"The Sustainability of South Africa's Energy Resources: The Impact of International Trade"

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Abstract:

South Africa's energy system has been, and still is, one of the key contributing factors to the social and economic development of the nation. By international standards, the South African economy is very energy-intensive, meaning that the country uses a large amount of energy for every rand of economic output. Historically world economic and political factors have had a profound effect on international oil prices which in turn have impacted heavily on individual nation's energy policies.

The focus of this research centres on issues concerning industrial energy use. The theoretical background to this research is well grounded in traditional trade theory, with trade patterns and the international competitiveness of countries explained as a function of both supply and demand side factors. The empirical work undertaken seeks to verify such explanations by determining the extent to which changes in the energy intensity of the South African manufacturing sector are due to changes in the types of goods produced domestically versus changes in the types of goods internationally traded.

1. Introduction

Trade patterns change as a result of the international specialisation of production and the increased integration of world markets. This is especially evident in a small open economy such as South Africa. In 1990, the share of South African industrial production that was exported stood at 19 percent; by 2005, this share stood at 23 percent. A similar yet more pronounced trend applies to the share of domestic final demand for industrial goods imported. For 1990, the share of domestic final demand imported was 16 percent, this increased to 30 percent in 2005. The change in trade patterns reflected in these numbers has important implications for the use of resources in the economy. This study focuses on the implications of changes in South African industry trade patterns on the country´s energy use patterns.

It is a phenomenon well documented in South Africa's trade literature Hayter et al (2001), Nattrass (1998) and IMF (2000) that the country'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 South Africa's export-oriented industrial sectors are natural resource (and in some cases energy)[1] based. Furthermore it is argued by some Hayter et al (2001) and Fine & Rustomjee (1996) that many of South Africa's manufacturing and mining sectors which are linked through beneficiation and metals production have benefited substantially from the cheap industrial energy prices that the government's domestic energy policies have provided. There is thus sufficient reason to believe that South Africa's trade in industrial goods has a significant impact on the country's domestic energy requirements. This study adopts a structural input-output approach to test the extent to which this hypothesis is valid. Finally, the effect that South Africa's industry trade components have on the country'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.

2. International Trade and Energy Inputs

Patterns of energy use in an economy can change substantially over time. In South Africa, 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 energy use patterns. Explanations for changes in industrial energy use and improvements in energy efficiency in industry are numerous.

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 South Africa. More precisely, this figure shows the ratio of the producer price index for energy carriers used by South African industry relative to the mining and manufacturing output deflator over the period: 1993 to 2005. 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. This period also corresponds to a period of substantial structural changes to the South African economy as a result of the democratically elected government's economic policy changes and the country's trade policy reforms under its WTO commitments.

Figure 1 depicts a fairly significant rise in the relative price of energy inputs for the period 1993 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 as intensity (or technology) effect changes, in the energy literature.

Secondly, the price of industrial energy inputs can vary substantially across countries because of differences in government policies in respect of energy. Countries through out the world have different energy taxation or even subsidization policies. Such differences have a dramatic impact on industrial energy price differentials between countries. South Africa's domestic energy policies have a substantial impact on lowering the cost of the country's industrial energy inputs. Table 1 compares the industrial energy input prices of South Africa with that of her major trading partners. Coal as an energy input is responsible for 75 per cent of South Africa's energy requirements (DME, 2006). Fine & Rustomjee (1996) report that on a global scale, the South African economy 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, are highlighted in Table 1. These low prices 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.

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 South Africa manufactures proportionally more goods that require large amounts of energy to produce, then the amount of energy that South Africa uses per rand of its GDP will likely increase. Part of the movement toward the production of energy-intensive products when a country has high growth requirements may be explained by the idea 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 and 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.

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 South Africa has 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 South African 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 South Africa's energy use in industry will not be complete without an analysis of the impact of international trade on the domestic energy requirements of the country. Unfortunately, undertaking such an analysis is not as straightforward as it would seem. The problem is that, when trade patterns in a country 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 South Africa's international trade in mining and manufacturing goods on the country'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 U.S. trade flows. Leontief discovered what came to be known as the *Leontief Paradox* of U.S. international trade when he observed paradoxically that the U.S. exported 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 U.S. net trade with that of U.S. consumption.

A factor content study of South Africa's international trade as undertaken by Tsikata (1999) observed that South Africa exports the services of capital rather than the service 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 South Africa is most abundant in. The IMF (2000) concurs with these findings, stating that the majority of South 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 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). South Africa ends up thus with a comparative advantage in capital and energy-intensive production as a result of the country's vast endowment of natural resources and the policy distortions introduced by the state.

Poduction inputs such as energy have also been the subject of factor content studies 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 South African energy content of trade we use an approach 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 South Africa'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 South Africa is a net exporter or importer of energy services via its 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 locally 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 following simplifying assumptions are often adopted in order to make the calculations tractable. The most common assumptions 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 there exists a technical relationship 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 logically 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:

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

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:

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

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:

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

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:

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

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 South African 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 South Africa'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 the technology matrix to calculate South Africa'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, of an increase of one South African rands worth of final demand for both domestic and foreign commodities.]

Using equation (4) combined with a vector of industry energy intensities, it is possible to sum over all industries to get 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:

$$e = c\,y = c\,(I - A)^{-1}\,d \qquad (5)$$

where (e) is the value of energy embodied in the vector of outputs of the (n)-industries and (c) is a vector of industry energy intensities (e_i/y_i). In order to calculate the vector of industry energy intensities (i.e., the direct energy coefficients (c_i)) the major energy producing industries in the South African economy, namely: the coal, the petroleum and the electricity industries input requirements 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 the country'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 to estimate 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 are unavailable and since South Africa imports most industrial goods from outside of the region in which it is located this approach is deemed inappropriate. In this study we assume that imports are produced with the same energy intensities as domestically produced industrial goods and that the technology matrix used to calculate the home and foreign economies' outputs is the same. This is the standard HOV assumption and its validity has been the subject of much debate in the trade literature. [In this regard see Trefler (1995), Davis & Weinstein (2001) and Fisher & Marshall (2007) among others.]

Despite its limitations, this assumption is nevertheless applied in the present study. In particular, given the fact that South Africa's imports are largely sourced from economies that adopt more advanced production techniques, the direct input-output coefficients which constitute the technology matrix in South Africa's case will (for most sectors) almost certainly be higher than that of her more advanced trading partners. This difference reflects a lower productivity on the part of South African economic activities and substituting this technology matrix for that of foreign trading countries will tend to exaggerate the energy content of imports. The calculated embodied energy in South African industry imports and output is at best an estimate of the energy embodied in these activities.

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 South Africa's net exports. This can be estimated by replacing total final demand in equation (5) with an industry vector of the net export portion of final demand. This is written in matrix notation as:

$$e^{nx} = c\,(I - A)^{-1}\,(nx) \qquad (6)$$

where (e^{nx}) is the amount of energy embodied in net exports and (nx) is a vector of net-exports for each of the (n)-industries. If (e^{nx}) is positive then the country is a net exporter of energy services as embodied in its trade components, and if it is negative then the country is a net importer.

The value of energy embodied in exports and imports could respectively be calculated as:

$$e^{x} = c\,(I - A)^{-1}\,(x) \qquad (7)$$

$$e^{m} = c\,(I - A)^{-1}\,(m) \qquad (8)$$

where (x) is a vector of industry exports and (m) is a vector of industry imports.

It is also interesting to note that instead of summing embodied energy over all industries one can simply have an estimate by industry, 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. It is important to be very explicit with regards to what this calculation means. In other words, in order to meet the net export levels of output, intermediate manufactured goods are needed. The adoption of a structural input-output approach, as in this study, makes it possible to calculate the amount of each of the intermediate goods that is needed to exactly meet the net export demands. The value of the energy that is required to meet the intermediate and final demands in South African industry is what is analysed and reported here. This can simply be denoted as follows:

$$e_i^{nx} = c_i (I - A)^{-1} (nx_i) \quad (9)$$

where (e_i^{nx}) is the net exported embodied energy for industry (i) as a result of trade in industries one through (n), the scalar (c), is the energy intensity of industry (i).

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. Furthermore, a time series investigation of embodied energy estimates for South Africa's trade components can be undertaken on the assumption that the input-output (I-O) structure of the SA economy remains unchanged over the years in between published input-output tables. This assumption is without doubt an over simplification of the real world scenario where structural changes to the SA economy brought about by trade liberalisation efforts and other economic policy changes will amongst other factors affect both the factor proportions and production processes used in the economy's production.

The following equations are those employed in a time series investigation of the embodied energy of domestic output, net exports, exports and imports respectively by specific South African mining and manufacturing industry:

$$e_{i,t}^{d} = c_{i,t} (I - \delta A)^{-1} (d_{i,t}) \quad (10)$$

$$e_{i,t}^{nx} = c_{i,t} (I - A)^{-1} (nx_{i,t}) \quad (11)$$

$$e_{i,t}^{x} = c_{i,t} (I - \delta A)^{-1} (x_{i,t}) \quad (12)$$

$$e_{i,t}^{m} = c_{i,t} (I - A)^{-1} (m_{i,t}) \quad (13)$$

where (δ) is the ratio of domestic goods to total supply (i.e., the import penetration ratio).

In the case of equations (10) and (12), the inclusion of the import penetration ratio (δ) ensures that the estimates of the embodied energy content of domestic output and exports includes only the energy content of domestic inputs (but not imported inputs) used in downstream production to produce both local and traded goods. In the case of equations (11) and (13), the absence of the import penetration ratio (δ) ensures that the estimates of the embodied energy content of net trade and imports includes the estimates of the energy content of both domestic and foreign (imported) components used in downstream production to produce the traded goods. Equations (11), (12) and (13) together represent the embodied energy in mining and manufacturing commodities traded by South Africa.

4. The Energy Content of SA Industry Trade

Using equations (10), (12) and (13) and the data described in the Data Appendix, the value of energy that is effectively embodied in S.A. Mining and Manufacturing exports and imports and domestically consumed goods can be calculated. Figure 2 gives a graphical representation of the results.

Figure 3 on the other hand shows the value of South African Mining and Manufacturing exports, imports and domestically consumed goods for the same time period. From the figures, it is clear that the level of domestic consumption, exports and imports are important determinants of the respective embodied energy value of these goods. Note, 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, 1993 to 2005, energy is being exported via the trade in mining and manufacturing goods. Over this period, South African trade in aggregate mining and manufacturing goods is pretty balanced. However, from 2002 onwards, South Africa runs a rising trade deficit in aggregate mining and manufacturing goods yet remains a net exporter of embodied services of energy. This somewhat surprising result arises because mining and manufacturing exports are significantly more energy-intensive than imports, and as Figure 2 illustrates, this continues to be the case, even in the years when South Africa runs a trade deficit. Figures 2 and 3 together indicate that South Africa is adding significantly to its domestic energy consumption by being a net exporter of energy via 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 the role South African industry trade plays in the implicit exportation of the country's energy services is provided by 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 domestically consumed goods. The embodied energy intensity values show the energy content of industrial exports, imports and domestically consumed goods in constant (2000) S.A 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 domestically consumed, under the assumption that all the goods are produced in South Africa. This calculation can be interpreted as an approximation of the average value of mining and manufacturing exports, imports and domestically consumed goods that would be required to purchase the energy inputs needed to produce these products along with their intermediate inputs domestically.

This is calculated by dividing equations (10), (12) and (13) by the total domestic consumption of mining and manufacturing goods (D), exports of mining and manufacturing goods (X) and imports ~~of~~ mining and manufacturing goods (M) respectively:

$$\frac{e_t^d}{D} = \frac{c_t (I - A)^{-1} (d_t)}{D} \qquad (14)$$

$$\frac{e_t^x}{X} = \frac{c_t (I - A)^{-1} (x_t)}{X} \qquad (15)$$

$$\frac{e_t^m}{M} = \frac{c_t (I - A)^{-1} (m_t)}{M} \qquad (16)$$

The graphical representation of the embodied energy intensities of South African domestically consumed industry output and South African industry trade components for the period 1993 to 2005 is shown in Figure 4.

Throughout the period under investigation, the embodied energy intensity of mining and manufacturing exports is higher than that of imports or domestically 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 domestically consumed goods for the period 1998 to 2002. This convergence is however negated during the period 2002 to 2005 when despite falling embodied energy intensities the differences in the intensities increases again.

A closer inspection of the energy intensities (as illustrated in Table 2) reveals that the amount of energy relative to other factors of production embodied in South Africa's net exports of mining and manufacturing goods exceeds that of the domestic production and consumption of these goods. Table 2 indicates this for 1993, 1998 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.

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 South African mining and manufacturing industries are substantially more energy-intensive for exports than for imports and domestically consumed goods. These findings suggest not only that energy inputs play an important role in the international trade of South African mining and manufacturing goods, but that South Africa is adding significantly to its domestic energy resource requirements through the exportation of her energy services implicitly embodied in the country's traded goods whether mined or manufactured.

Table 3 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 3 reveals several interesting features. Firstly, all of the energy-intensive industries show a decrease in their energy intensity over the time period 1993 to 1998, with eleven of the fifteen industries recording a slight increase in energy intensity for the period 1998 to 2002. A somewhat substantial drop in energy intensity is experienced in most South African industries in the period 2002 to 2005. This is consistent with the results reported in Figure 2 and the fairly significant drop in the embodied energy intensity of exports and imports recorded for this period. Note the industry energy intensities shown in Table 3 are the value per rand of output that the industry has spent on energy inputs.

Table 4 shows the contribution of each of South Africa's most energy intensive industries to the country's total aggregate mining and manufacturing exports, imports, production and to the effective exportation and importation of energy services. As far as South African industry exports go, the most interesting industries to report on are the iron & steel and chemical industries whose importance in terms of their contribution to S.A industry exports and embodied energy in S.A industry exports continue to grow. The importance of the mining industry's exports and its relative contribution to the embodied energy in exports is on the other hand significantly reduced. The South African mining industry which in 1993 contributed 49.67 percent of manufactured exports only made up 41.97 percent of the sector's exports in 2005. As a result, mining's contribution to embodied energy in South African industry exports fell significantly from 47.78 percent in 1993 to 29.61 percent in 2005. Non ferrous metals, the most energy intensive of the South African industrial sectors, contribution to both industry exports and exports of embodied energy remains relatively unchanged with only minor reductions recorded during the period under investigation.

On the import side there is not that much of interest to report on. In particular, it appears that the relative contributions to South African industrial imports and the imported energy embodied in the specified industrial sectors remain largely unchanged during the period 1993 to 2005. The exceptions to this are the chemicals and mining sectors. These sectors are the most important in as far as their contribution to total South African industry imports is concerned and recorded large contributions to imported embodied energy. The mining sector's contribution decreased significantly from 30.08% of industry imported embodied energy in 1993 to 19.13% in 2005 whereas the chemical sector's contribution to this increased somewhat from 20.50% of industry imported embodied energy intensity in 1993 to 24.16% in 2005. Note the only way that an industry can have a higher embodied import share than import share is if it has higher energy intensity relative to other industries, or if it provides large amounts of products necessary for intermediate inputs into import industries. Such explanations are well suited to explaining the situation for the chemical and mining industries, since these sectors are both highly energy intensive and at the same time contribute significantly to the intermediate inputs of other importing manufacturing sectors. As is clear from Table 4, the chemical sector's share of imported embodied energy remains the highest of the industrial sectors for the period under consideration. The saving that this sector creates for the country's domestic energy resources through this large importation of explicit energy services is fairly significant. As it stands, mining is the sector that is most responsible for offsetting the high demand South Africa's trade components have on the country's domestic energy requirements. This is true for mining since the sector's share of exported embodied energy decreases by more than its share of imported embodied energy.

A final observation of interest to comment on from Table 4 is that the iron and steel and non ferrous metals industries make up a higher percentage of South African industry exports than they do of South African industrial production. The only other industry reported where this is true is in the mining industry. In empirical research, when an industry has a higher export share than domestic production share it is an indication of a revealed comparative advantage in that industry. In the case of mining, the industry's revealed comparative advantage is significantly smaller in 2005 than in 1993 a clear indication of a fall in this industry's international competitiveness over this time period. A similar yet less pronounced trend is visible in the case of the non ferrous metals industry. South Africa on the other hand clearly appears to becoming more competitive internationally in the iron and steel industry. In addition to being an energy-intensive industry, the iron and steel industry's competitiveness in international markets is a function of the availability of cheap raw materials and technological improvements such as the implementation of the electric arc furnace (EAF) technology by industry producers (West et al, 1995).

This section has undertaken a calculation of the effective energy content of South African industry trade components over the period 1993 to 2005 to determine whether there is any evidence of South Africa adding to its domestic 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 South Africa's trade in mining and manufacturing goods has a significant impact on the country'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 South African industry exports is concerned, this decreases through out the period under investigation. For South Africa's imports of mining and manufacturing goods, embodied energy intensity is also significantly lower in 2005 then in 1993 although most of the registered decrease in energy intensity occurs after 2002. The underlying cause of the changes in the energy intensity of both exports and imports is the subject of the next section. Specifically, the changes in the energy intensities are decomposed into three effects. The recorded changes are likely due to a combination of the following: the composition of exports and imports changing in energy-intensity, the average energy-intensity of intermediate inputs changing and technological innovation resulting in changes in the energy efficiency of intermediate and final goods production.

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 South African industry exports relative to imports is more energy-intensive throughout the period of analysis. This is an interesting conclusion, as it suggests that given the country's vast endowment of natural resources and its policy of subsidising industrial energy prices, South Africa ends 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 SA Industry Trade Components

The purpose of the previous section was to calculate and analyse the value of energy effectively embodied in S.A industry exports and imports and domestically consumed goods. This section undertakes to decompose the changes in the embodied energy intensity of South African 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 increases in embodied energy intensity as well as to decreases.

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 indicates that the value of embodied energy per unit of both S.A industry exports and imports decreased from 1993 to 2005. Essentially, this section attempts to provide a better understanding of the factors responsible for the changes in the energy intensity of South Africa's mining and manufacturing exports and imports as reported here.

(a) 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). (See Ang & Zhang (2000), for a comprehensive review of the decomposition literature as applicable to energy and environmental studies.) 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 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, there is some portion of the change in energy intensity from the base period to the analysis period that remains unassigned, i.e., it is "unexplained". The Laspeyres Index approach and most applications of the Divisia Index approach suffer from this problem. If the residual term is large enough, the empirical exercise may have little meaning. Ang & Zhang (2000) reports 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 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

$$\begin{aligned}\Delta V = V^t - V^0 &= x^t \cdot y^t - x^0 \cdot y^0 \\ &= (x^t - x^0)\, y^0 + (y^t - y^0)\, x^0 + (x^t - x^0)(y^t - y^0) \\ &= y^0 \cdot \Delta x + x^0 \cdot \Delta y + \Delta x \cdot \Delta y\end{aligned}$$

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. 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. The complete decomposition technique for a two-factor system is as follows.

The total change of the variable is

$$\Delta V = V^t - V^0$$

and the contributions of the factors (explaining effects) are

$$X_{effect} = y^0 \cdot \Delta x + \tfrac{1}{2}\, \Delta x \cdot \Delta y$$

$$Y_{effect} = x^0 \cdot \Delta y + \tfrac{1}{2}\, \Delta x \cdot \Delta y$$

and

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

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 [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); Rose & Calser (1996)] is known as Input-Output Structural Decomposition Analysis (IO SDA) or 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. An input-output approach has been adopted here so that the embodied energy of traded goods can be estimated correctly. Furthermore, the value of embodied energy per unit of exports in comparison to imports is interesting because it shows whether a country exports or imports goods that are relatively more energy-intensive. The decomposition of embodied energy intensity on the other hand addresses why the changes in the embodied energy intensity of exports and imports took place.

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). The assumptions by the Divisia Index calculation technique are not applicable to this study. 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.

(b) 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 15 and 16. Substituting industry shares of exports and imports and rewriting these equations slightly, the embodied energy intensity can be calculated as follows:

$$\varepsilon^x = c \forall \chi \qquad (17)$$

$$\varepsilon^m = c \forall \mu \qquad (18)$$

where $\boldsymbol{\varepsilon^x}$ is the embodied energy intensity for mining and manufacturing exports, $\boldsymbol{\varepsilon^m}$ is that for imports, $\boldsymbol{\chi}$ is a vector of industry shares of S.A mining and manufacturing exports (x_i/X), $\boldsymbol{\mu}$ is a vector of industry shares of S.A mining and manufacturing imports (m_i/M), and $\boldsymbol{\forall}$ 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:

$$\Delta\varepsilon^x = (\Delta c)\forall\chi + c(\Delta\forall)\chi + c\forall(\Delta\chi) + (\Delta c)(\Delta\forall)\chi + (\Delta c)\forall(\Delta\chi) + c(\Delta\forall)(\Delta\chi) + (\Delta c)(\Delta\forall)(\Delta\chi) \qquad (19)$$

$$\Delta\varepsilon^m = (\Delta c)\forall\mu + c(\Delta\forall)\mu + c\forall(\Delta\mu) + (\Delta c)(\Delta\forall)\mu + (\Delta c)\forall(\Delta\mu) + c(\Delta\forall)(\Delta\mu) + (\Delta c)(\Delta\forall)(\Delta\mu) \qquad (20)$$

This decomposes changes in the embodied energy intensity of South African industry 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 distributing the residual (or interaction terms) according to the principle of jointly created and equally distributed as suggested by Sun (1996):

$$I^x = (\Delta c)\forall\chi + (1/2)(\Delta c)(\Delta\forall)\chi + (1/2)(\Delta c)\forall(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \quad (21)$$

$$IO^x = c(\Delta\forall)\chi + (1/2)(\Delta c)(\Delta\forall)\chi + (1/2)c(\Delta\forall)(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \quad (22)$$

$$C^x = c\forall(\Delta\chi) + (1/2)(\Delta c)\forall(\Delta\chi) + (1/2)c(\Delta\forall)(\Delta\chi) + (1/3)(\Delta c)(\Delta\forall)(\Delta\chi) \quad (23)$$

where $\mathbf{I^x}$ is the total intensity effect, $\mathbf{IO^x}$ is the total input-output effect and $\mathbf{C^x}$ is the total compositional effect. There exists identical equations for the decomposition of embodied energy intensity of imports.

(c) The Decomposition Results

The decomposition investigates the reasons for differences in embodied energy intensity from one reporting period to the next. Table 6 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 6 shows that for the period 1993 to 2005 that for a rands worth of South African industry exports, the expenditure on energy went down by 2.3 cents and for a rands worth of South African industry imports, the energy expenditure went down by 2 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 Figures 5, 6 and 7 present the results of the complete direct decomposition of the embodied energy intensity of South Africa'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 21, 22 and 23 respectively. This decomposition technique ensures that the residuals (or interaction terms) are equally distributed amongst the three effects in the manner identified by the refined Laspeyres index approach.

Figure 5 presents the results of the decomposition of South Africa's traded mining and manufacturing goods for the entire period under investigation, namely: 1993 to 2005. It is clear from these results 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 South Africa 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.

Focusing on the results for exports over the years 1993 to 2005, it is clear that embodied energy per rands worth of exports is almost 2.3 cents lower due to the employment of energy saving technologies (i.e., the intensity effect). Similar although slightly smaller changes are recorded in the case of the embodied energy intensity of imports. Explanations for these changes are slightly different though in that only 1.5 cents of the 2 cents decrease in the embodied energy per rands worth of imports is due to the employment of energy saving technologies the remaining 0.5 cents is due to changes in the types of mining and manufacturing goods imported (i.e., the composition effect). Clearly the composition of mining and manufacturing goods that South Africa imports has changed somewhat to goods that are on average less energy intensive. This can be taken as evidence of a slight shift in the competitiveness of South Africa'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 South Africa in the prices of energy inputs during the twelve 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 1993.

Figure 6 and Figure 7 examine the decomposition results of the embodied energy intensity of South African industry exports and imports for each of the separate reporting periods. Starting with Figure 6 and inspecting the graphs, it is clear that the decreases recorded in the embodied energy intensity of exports are fairly evenly distributed over the three reporting periods. The more significant decreases are however recorded after 1998 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 1993 to 1998, the recorded 0.6 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 the period 1998 to 2002, 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 substitution effects exist (e.g. if the price of energy inputs rises, energy intensity will fall while other input usage will increase). Finally, for the period 2002 to 2005, the driving force behind the nearly 1 cent on the rand decrease in the embodied energy intensity of exports is the intensity effect.

Turning to Figure 7 and focusing on the results for the embodied energy intensity of imports a slightly different picture emerges. Firstly, the overall energy intensity changes recorded for the two reporting periods: 1993 to 1998 and 1998 to 2002, virtually all but offset one another. Secondly, it is the final reporting period: 2002-2005, that brings with it the most significant changes in the embodied energy intensity of imports. What is clear furthermore, is that the almost 2 cent on the rand reduction in the embodied energy intensity of imports is driven largely by the intensity 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 1998 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 the energy input price increases. This finding is fairly plausible given that changes in the relative price of industrial energy inputs stand at around 30 per cent for the twelve years under investigation.

Lastly, despite the reduction in both the embodied energy intensity of South African industry exports and imports (as reported in Figure 5), it is clear that the composition of South African mining and manufacturing exports remains significantly more energy intensive than that of imports throughout the period under investigation. This result affirms South Africa's position as a producer and exporter of energy-intensive industrial goods. A finding that is not surprising given the fact that the prices of industrial energy inputs in South Africa are lower than those reported in the major world economies, as indicated in Table 1.

6. Conclusion

A structural input-output approach is applied in this study to calculate the effective energy content of South African industry trade components for the period 1993 to 2005. The study finds that the embodied energy intensity of South African mining and manufacturing exports is a great deal higher than that of imports over the period under consideration. Since the volume of South Africa's international trade in these goods increased significantly during this period, the total value of embodied energy in the country's industry trade components followed a similar pattern. These results provide evidence of a significant impact on the country's energy use patterns by its trade in mining and manufacturing products.

The study's findings suggest that given the country's vast endowment of natural resources and its policy of subsidising industrial energy prices, South Africa ends up with a comparative advantage in energy- and capital-intensive industrial goods. This confirms that South Africa is adding significantly to its domestic energy resource requirements through the exportation of energy-intensive services implicitly embodied in the country's traded industrial goods.

Data Appendix

1. Industry Data

All industry data for South Africa relating to inputs, outputs, exports and imports has been obtained from the supply-use (input-output) tables for the country. These tables are published for manufacturing census years. The 1993, 1998 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**.

2. Energy Data

Data on industrial energy prices were obtained from two sources. International price comparisons on industrial energy inputs are supplied by the U.S. 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 in South Africa were calculated by weighting the relevant producer price indices for the country's main industrial energy carriers: coal, petroleum products, electricity and gas. This data by Statistics South Africa 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**.

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Table 1. Industrial Energy Prices in South Africa and trading partners (in 2000 in US$ using PPPs)

Country	Heavy Fuel Oil for industry (tons)	Natural Gas for industry (10^7 Kcal GCV)	Steam Coal for industry (ton)	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	136.10	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

Table 2: Factor Intensity of SA Consumption, Production

and Trade in Mining and Manufacturing Products

	Production	Net Exports	Consumption*
	(millions of constant 2000 rands)		
1993			
Energy	R 11,722	R 5,419	R 6,303
Value added#	R 113,994	R 30,919	R 83,075
Energy/Value added	0.1028	**0.1753**	0.0759
1998			
Energy	R 10,886	R 4,298	R 6,588
Value added#	R 99,281	R 9,031	R 90,250
Energy/Value Added	0.1097	**0.4759**	0.0730
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 employees and gross operating surplus
1. Ratio not required since net trade in energy is positive and value added factors is negative

Table 3: Energy Intensity of SA Industries

	1993	1998	2002	2003	2005	Average
			Industry Energy Intensity (e_{it}/y_{it})			
Non-ferrous metals	0.1612	0.1478	0.1752	0.1807	0.1241	0.1578
Iron & steel	0.1510	0.1353	0.1446	0.1134	0.1151	0.1319
Metal products	0.0718	0.0576	0.0796	0.0682	0.0500	0.0655
Mining	0.0753	0.0664	0.0443	0.0405	0.0417	0.0537
Non metals	0.0687	0.0595	0.0435	0.0394	0.0399	0.0502
Chemicals	0.0437	0.0398	0.0565	0.0553	0.0376	0.0466
Electrical machinery	0.0387	0.0310	0.0422	0.0406	0.0310	0.0367
Wood products	0.0457	0.0396	0.0276	0.0272	0.0350	0.0350
Food, Bev & Tobacco	0.0283	0.0252	0.0326	0.0291	0.0302	0.0291
Paper & Printing	0.0361	0.0339	0.0211	0.0218	0.0283	0.0283
Other Manufactures	0.0217	0.0175	0.0353	0.0203	0.0146	0.0219
Machinery	0.0248	0.0151	0.0264	0.0231	0.0160	0.0211
Textiles	0.0176	0.0148	0.0262	0.0182	0.0146	0.0183
Transport equipment	0.0243	0.0159	0.0190	0.0161	0.0124	0.0176
Radio & Scientific	0.0084	0.0043	0.0054	0.0081	0.0044	0.0061
All Industries (Mining & Manuf.)	0.0741	0.0641	0.0832	0.0628	0.0520	0.0672

Source: Author's own calculations

Table 4: Industry Shares of Trade Components and Embodied Energy Traded (%)

	1993	1998	2002	2003	2005
		Industry Share of Exports [(x_i/x) x 100]			
Non-ferrous metals	4.69	4.88	2.57	2.73	3.27
Iron & steel	9.25	9.70	10.24	11.85	12.96
Metal products	2.04	2.42	2.10	1.92	2.11
Mining	49.67	41.24	42.40	41.74	41.97
Non metals	0.93	0.94	0.73	0.66	0.67
Chemicals	6.89	9.75	9.13	7.98	8.44
Electrical machinery	0.90	1.11	0.99	0.88	0.75
All other manufactures	25.64	29.94	31.84	32.23	29.82
		Industry Share of Exported Embodied Energy [(e^x_i/e^x) x 100]			
Non-ferrous metals	13.24	13.75	13.29	14.60	11.25
Iron & steel	21.77	24.50	29.91	27.47	34.61
Metal products	1.10	1.29	1.88	1.94	1.36
Mining	47.78	41.56	27.91	29.61	33.27
Non metals	1.10	1.05	0.57	0.55	0.69
Chemicals	7.35	9.74	16.18	15.95	10.71
Electrical machinery	0.44	0.47	0.60	0.59	0.44
All other manufactures	7.22	7.63	9.67	9.29	7.68

	Industry Share of Imports [$(m_i/m) \times 100$]				
Non-ferrous metals	1.07	1.92	1.36	1.59	1.49
Iron & steel	1.73	1.47	1.40	1.13	1.05
Metal products	1.47	2.09	2.45	2.10	1.87
Mining	21.16	11.45	13.32	13.04	13.76
Non metals	1.54	1.68	1.54	1.36	1.25
Chemicals	14.08	13.82	14.68	12.93	11.55
Electrical machinery	4.44	3.68	3.15	3.30	2.64
All other manufactures	54.52	63.89	62.09	64.55	66.39
	Industry Share of Imported Embodied Energy [$(e^m_i/e^m) \times 100$]				
Non-ferrous metals	8.83	12.37	14.21	15.12	11.43
Iron & steel	14.89	14.36	16.53	11.26	14.81
Metal products	1.32	1.79	2.41	2.31	1.86
Mining	30.08	19.84	11.53	12.14	19.13
Non metals	2.29	2.64	1.18	1.14	1.70
Chemicals	20.50	24.00	31.34	31.51	24.16
Electrical machinery	2.75	2.59	1.94	2.40	2.03
All other manufactures	19.35	22.41	20.86	24.12	24.88
	Industry Share of Total Industrial Output [$(y_i/y) \times 100$]				
Non-ferrous metals	1.61	2.64	2.64	2.46	2.22
Iron & steel	4.49	5.03	6.75	6.59	6.69
Metal products	4.50	4.44	4.25	3.86	3.79
Mining	28.87	26.34	21.85	22.06	21.67
Non metals	2.32	2.15	2.07	2.13	2.29
Chemicals	10.63	12.62	14.32	14.49	13.63
Electrical machinery	1.95	2.35	2.59	2.50	2.38
All other manufactures	45.63	44.44	45.52	45.90	47.34

Source: Author's own calculations

Table 5: Energy Intensities of SA Industry

Year	Exports	Imports	Net Exports	Dom Cons Goods
1993	0.0828	0.0619	0.0210	0.0432
1998	0.0766	0.0527	0.0240	0.0377
2002	0.0689	0.0609	0.0079	0.0460
2005	0.0600	0.0417	0.0183	0.0336

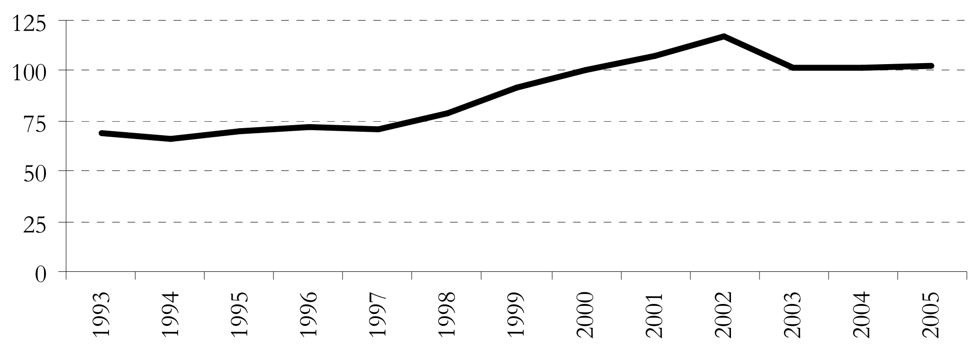
Source: Authors own calculations

Table 6: Changes in Embodied Energy of Exports and Imports

	Exports	Imports
1993-1998	-0.0062	-0.0092
1998-2002	-0.0078	0.0083
2002-2005	-0.0089	-0.0193
1993-2005	**-0.0229**	**-0.0202**

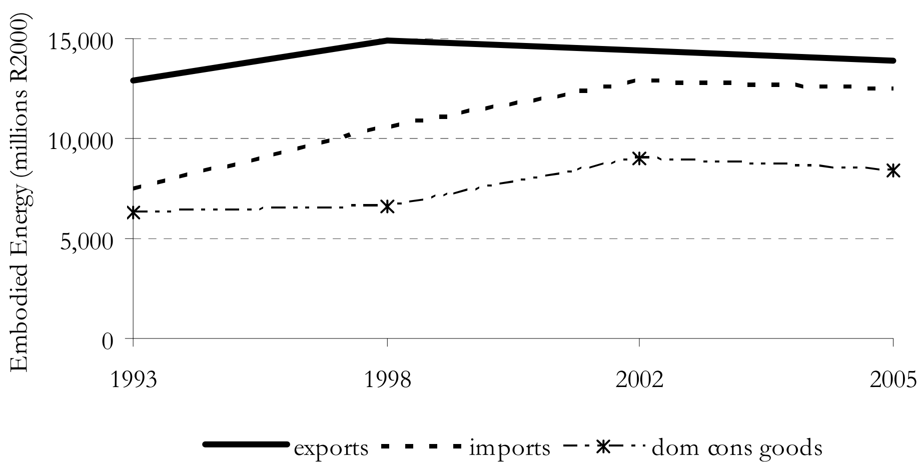
Source: Author's own calculations

Figure 1:
Industrial Energy Price Deflator Relative to Industrial Output Deflator
(2000=100)



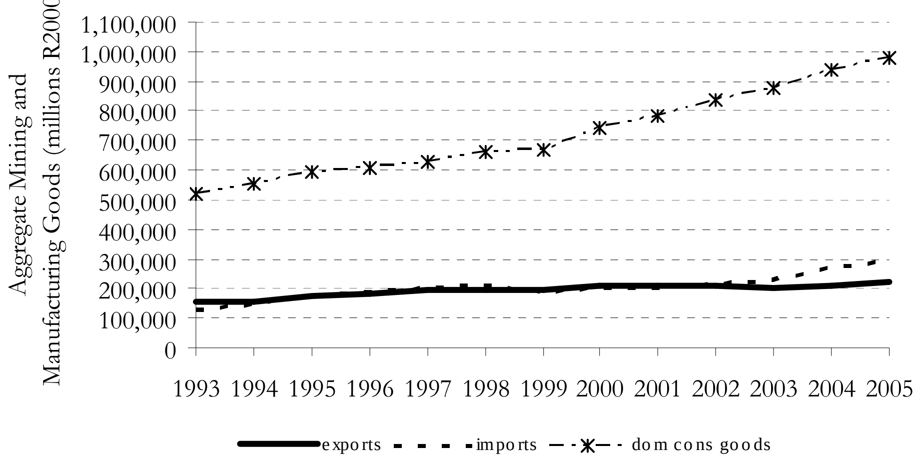
Source: Author's own calculations

Figure 2: Embodied Energy of SA Industry Exports, Imports and Domestically Goods, 1993-2005



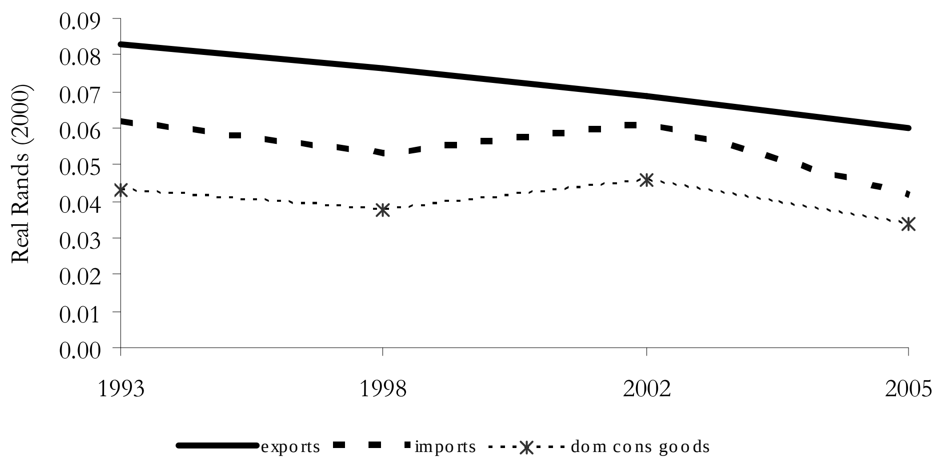
Source: Author's own calculations

Figure 3: Real Value of SA Industry Exports, Imports and Domestically Consumed Goods: 1993-2005



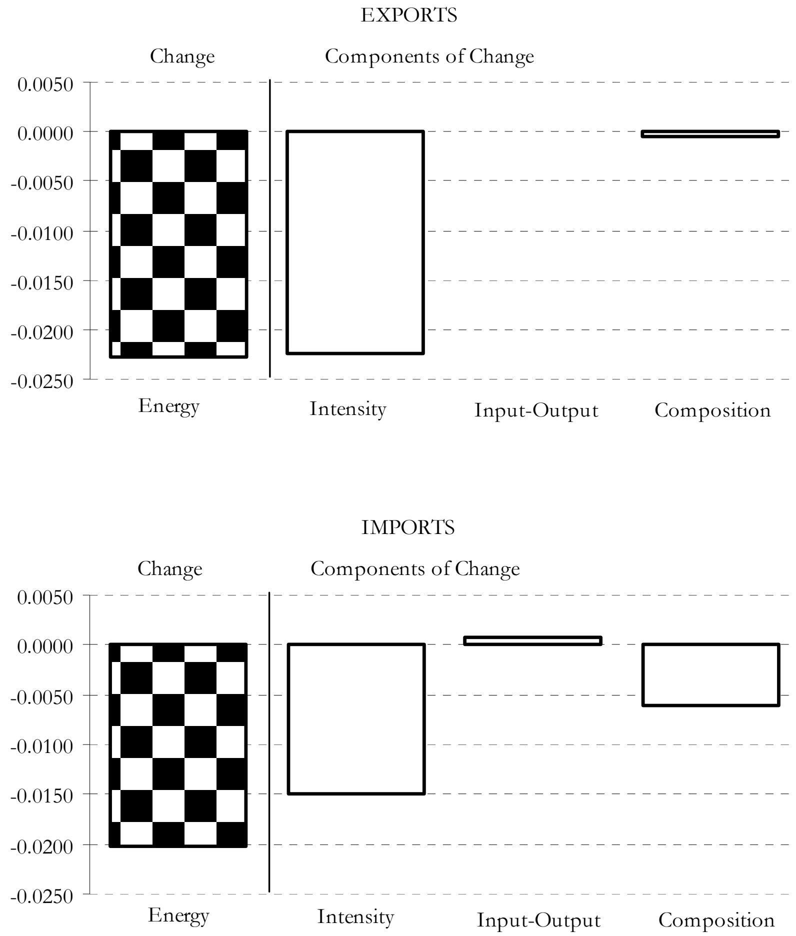
Source: Author's own calculations

Figure 4: Embodied Energy Intensity of SA Industry Exports, Imports and Domestically Consumed Goods, 1993-2005



Source: Author's own calculations

Figure 5:
Decomposition Results of Embodied Energy Intensity of South African Industry
Trade Components: 1993-2005



Source: author's own calculations

Figure 6: Decomposition Results of Embodied Energy Intensity of SA Industry Exports

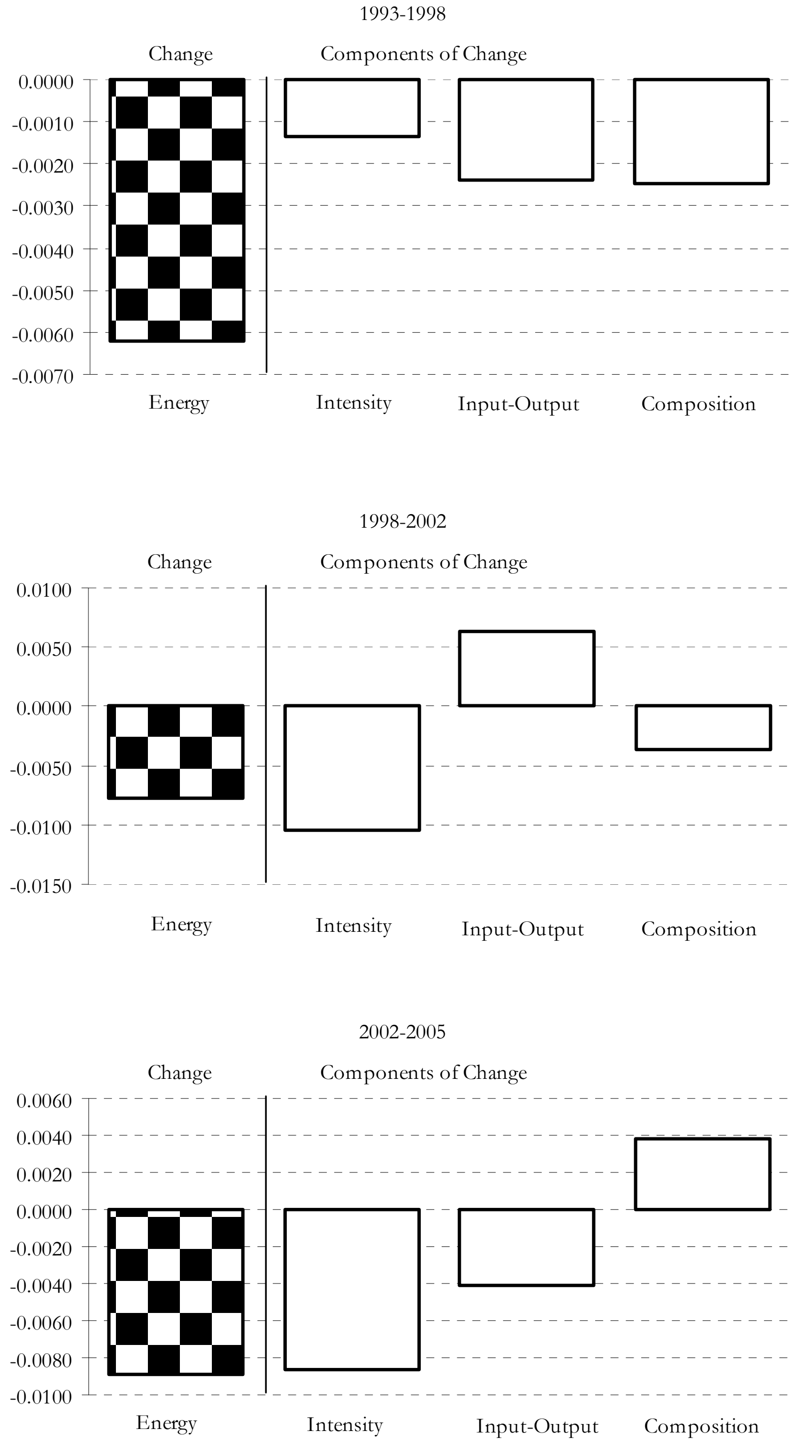


Figure 7: Decomposition Results of Embodied Energy Intensity of SA Industry Imports