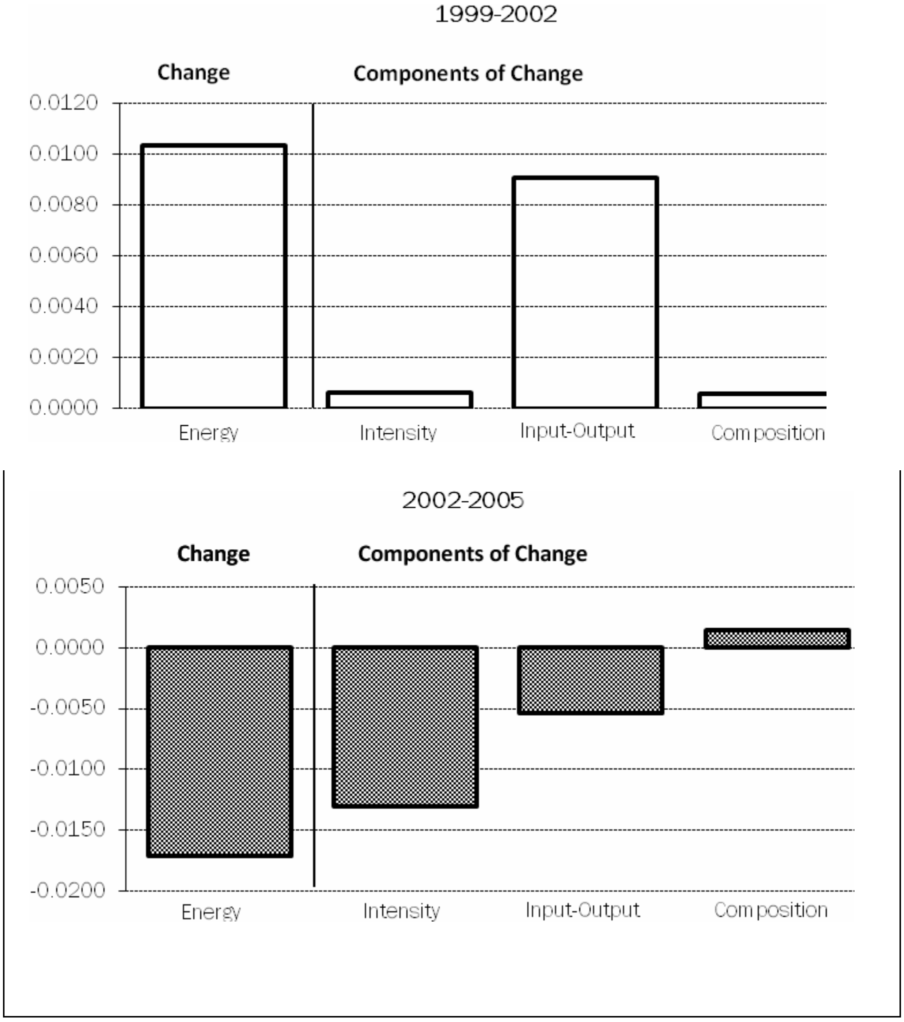


Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS.

Starting with Figure 7 and inspecting the graphs, it appears that the decreases recorded in the embodied energy intensity of exports are fairly evenly distributed over the two reporting periods. The more significant decreases are, however, recorded before 2002 which corresponds well with the period of rising energy input prices reported in Figure 1. As far as the separate reporting periods are concerned, for 1999 to 2002, the recorded 0.8 cents on the rand decrease in the embodied energy intensity of exports is due to a combination of intensity, input-output and composition effects. For this 1999 to 2002 period, the intensity and input-output effects are inversely related. This outcome probably reflects a composition effect and is common in cases where there are errors in measurement and where substitution effects exist (e.g., if the price of energy inputs rises, energy intensity will fall while other input usage will increase). For the 2002 to 2005 period, the driving force behind the nearly 0.6 cents on the rand decrease in the embodied energy intensity of exports is again the intensity effect although this is substantially negated by the composition effect. The strong positive composition effect suggests that, for the 2002 to 2005 period, SADC countries exported a selection of goods that, on the whole, were more energy intensive in their composition than in the 1999 to 2002 period.

Turning to Figure 8 and focusing on the results for the embodied energy intensity of imports, a slightly different picture emerges.

Figure 8. Decomposition of Embodied Energy Intensity of SADC Industrial Exports: 1999-2002 and 2002-2005



Source: Author's own calculations using data from Statistics South Africa, Quantec and TIPS.

Firstly, the overall energy intensity changes recorded for the two reporting periods: 1999 to 2002 and 2002 to 2005, all but offset one another. Secondly, it is the second reporting period, 2002-2005, that brings with it the most significant changes in the embodied energy intensity of imports. What comes through sharply furthermore in the analysis, is that the almost 2 cents on the rand reduction in the embodied energy intensity of imports is driven largely by the intensity or technology effect. Overall, this result is somewhat surprising especially when looking back at the fairly insignificant changes in the relative price of energy inputs recorded over this final period of analysis. The decomposition results suggest that there is limited corresponding substitution away from energy in terms of the intensity effect for import industries during the period 1999 to 2002 when the relative price of energy in relation to other production inputs increases most. The decrease in the intensity effect for imports does not happen until sometime after 2002. Reductions in the energy intensity of import industries seem thus to lag behind the energy input price increases. This finding is fairly plausible given that changes in the relative price of industrial energy inputs are about 15% for the six years under investigation.

Lastly, despite the reduction in both the embodied energy intensity of SADC industrial exports and imports (as reported in Figure 5 and in Figure 6), it is clear that the composition of SADC mining and manufacturing exports remains significantly more energy intensive than that of imports throughout the period under investigation. This result affirms SADC countries' position as producers and exporters of energy-intensive industrial goods. This finding is not surprising given the fact that the prices of industrial energy inputs in the SADC region are lower than those reported in the major world economies.

6 Conclusion

A structural input-output approach is applied in this study to calculate the effective energy content of SADC industrial trade components for the period 1999 to 2005. The study finds that the embodied energy intensity of SADC mining and manufacturing exports is a great deal higher than that of imports over the period under consideration. This finding is reinforced by the fact that the study at best over-states the embodied energy intensity of SADC imports given the bias introduced into the calculations by adopting the standard Heckscher-Ohlin assumption which assumes foreign and local goods are produced with the same technologies. Given furthermore that the volume of SADC's international trade in mining and manufactured goods increased significantly during this period, the total value of embodied energy in the region's industry trade components followed a similar pattern. These results provide evidence of a significant impact on the region's energy use patterns by its trade in mining and manufacturing products.

The study's findings suggest that, given the SADC region's vast endowment of natural resources and its member countries' policy of subsidising industrial energy prices, SADC countries end up with a comparative advantage in energy- and capital-intensive industrial goods. This confirms that SADC countries are adding significantly to their local energy resource requirements through the exportation of energy-intensive services implicitly embodied in the region's traded industrial goods.

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8 Data Appendix

8.1 Industry Data

All industry data for the SADC region relating to inputs and outputs are the data for South Africa and have been obtained from the supply-use (input-output) tables for this country. Detailed supply use tables are not available for the SADC region. Note the supply-use tables for South Africa are published for manufacturing census years. The 1999 and 2002 data has been supplied by Statistics South Africa and is available online at the following web address: www.statssa.gov.za/publications/Report-04-04-01&SCH=3496. The data for 2005 are from the supply-use table supplied by QUANTEC Research South Africa. Note, this supply-use table is a table which adjusts the Statistics South Africa supply-use table of 2002 for 2005 market conditions. All industry data have been aggregated to the 2 digit ISIC level. This high level of aggregation has been necessary in order to calculate energy intensities for the various mining and manufacturing sectors. Since energy expenditure data are only available at that 2 digit ISIC level, this high level of aggregation in the data is required. In order to compare industry data across supply-use reporting periods, all current market expenditures by mining and manufacturing sector were deflated to a common base year. The respective mining and manufacturing sector price deflators were obtained from Statistics South Africa and are available at the following web address: www.statssa.gov.za/keyindicators/ppi.asp.

8.2 Trade Data

All export and import data for the SADC economies have been obtained from the Southern African Trade Database administered and maintained by Trade and Industries Policy Strategies (TIPS) and are available at the following web address: http://data.sadctrade.org/st. The SADC combined trade data are reported at the HS4 level of aggregation at a constant 2000 US dollars.

8.3 Energy Data

Data on industrial energy prices were obtained from two sources. International price comparisons on industrial energy inputs are supplied by the US Department of Energy, Energy Information Administration. Data are available online at the following web address: www.eia.doe.gov/emeu/international/contents.html. The time series data on industrial energy prices are for South Africa and were calculated by weighting the relevant producer price indices for the country's main industrial energy carriers: coal, petroleum products, electricity and gas. The data are supplied by Statistics South Africa and are available online at the following web address: www.statssa.gov.za/keyindicators/ppi.asp. The weights used for the respective energy carriers are calculated from data supplied by the South African Department of Minerals and Energy in its publication, Digest of South African Energy Statistics, available online at the following web address: www.dme.gov.za. The data on relative industrial energy prices were calculated by comparing the weighted sum of producer price indices on South Africa's industrial energy carriers to the mining and manufacturing output deflator.

Industry output deflators for the various years are available from Statistics South Africa at the following web address: www.statssa.gov.za/keyindicators/ppi.asp. Data on energy intensities by South African mining and manufacturing sector were calculated from the energy expenditure data contained in various supply-use (input-output) tables supplied by Statistics South Africa. These are available online at the following web address: www.statssa.gov.za/publications/Report-04-04-01&SCH=3496.