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The role of the domestic market in promoting the beneficiation of raw materials in South Africa

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SYNOPSIS

A mineral economic analysis of South Africa's mineral-beneficiation industry, comprising both economic theory and case studies, suggests that the domestic market has proved to be a more effective vehicle for promoting the establishment of *advanced* beneficiation projects than the availability of domestic raw materials. Although the domestic market plays an important role in the promotion of beneficiation by providing a secure outlet for sales, its most vital role is in the development of technological and marketing know-how that may give South African beneficiated products the competitive advantage required to penetrate export markets. The real wealth of a country lies primarily in the skills of its people rather than in its natural resources, and the domestic market plays a pivotal role in the development of these skills.

SAMEVATTING

'n Mineraalekonomiese ontleding van Suid-Afrika se mineraalveredelingsbedryf, bestaande uit ekonomiese teorie en gevallestudies, toon dat die plaaslike mark 'n meer effektiewe aansporing vir die vestiging van *gevorderde* veredelingsprojekte is as verkrygbaarheid van plaaslike grondstowwe. Hoewel die plaaslike mark 'n belangrike rol speel in die aansporing van veredeling deur 'n versekerde afsetgebied, is sy hoofrol die ontwikkeling van tegnologiese- en bemarkingskennis wat die Suid-Afrikaanse veredelingsprodukte die kompeterende voordeel verskaf wat verlang word om die uitvoermark binne te dring. 'n Land se ware rykdom lê in die kundighede van sy mense eerder as in sy natuurlike hulpbronne, en die plaaslike mark speel 'n kernrol in die ontwikkeling van hierdie kundighede.

Introduction

Since South Africa first undertook the large-scale processing of chromium and manganese ores to ferro-alloys in the early 1960s, the debate on the beneficiation of raw materials has intensified. Much stress has been laid on South Africa's domestic production of a wide diversity of raw materials, and it has frequently been noted that, although in the world context South Africa is a major producer of many ores and metals, it is nevertheless a relatively small producer of processed mineral products—particularly the more sophisticated processed products. This suggests that the domestic production of ores and metals does not necessarily provide South African processors with an overwhelmingly competitive advantage. In fact, an analysis of several very successful projects in South Africa that process raw materials to more advanced stages of beneficiation reveals that it is the domestic market, rather than the domestic production of raw materials, that has played the decisive role in the success of these projects.

Stages of Beneficiation

South Africa is one of the world's major producers of minerals. The total value[1] of South African mineral sales in 1988 was R33 413 million, of which 81 per cent was derived from exports and the balance from domestic sales. In that year gold contributed 72,7 per cent of the total value of South African mineral exports, and in 1987 it comprised 41,4 per cent of the value of the country's total exports[2].

There has been growing concern since the end of World War II over the South African economy's unhealthy dependence on this single commodity. There has also been a simultaneous growth in awareness of the enormous potential for increasing the value of exports of other mineral commodities by means of beneficiation processes, thereby reducing the country's dependence on gold.

Beneficiation can be defined as any further processing of a mineral beyond the stage where it represents a saleable raw material. The first saleable products of metallic minerals that occur in nature in the form of oxides, e.g. manganese and chromium, are usually the ores, whereas concentrates represent the most basic saleable products of metallic minerals that occur in nature as sulphides, e.g. copper, lead, and zinc. In some cases, when the ore cannot be concentrated sufficiently by physical means, it must be subjected to pyrometallurgical and chemical processes to produce a saleable basic product such as vanadium pentoxide, which is produced from vanadiferous magnetite. Any further processing—whether by separation processes that produce a more refined product, or by chemical or pyrometallurgical processes, which change the chemical composition of the material—represents beneficiation and adds value to the product. In some cases there is no saleable raw material or basic product, and the metal must be smelted from the ore and refined before it can be sold, such as in the cases of gold and platinum.

In order to compare the levels of beneficiation for different raw materials, one must devise a classification system. The following classification of the beneficiation process into four separate stages is intended as a simpli-

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fication of a very complex subject. The four stages of beneficiation after the production of the saleable raw material or basic saleable product are as follows:

(1) saleable smelted or refined products,
(2) fabrication alloys,
(3) semi-manufactured articles, and
(4) fabricated articles.

No classification system is precisely applicable to all commodities, but two examples—the beneficiation routes for chromium and gold—suffice to illustrate the successive stages of beneficiation according to this system. In the case of chromium, ore is first smelted to ferrochromium; ferrochromium is melted with iron and with other alloying elements to produce a fabrication alloy in the form of stainless-steel billets; these are then rolled to produce semi-manufactured articles in the form of flat stainless-steel products; and, finally, a great variety of fabricated articles, ranging from teaspoons to pressure vessels, are produced from the rolled flat products. In the case of gold, the metal is extracted from the ore, smelted, and refined; it is then alloyed with other metals, for example copper, to produce fabrication alloys suitable for jewellery manufacture; semi-manufactured articles may then be produced, e.g. in the form of granules of specified carat; and, finally, gold alloys are fabricated into gold jewellery.

Whereas the first three stages constitute successive steps in extractive metallurgy and transform the chemical composition of the raw materials, the fourth stage lies in the realm of engineering, and involves changes of physical shape rather than of chemical composition. In contrast to the first three stages, which are capital-intensive, the final stage is labour-intensive since the diversity of product shapes and forms renders mass-production methods more difficult.

Advantages and Current Status of Beneficiation

Beneficiation has several obvious advantages. Firstly, value is added with each succeeding stage of beneficiation. The successive stages in the beneficiation of chromium ore to ferritic-grade (nickel-free) stainless steel can be used to illustrate this concept. The value added to the chromium content at successive beneficiation stages can be calculated on the assumption that the chromium content and the value added by beneficiating the product comprise the entire value of the product. This is, of course, not strictly correct since the beneficiation process involves the incorporation of chromium into alloys that comprise mainly iron. However, for the sake of simplicity and for the purpose of illustration, the value of the iron (and other ingredients) can be ignored. This can be justified by the fact that chromium is the most valuable ingredient and, in the case of chromium ore and ferrochromium, the product is sold on the basis of its chromium content and the iron is effectively supplied free. Table I, which is based on the annual South African prices of chromium ore and the beneficiation products of chromium, shows that the value of the chromium content in the ore is increased by a factor of over 300 in the production of fabricated articles of 3CR12 (a low-grade proprietary ferritic stainless steel produced by Middelburg Steel & Alloys).

TABLE I
VALUE OF CONTAINED CHROMIUM IN BENEFICIATION PRODUCTS
DECEMBER 1989

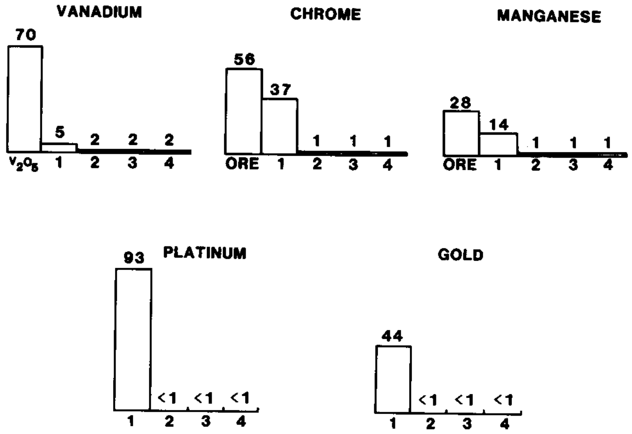
Product	Price R/t	Cr content %	Value R per kg contained Cr	Increase in value of Cr content
Chromium ore*	70	27	0,26	–
Ferrochromium†	1 500	52	2,88	11
3Cr12 (flat product)‡	4 000	12	33,33	12
3Cr12 (fabricated)‡	10 000	12	83,33	2,5

Prices
* Rand Mines (Mining and Services) Limited
† Middelburg Steel & Alloys
‡ South African Stainless Steel Development Association

A second major advantage that is derived from beneficiation is increased employment. This applies particularly to the labour-intensive fourth stage, at which fabricated articles are produced. In addition to the advantages of the value added and new jobs created, fabrication provides much greater scope for product diversification, which facilitates the choice of products best-suited to penetrate export markets.

Despite these strong incentives, progress in the beneficiation of minerals in South Africa has not always fulfilled expectations. A comparison of South Africa's percentage share of the world's production of saleable raw mineral commodities with the beneficiated products of these minerals highlights the relatively 'immature' status of mineral beneficiation in South Africa. Fig. 1 shows South Africa's relative contribution to the beneficiation of five mineral commodities for which the South African ore reserves exceed 50 per cent of the non-socialist world's reserves. The diagram was compiled from specific beneficiation routes since the same mineral commodity may follow different beneficiation routes according to the industry in which it is used. For example, chromium ore can be beneficiated to products for the metallurgical or the chemical industries. Where such alternative beneficiation routes exist, the values in Fig. 1 were based on the route in which most progress has been achieved in South Africa. For example, South Africa's production of ferrochromium, the first stage of beneficiation along the metallurgical route for chromium, is much larger than its production of sodium dichromate, the first stage of beneficiation along the route for chemicals. Published statistics of the world's and South Africa's production of stage (2), (3), and (4) beneficiated products are seldom available but, wherever possible, the estimates were based on discussions with experts within the domestic industries.

The competitive advantage resulting from the domestic production of raw materials in the beneficiation of ore to smelted products is augmented by the additional advantage of cheap electric power, and Fig. 1 shows that, in the case of four of the five mineral commodities, South Africa is a major world producer of both the saleable raw material (if it exists) and the stage 1 beneficiated product. Vanadium is the exception; although South Africa is the non-socialist world's leading producer of the basic saleable product, vanadium pentoxide, it is a relatively minor producer of ferrovanadium. In the case of gold and platinum, where no saleable raw material or basic primary



SOURCE : AUTHORS' ESTIMATES

Fig. 1—South Africa's estimated percentage share of the non-socialist world's production of five mineral commodities and their beneficiated products

product is produced, South Africa is the dominant producer of the refined metals.

In contrast to its emergence as a major producer of stage 1 beneficiated products, South Africa has failed to become an important producer, in world terms, of the more advanced beneficiated products (stages 2, 3, and 4) of any of the five commodities listed. This leads to the conclusion that domestic production of raw materials does not confer a major competitive advantage in the production of advanced beneficiated products. The possible reasons for this are twofold: the potential advantage conferred by lower-cost raw materials may not be fully realized and, even when fully realized, may be offset by competitive disadvantages. Domestic production of raw materials does not in itself constitute a competitive advantage in beneficiation processes; it is a potential advantage that can be realized only when domestic producers sell raw materials to processors at advantageous prices.

The Mining Industry's Role in Promoting Beneficiation

Despite the success achieved in the establishment of export-orientated projects that process domestic raw materials to low levels of beneficiation, a study of the history of beneficiation projects in South Africa shows that the domestic market has played a larger role than the domestic production of raw materials in promoting the processing of raw materials to higher levels of beneficiation.

Since the discovery of diamonds at Kimberley in 1870, and of gold on the Witwatersrand in 1886, the mining industry has been the backbone of the South African economy. The mining industry has frequently required the development of beneficiated products, and this requirement has ensured a large and secure domestic market for these products. Such products have been developed in response to the mining industry's needs, irrespective of the domestic availability of the raw materials.

Dynamite

One of the earliest examples of beneficiation in South Africa in response to the needs of the domestic market was the production of dynamite. Following the discovery of gold on the Witwatersrand in 1886, a small factory was established at Leeuwfontein, near Pretoria, for the preparation of cartridges from blocks of imported dynamite. However, the demand for dynamite for the gold mines grew so rapidly that the Transvaal soon became the largest market for dynamite in the world, and in 1894 President Kruger asked the Nobel organization in Hamburg to build a factory in the Transvaal. Apart from pyrite, a by-product from the gold mines that was used for the production of part of the factory's sulphuric acid requirements, all the raw materials required for the manufacture of dynamite were imported. These included glycerine, nitrate salts from Chile for the production of nitric acid, sulphur from Italy for the production of sulphuric acid, stabilizing clays, and even paper for the wrapping of dynamite cartridges[3]. Hence, despite being dependent on imported raw materials, the Transvaal's first major manufacturing industry—the dynamite industry—was established in response to the gold mines' critical need for security of supply.

Drill Bits

Boart diamonds provide another example of the mining industry's role in promoting the beneficiation of raw materials in South Africa although, in contrast to dynamite, the original stimulus for development was derived both from the availability of imported supplies and the perceived needs of the mining industry. In 1934 Sir Ernest Oppenheimer became concerned about the large quantities of low-grade diamonds being generated as a by-product of the diamond industry in the Belgian Congo (Zaire). The continuing search for gold in the Witwatersrand Basin required drill bits, or crowns, for core-drilling, and the company undertook research in partnership with the Minerals Research Institute of the University of the Witwatersrand to develop uses for industrial diamonds, and to improve the design and production of diamond crowns. This research resulted in the development of an inexpensive and efficient powder-press diamond crown, which was used with great success on the Zambian Copperbelt and on the Orange Free State goldfields. Since its establishment in 1936, the Boart international group has grown both in product range and internationally, and now has companies or offices in over twenty countries. The company is engaged in three major areas of activity: industrial diamonds and their uses, diamond drilling, and hard-metal drilling tools and wear parts.

South Africa has thus become a world leader in the production and technology of industrial-diamond tools using both natural and synthetic diamonds. The major factor contributing to South Africa's emergence as a world leader in these products was the expertise gained in the domestic market, and Boart itself has always acknowledged this fact. In 1975 the company's Managing Director, Mr Hilton Davies, said in an address that Boart would never forget that it owed much of its success to 'experience gained in one of the toughest mining schools in the business—South Africa's hard-rock mining school', and that Boart subsequently decided 'that the skills and know-how we acquired were exportable to other mining markets, and so we took them to other countries in Africa and then overseas'[4].

During the 1940s, Boart observed that the use of rock drills tipped with tungsten carbide would have an enormous impact on mining in South Africa. Hard-metal or cemented tungsten carbide components are used in many applications where a combination of extreme hardness, toughness, and resistance to wear is required, such as machine-tool inserts, metal-forming dies, components for the manufacture of synthetic diamonds, and armaments such as armour-piercing shells. Although South Africa's reserves and production of tungsten ore (scheelite and wolframite)—the raw material required for the production of tungsten carbide—were insignificant and totally inadequate to support the domestic production of tungsten carbide, the manager of Boart at the time, Mr Ted Brown, decided that 'the demands of the mining programme made it necessary to manufacture tungsten carbide in South Africa'[5]. Boart established a plant for the production of tungsten carbide at Springs, and the Boart International Springs Centre has become the largest manufacturer of cemented tungsten carbide in the southern hemisphere. Thus, as in the case of dynamite, the needs of the mining industry prevailed despite the lack of domestic raw materials required to manufacture tungsten carbide components.

DMS Ferrosilicon

Another example of the importance of the mining industry as a generator of beneficiation projects in South Africa was the development of a domestic industry to produce ferrosilicon for dense-medium separation (DMS). The need for improved diamond-recovery methods provided the initial stimulus, and has maintained the momentum that has raised Samancor's status as a producer of ferrosilicon for DMS to that of world leader. In the mid-1940s, when the Anglo American Corporation was investigating the best means of ore treatment for the reopening of the Premier Diamond Mine, which had ceased operations in 1932, it appeared possible that DMS would offer an improvement on the previous jigging plant[6]. A pilot plant with a capacity of 100 tons per hour was erected in 1947, and ferrosilicon was imported from the USA.

Following successful trials at Premier Mine, a production-scale dense-medium plant with a capacity of 13 000 tons per day was commissioned in 1950. In order to meet the needs of the Premier plant, African Metals Corporation (Amcor) pioneered the production of 14 to 16 per cent grade ferrosilicon in South Africa[7]. The first production of the alloy took place in a 1,2 MVA pilot furnace at Amcor's Vereeniging ferro-alloy works in May 1949. Since 1949 De Beers Consolidated Mines has been the driving force behind the continuous improvement in product quality. De Beers has endeavoured to reduce the consumption of ferrosilicon and improve the performance of the process, and this has compelled Samancor to develop sophisticated technology that enables the production of a wide range of products according to exacting standards[8]. The quality of its products has enabled Samancor to become a major exporter of ferrosilicon, as well as the sole supplier to the domestic market.

Summary of Mining's Role

These case histories illustrate the important role that the mining industry has played in promoting the development of projects based on the beneficiation of raw materials in South Africa. So that the level of beneficiation achieved in the projects described can be assessed, it is necessary to attempt to relate the products manufactured to the four stages of beneficiation outlined in the first section of this paper. This classification refers specifically to metals rather than to industrial minerals. Table II relates the four stages of metal beneficiation to the processing of industrial minerals into finished products required by the mining industry.

TABLE II
STAGES IN THE BENEFICIATION OF METALS AND INDUSTRIAL MINERALS

Stage	Metals	Industrial Minerals
1	Saleable smelted or refined products	Processed raw materials
2	Fabrication alloys and metals	Basic final products
3	Semi-manufactured articles	Refined final products
4	Fabricated articles	Fabricated articles

Table III lists the raw materials, the intermediate products, and the final products of the four beneficiation processes described above. Two of the final products—drill crowns set with natural industrial diamonds and integral drill steels with tungsten carbide tips—can be classified as stage 4 beneficiated products, whereas DMS ferrosilicon and explosives derived from dynamite are stage 3 beneficiated products.

TABLE III
RAW MATERIALS AND INTERMEDIATE PRODUCTS IN BENEFICIATION PROCESSES FOR INDUSTRIAL MINERALS

	Stage 1	Stage 2	Stage 3	Stage 4
Basic raw materials	Processed raw materials	Basic final products	Refined final products	Fabricated articles
Sulphur Coal Water Air	Sulphuric and nitric acid Glycerine	Nitro-glycerine	Ammon gelignite Ammon dynamite	
Industrial diamonds (boart)	Sorted and crushed diamonds			Drill crowns
Tungsten ore (scheelite)	Ammonium paratung-state	Tungsten carbide powder	Sintered tungsten components	Integral drill steels
Steel scrap Quartz Reductants	75% Si ferrosilicon	14–16% Si ferrosilicon	Milled or atomized ferrosilicon	

The needs of the domestic mining industry provided both the initial stimulus and the continuing momentum for the establishment of three of these four projects—those producing dynamite, tungsten carbide bits, and DMS ferrosilicon. In the case of industrial diamonds, the availability of supplies from Zaire provided the initial stimulus, but it was the development of the domestic market that provided the continuing momentum.

Beneficiation Projects Outside the Mining Industry

In contrast to the domestic mining industry, which provides a market that is large enough to support the production of these various beneficiated products on an economic scale, the other domestic markets in South Africa are usually too small to justify the establishment of capital-intensive plants. It has therefore proved more difficult to promote the beneficiation of raw materials for domestic markets outside the mining industry because it is usually necessary to supplement sales on the domestic market with sales to international markets so that economies of scale can be realized. As export markets usually pose greater risks for producers than domestic markets, manufacturers are reluctant to embark on projects that are too dependent on exports.

Two industries that have established large capital-intensive plants producing stage 2 and stage 3 beneficiated products (fabrication alloys and semi-fabricated products), and are now vigorously promoting the production of stage 4 products (fabricated articles), are those of aluminium and stainless steel.

Aluminium

In contrast to the production of stainless steel, which is based on domestic supplies of feed materials—steel scrap, ferrochromium and nickel—the production of aluminium is based entirely on imported alumina. The aluminium industry was developed in response to domestic demand but, unlike the demand for beneficiated products such as dynamite, tungsten carbide, and ferrosilicon, which arose spontaneously from the needs of the mining industry, the demand for aluminium products was cultivated actively. The usage of aluminium was first promoted in South Africa in the 1930s by Alcan Aluminium of Canada, which was looking for export markets for its production of aluminium metal[9]. Alcan established a fabricating plant in Pietermaritzburg in 1948, and aluminium billets were imported from Canada. The Industrial Development Corporation started to investigate the possibility of building an aluminium smelter in the late 1950s, and construction of the Alusaf plant eventually commenced in January 1969.

The establishment of the smelter at Richards Bay, which was partly motivated by the domestic fabricators' need for a secure supply of aluminium ingots, shows that beneficiation is not always driven towards more sophisticated products by perceived competitive advantages in production costs but can also move backwards towards less sophisticated products in response to the demand for feedstock for further processing[9].

Hulett Aluminium is the largest manufacturer of semi-finished aluminium products in South Africa. In 1973, Hulett Corporation obtained a controlling interest in Alcan Aluminium of South Africa, and Hulett now have four fabricating plants in South Africa. Hulett forecasts that the annual domestic demand for aluminium will double over the next ten years, and will reach nearly 200 kt[10]. Domestic consumption is being vigorously promoted by the Aluminium Federation of South Africa, an organization of domestic aluminium producers and consumers. One of the strategies being successfully employed in this promotion is the importation of products that are not manufactured domestically, with the specific objective of creating new markets in South Africa[9]. Once consumers become aware of these products and a market develops, opportunities for import replacement are created for domestic fabricators.

Stainless Steel

In contrast to the establishment of Alusaf's aluminium smelter, which was partly motivated by the needs of the domestic market, RMB Alloys' drive to develop technology to exploit South Africa's vast reserves of chromium ore provided the impetus leading to the establishment of South Africa's first—and still its only—stainless-steel plant. In the late 1950s, mining groups with large reserves of chromium ore in the Transvaal recognized the enormous potential market in the metallurgical sector. This market was inaccessible at that time, because Transvaal ore was regarded as unsuitable for the production of ferrochromium that could be used for the manufacture of stainless steel on account of its friable nature and low chromium-to-iron ratio[11].

Rand Mines Ltd, the largest holder of chromium ore reserves in South Africa, took the lead in research towards the development of a process to convert chromium ore to ferrochromium. A new company was registered under the name of RMB Alloys (Pty) Ltd, and it was decided to build a full-scale production plant with an annual capacity of 14 kt of low-carbon ferrochromium at Middelburg. Production commenced in May 1964, and the breakthrough achieved in the beneficiation of chromium ore to low-carbon ferrochromium led RMB Alloys to consider undertaking the next step in the beneficiation of chromium—the manufacture of stainless steel. The development of a new process based on the production of high-purity low-carbon iron without oxygen blowing gave impetus to this idea[12].

The Southern Cross Stainless Steel Company was formed in December 1964, and commenced construction of a stainless-steel plant, which was commissioned in 1966[11].

Together the two plants represented the first integrated ferrochromium and stainless-steel manufacturing unit in the world. However, although the process for the production of stainless steel without oxygen-blowing proved to be a technological success, the product mix and small production volume limited the potential income, and at times the project operated at a loss[13]. Not only was the domestic market too small and fragmented to support a profitable venture, but the design of the rolling-mill facilities was incompatible with domestic requirements.

In 1969 RMB Alloys merged with another producer of ferrochromium, Palmiet Chrome near Krugersdorp, and a new company, Middelburg Steel & Alloys (MS&A) was formed as a holding company for the group's ferrochromium and stainless-steel production.

In 1980 work commenced on a R180 million expansion programme designed to make South Africa virtually self-sufficient in all its requirements of stainless steel, and commissioning of the new mill took place in December 1981. Expanded meltshop facilities to feed the mill were completed in mid 1982. The annual saleable mill production is about 100 kt per annum, of which 60 per cent is cold-rolled and 40 per cent is hot-rolled. Sales are split approximately evenly between the domestic and the export markets.

Not only would growth in the domestic consumption of stainless-steel flat products provide MS&A with more secure sales outlets than the highly competitive export markets, but it would also result in lower unit production costs because of larger production runs. South Africa has a very low per capita annual consumption of stainless steel—less than 2 kg compared with 5 to 8 kg in many developed countries. MS&A is therefore actively promoting the consumption of stainless-steel flat products in South Africa by encouraging domestic fabricators to manufacture products that were previously imported, and also to find export markets for their products. There are a large number of small stainless-steel fabricators in South Africa making a wide range of products. MS&A believes that the growth of the stainless-steel market in South Africa is a long-term project, and can be accomplished only through the gradual development of downstream industries by incremental additions[14].

Hence both the aluminium and the stainless-steel industries have recognized the necessity to expand the domestic market while also striving to superimpose export-market potential on the demand from the local market.

Theoretical Basis for the Promotion of Beneficiation by the Domestic Market

Economic theory of plant location and international competitiveness supports the hypothesis that the domestic market plays an important role in promoting the local beneficiation of raw materials. Location theory suggests that plant location is dictated by both the production-cost advantages existing at a particular site, and by the locational interdependence of firms[15]. The second element of this theory, better known as the concept of market–area locational interdependence, refers to the existence of a consumer market at a specific location that attracts production facilities. The location of mining-equipment factories on the Witwatersrand to serve the extensive local mining industry illustrates this point.

Fagerberg[16] developed a model of international competitiveness that relates growth in market shares primarily to the ability to compete in capacity, which in turn reflects technological competitiveness. The term 'competitive capacity' is introduced to distinguish between the concept of capacity familiar to most industrialists, i.e. production capability, and the ability to compete due to the availability of technical know-how and physical infrastructure. Empirical analyses indicate that factors related to competitive capacity are very important for medium- and long-term differences between countries in the growth of market shares and GDP, while the cost-competitiveness of mineral raw materials plays a more limited role than is commonly assumed.

Growth in competitive capacity, dC/C, which can be defined as the ability to meet demand, depends on three factors[17]:

(i) the growth in technological capability and know-how that is made possible by the diffusion of technology from the countries on the world innovation frontier to the rest of the world (dQ/Q),

(ii) the growth in physical production equipment, buildings, transport equipment, and infrastructure (dK/K), and

(iii) the rate of growth of demand (dW/W).

Hence the growth of competitive capacity can be expressed as follows:

$$\frac{dC}{C} = z\frac{dQ}{Q} + r\frac{dK}{K} - l\frac{dW}{W}, \qquad (1)$$

where z, r, and l are positive constants.

Investment in additional physical production capacity (dK/K) should therefore be analysed as one of several factors necessary for the generation of growth in technological capability. This implies that growth of physical production capacity should be seen as being complementary to the growth of other resources such as the number of scientists and engineers, research-and-development (R&D) facilities, technologically advanced installations, etc.

Equation (1) indicates that growth in competitive capacity is inversely proportional to the rate of growth in demand. In order to maintain competitiveness while the demand for his product is appreciating, the producer has to expand his technological capability and physical production equipment. The inverse proportionality might easily lead to the erroneous concept that demand is counterproductive in the drive towards increased competitiveness. It should rather be seen as a very powerful incentive to invest in additional technological capability and physical plant, the so-called 'demand–pull' effect. In this paper it is argued that local demand, owing to its unique characteristics shaped by the close contact between producer and consumer, acts as a prominent incentive in the establishment and expansion of competitive local beneficiation industries.

Historically, the domestic market has proved to be the most effective means of stimulating both research and the establishment of new production facilities for advanced beneficiation. Not only does the domestic market provide a much more secure outlet for production from new plants, but it also provides a testing ground for the development of know-how that eventually enables the domestic industry to compete successfully in foreign markets. The development of an advanced level of competence in the local labour force is of crucial importance in the drive to establish South Africa as a prominent manufacturer of mineral beneficiation end-products.

Summary and Conclusions

This paper has described the case histories of the development of six advanced-beneficiation projects in South Africa. Projects to produce four of these products —explosives, tungsten carbide drill bits, diamond-drill crowns, and DMS ferrosilicon—were established to serve the mining industry. In all four cases these projects were established on the basis of the proven needs of the domestic market, rather than on the promise of export markets resulting from a perceived competitive advantage derived from the domestic production of raw materials. The large domestic market offered two major advantages for producers of these four products: a secure source of income through guaranteed sales at profitable price levels, and the opportunity to develop superior technological know-how in partnership with the consumers. The sound base provided by the domestic market and the development of technological know-how subsequently enabled these producers to become large exporters. The success of these projects suggests that the existence of a large domestic market has proved to be a more effective vehicle for promoting the establishment of advanced-beneficiation projects in South Africa than the availability of domestic raw materials.

A comparison between the history of the development of the aluminium and stainless-steel industries in South Africa provides further support for this conclusion. Table IV compares annual sales turnover at the first three stages of beneficiation of chromium ore and bauxite (aluminium ore).

TABLE IV
SALES TURNOVERS OF ALUMINIUM AND CHROMIUM BENEFICIATION PLANTS IN SOUTH AFRICA

	Aluminium		Chromium	
Beneficiation stage	Product	Sales Rands (million)	Product	Sales Rands (million)
Raw material	Bauxite	–	Chromium ore	242*
Stage 1 Smelter product or processed raw materials	Aluminium	–	Ferro-chromium	723*
Stage 2 Fabrication alloys	Aluminium	563*	Stainless steel	–
Stage 3 Semi-manufacturered articles	Aluminium	1600†	Stainless steel	300 to 400‡

* Minerals Bureau of South Africa
† Aluminium Federation of South Africa
‡ Authors' estimate based on MS&A's total sales turnover (ferrochromium and stainless steel) of R721,7 million in 1987 financial year

It can be seen that the value of the annual sales turnover of aluminium semi-manufactured products was between four and five times that of semi-manufactured products of stainless steel. This comparison must be qualified by the fact that aluminium semi-manufactured articles include a much greater diversity of products than those of stainless steel. Whereas aluminium semi-manufactured articles include four categories of products —extrusions, rolled products, remelt ingots, and redrill rods—semi-manufactured articles of stainless steel comprise only rolled flat products produced by Middelburg Steel & Alloys. About three-quarters of the total sales value of aluminium semi-manufactured articles is sold on the domestic market. The comparison is intended to illustrate that the domestic availability of raw materials is not a prerequisite for beneficiation, which can be successfully undertaken using imported raw materials.

The contrasting beneficiation routes taken by chromium and aluminium suggest that a dual 'push-pull' approach should be adopted as the most effective policy to promote the beneficiation of raw materials in South Africa. The development of the stainless-steel industry in South Africa conforms to the pattern of other domestic industries based on the beneficiation of raw materials (gold, platinum, manganese, vanadium, and others), where the impetus provided by the domestic availability of raw materials was sufficient to 'push' the beneficiation process upwards to the lower levels but lacked the momentum to 'push' it further to the higher levels without the support of an expanding domestic market. In contrast, it was the 'pull' of the domestic market that stimulated the backward integration of aluminium beneficiation from the more advanced semi-fabricating stage to the less advanced smelting stage. This indicates that the domestic market may provide the 'pull' required to continue the beneficiation process to higher levels when the 'push' of the domestic production of raw materials loses momentum and, as we have seen from some case histories, may even create beneficiation projects when there is no domestic production of the raw material.

The intention of this paper is to focus attention on the promotion of raw-materials beneficiation through the development of the domestic market. So much emphasis has been placed on South Africa's mineral wealth and the need for South Africa to beneficiate its raw materials before exportation that it has tended to obscure two important facts: firstly, that a competitive advantage in the production of raw materials does not constitute a *sine qua non* for successful beneficiation projects in South Africa and, secondly, that technological know-how developed on the domestic market is essential to convert any potential competitive advantages accruing from the domestic production of raw materials into a real competitive advantage for advanced beneficiation products for export markets.

Nature has bestowed mineral treasures on South Africa in abundance but, according to Adam Smith[18], a country's real wealth lies in the skills of its people. The optimum exploitation of a country's mineral resources therefore involves the development of the skills of its people. Whereas the first three stages of beneficiation—saleable smelted or refined products, fabrication alloys, and semi-manufactured articles—are capital-intensive, the fourth stage—fabricated articles—is labour-intensive. It is therefore the fourth stage of beneficiation that has the most important potential role in providing employment and developing skills. The domestic market has proved to be the most effective vehicle for promoting beneficiation to advanced stages, and thereby for harnessing the skills of South Africa's peoples.

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