


Employment-oriented Industry Studies

Resource-based Technology Innovation in South Africa:

Gunric and RGR Valves

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RESOURCE-BASED TECHNOLOGY INNOVATION IN SOUTH AFRICA:

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1. Background: valve manufacture

The manufacture of valves involves engineering skills in the working of materials, mainly metal, to produce a piece of equipment which can open and close the flow of liquid or gas in pipes. While a valve may seem to be a relatively unsophisticated mechanical device, it can be highly specified depending on the size of the pipe and the pressure and abrasiveness of the liquid.

In large industrial operations, which run on a continuous basis, having to change a valve because of wear and tear is potentially costly in terms of downtime. There are also other challenges in the design itself: the valve should enable full flow when open, otherwise the diameter of the pipe would not be used optimally.

As with the markets for many items of machinery, the market for valves has distinct segments. In addition to differentiating according to the diameter and the type of liquid, there is an important difference between commodity products, which are made in large volumes, and products which are made to a customer's specification depending on the exact usage for which they are required.

Innovation and ongoing product developments are important in both large-scale and small-scale production, but the nature of competitiveness is quite different. The South African industry has developed strengths in the more customised segments, although the availability of material inputs suggests that it could be internationally competitive in the large-volume products as well.

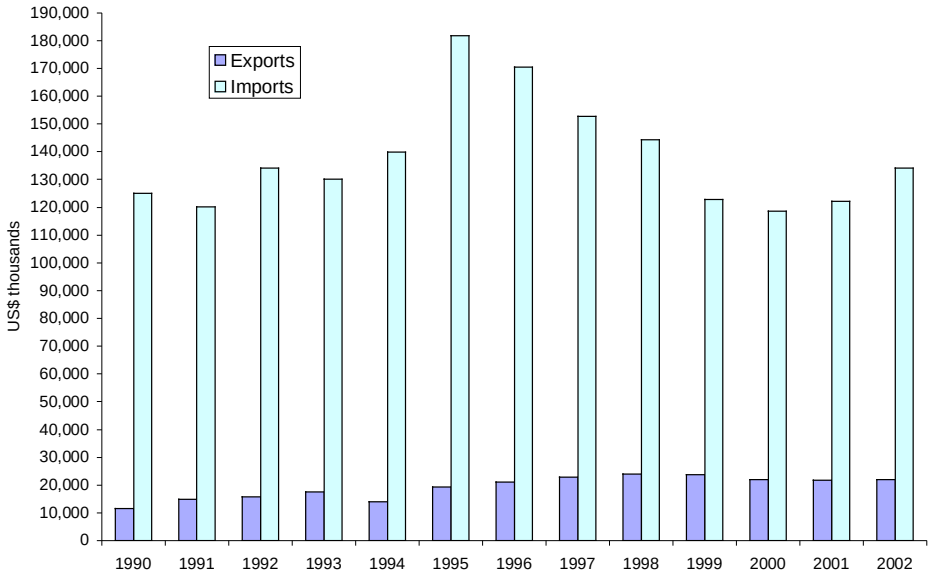
At present, however, it is estimated that local manufacturers supply less than half of local demand. Some estimates put the proportion of local demand met by imports at as much as 80%.[1] This is reflected in the large trade deficits of imports over exports throughout the last 12 years (Figure 1). Exports have improved somewhat, and imports have fallen from a peak in 1996; however, the fall in imports could reflect low levels of capital investment and thus a decline in the demand for valves rather than improved competitiveness of South African producers and import replacement.

Historically, valves have been sourced from European producers, especially German firms. This reflects industrial capabilities, coupled with the importance which the mines and other local customers attach to reliability. The repair of these valves by South African firms, coupled with immigration of engineers from Europe (particularly Germany) provided the impetus for local production. A combination of local demand linkages, reverse engineering and learning-by-doing, and ongoing product development and incremental innovation in making to order has underpinned the

[1] Halwindi, 2003.

development of capabilities. We will return to the conditions underlying successful innovation and commercialisation after describing the two firms studied here.

Figure 1 – South African trade in valves, taps and cocks for pipes and tanks (HS8481)



Source: Trade and Industry Policy Strategies (TIPS) Standardised Industrial Database

This case study covers two firms in different product niches. One firm makes ball valves for small-diameter pipes, the other makes butterfly valves for large-diameter pipes. Their experiences have been similar in certain respects. For example, both firms are small, with innovative activity based on strong engineering skills. Both firms also demonstrate the importance of the nature of local demand in stimulating the development of production capabilities. There are also important and interesting differences between them such as the choice of whether or not to purchase computer-numerically controlled (CNC) machinery, and the related training decisions.

Little institutional support has been received and testing is done in-house and with customers on site. Key obstacles to commercialisation of developments and exports are the cost of meeting international quality standards (ISO 9000 and PED), and the availability (and cost) of export finance.

Section 2 reviews the innovations made by Gunric Valves, and section 3 reviews those made by RGR Valves. Section 4 makes a comparative analysis of the two companies in order to arrive at insights into the main factors underpinning the innovative activities, their commercialisation, the relationship to firm competitiveness, the role of institutions, and obstacles encountered. Section 5 concludes the report.

2. Gunric Valves

Gunric Valves developed its own metal-to-metal sealing butterfly valve 14 years ago, in 1989, which made South Africa one of only four countries with a manufacturer of such valves. The innovation benefited from the efforts of a Swedish company whose valves it had been repairing. Generally, valves were made with rubber seals, but these could not stand up to very high pressures or heat of more than 70–80°C. The Swedish firm had succeeded in developing a butterfly valve that sealed metal onto metal, but not one that did not leak.

The Gunric innovation enabled import replacement, and three years later, in 1992, Gunric started to penetrate export markets. As other firms caught up (there are now estimated to be around 20 big players, mainly in Europe and USA), Gunric came to specialise in the large-valves niche.

The company employs 50 people. The owner continues to be the main person engaged in ongoing design and innovation. The amount of research and innovation remains high so that incremental improvements can be made. The R&D spending is estimated at 7–8% of firm costs. Much of this is the time spent by the owner and one other design engineer, together with the expense of making and testing prototypes.

2.1 Main products

As mentioned, Gunric specialises in butterfly valves for large-diameter pipes (0.5m up to 2.5m).

Its main markets are:

- Water (40%);
- Petrochemicals (20%); and
- Mining (15%).

Exports have accounted for as much as 35% of its market, although in 2003, with the strengthening of the rand, exports fell to 20%.

The product range includes:

- Valves to withstand high pressure in a water column for South African goldmines operating 2.5 km underground with a pressure of over 200 bar; and
- Valves to withstand extreme heat in the furnace of a platinum smelter operating at a temperature of 950°C.

2.2 The innovation

The specific innovation and the ongoing incremental improvements to the essential design stem from the internal capabilities of the firm and its strategic decisions. These relate, first, to the targeting of specific niches where design gives the firm a greater competitive edge than in products with large production runs; and second, to the commitment of internal resources including management time and expertise to design and product development.

The main innovations were:

- The metal seal;
- A closure mechanism, where the angle of closure as the valve turns shut also levers the valve into place (the particular mechanical leverage that the valve exerts as it seats itself adds an additional pressure to ensure that the valve stays closed); and
- Replaceable seals.

Gunric patented both the seal itself and the action resulting from the angle of closure that creates the seal.

The development of the metal seal was very important for the closure of large valves, which had previously required a rubber seal at the join. The metal seal offers the benefits of:

- Ability to withstand higher pressures;
- Ability to withstand higher temperatures; and
- More durability.

Gunric has further developed a locking pin (also patented) to prevent the valve being opened by mistake. In the very large pipes this has additional safety benefits, as checking the pipe means that people have to spend time inside the pipe making inspections. These people are at great risk if the valve is mistakenly opened.

2.3 Incentives and drivers of innovation

The main stimuli for the innovation were a combination of particular characteristics of the local market, the existence of research and development skills and international links, and the commercial returns. The local market impetus particularly came from the high pressures due to the depth of mines, and also from the need to remove abrasive waste-water from the mines. Although the mines were the main impetus to the development of capabilities, it is important to note that these capabilities are now used to a much greater extent in supplying the water sector. While similar applications are involved, the stimulus from the particular demands of mining underpinned the subsequent 'lateral migration' of technological capabilities to develop products for the

water sector. Research and development skills were largely due to the managing director, who had started as a consulting engineer, and had worked for a valve company.

Of these stimuli, the local market impetus and the presence of R&D skills are the most important. The initiative came from the firm's work in servicing and refurbishing Swedish-made valves. This enabled two processes, the first being a reverse engineering process for the manufacture of the valves, and the second being a research process to solve the problem of a metal seal that would be water-tight under pressure (the Swedish company was also working on this problem), and to guarantee market share through import replacement and also through export opportunities.

This innovation therefore represents an excellent example of the adaptation and adoption of international technologies, together with innovation to develop them further to meet local market requirements. The innovation was a cutting-edge one, as it led to the South African firm being the world leader in the particular niche, but it was not based on fundamental research that generated a completely new product.

As will be discussed below, the impetus and information flow from local demand was crucial to the learning-by-doing process, yet the commercial returns were not as large as might be expected, nor did the firm view possible large returns as the main reason for the product development. This partly reflects the differentiated nature of valves, with the innovation representing an important advance in one specific segment of the industry which required valves to close in a particular way. This segment, however, has been the fastest growing in the valve industry internationally in recent years. The firm itself has decided to limit itself only to customised, made-to-order products within this segment.

2.4 Firm capabilities

Firm capabilities are very important in two respects besides the ability to conduct research. The lack of support facilities for such activities meant that prototypes had to be built and tested in-house. The capabilities to do this building and testing could be burdensome for a small firm to develop, yet the size of the South African market means that most machinery manufacturers are small and engineering-oriented.

An important part of the innovation process is therefore the commitment to build an ongoing culture of in-house R&D, using available engineering and design skills, together with the financial commitment to carry out in-house testing. R&D expenditure was estimated to be a very large commitment, equal to 7% to 8% of production costs.

Ongoing skills development is an important part of the firm's capabilities. Much of this consists of in-house training for artisans and operators, including ensuring that the skills required for product testing are available. ISO 9000 certification requires this to be recorded and systematised. The company is also drawing back money from

the skills development levy for the training of artisans and operators. In addition, it has recently employed a trainee from Technikon Witwatersrand with financial support from the SETA.

2.5 Strategic choices, commercialisation, and competitiveness of the firm

As set out in the theoretical framework, technological capabilities are part of the strategic orientation of the firm. These choices are closely linked to decisions about the markets to be served and the firm's competitive positioning.

Gunric's main innovation provided a platform for growth through import replacement and penetration of export markets, which began three years after the innovation in the early 1990s. However, the firm is now operating at just under 70% utilisation of capacity. Its experience also usefully illustrates other factors affecting commercial success, which raise questions of whether industrial policies are consistent with goals of building technological capabilities.

The costs of investment decisions and economies of scale, rather than the firm's capabilities, were reported to be the key factors in Gunric's decision to target the large-valve market in particular. In other words, the strategy adopted was in some sense forced on the firm by the nature of demand, with lots of different orders making it difficult to yield economies from long production runs. Because CNC machinery is so expensive, it is important to have a high level of usage for the investment to be commercially viable. The relatively small size of the South African market meant that the returns might not be high enough to justify the initial investment. However, CNC equipment is necessary for the consistency required by international standards.

The combination of these factors led the firm to specialise in the manufacture of particularly large valves. This continues to be a process of making to order in cases where the valves required are too large to manufacture with typical CNC machinery. Being competitive in this specific niche does not therefore require CNC machinery but very good engineering capabilities. It is important to emphasise that it was the upfront costs of CNC machinery which drove the considerations of the market focus, rather than markets or products driving the choice of technology.

Making to order also involves more intensive interaction with customers, links which support research, and development activities to improve customisation of the product continuously. Gunric's main customer is Rand Water.

2.6 Cost competitiveness

The niche product capabilities are therefore a strength but they are also a result of prior decisions based on competitive conditions.

Not only have concerns about economies of scale inhibited investment in machinery; more and more international competitors are making similar products, which means that the costs of inputs and price competitiveness are becoming increasingly important. It was estimated that there are now approximately 20 competitors, mainly in the USA and Europe, although none make exactly the same product.

These manufacturers are located in the main markets, where quality standards and international certification are determined (complying with these standards places an added cost burden on South African firms). At the same time the manufacturers have increasingly outsourced component manufacture to countries like South Korea and India. As with products like watches, the firms maintain the 'made in Germany' certification while lowering input costs considerably by using locations where manufacturing costs are low.

South African manufacture of the most important input materials, like steel, is very competitive but the prices charged to local customers by firms like Iscor are high, which means that none of the local cost competitiveness of the steel industry is passed on to the machinery manufacturers.[2] For example, it was estimated that a casting in South Africa costs as much as the fully machined part purchased from India.

Like European and US valve manufacturers, Gunric is now exploring the possibility of sourcing components from India and South Korea, owing to the difference in cost. However, there are scale economies associated with this in terms of bearing the costs of the transactions; it requires strong links with component manufacturers to satisfy the full traceability of material required by safety standards; and it adds logistics problems to the other difficulties of making to order on a job-by-job basis.

2.7 Certification

The other major cost is that of the certification required to enter export markets in Europe and the US. Separate steps are required in order to meet the international ISO 9000 standard and the specific European standard (PED).

Building the ISO 9000 system from scratch cost Gunric R100,000 ten years ago (approximately 5% of turnover at the time), and an annual audit is required, costing approximately R30,000. A full audit is required for each certification every three to four years, at a cost of R40,000 to R50,000 per certificate.

[2] Basic iron and steel and non-ferrous metals account for 27% of input costs (excluding the costs of production, capital and labour). More than an additional quarter of input costs are due to machinery components, like gears, and fabricated metal products which themselves are metals-intensive. (Statistics South Africa, 1998)

Complying with the systems requires keeping detailed records on each product made and on the training undertaken, and proving all calculations. Maintaining the system therefore adds to the expense.

It should be noted that while the certification process involves payments to international consulting firms,[3] the expenses required to maintain it (staff time, etc.) are probably not greater in South Africa and may be a source of competitive advantage over competitors in industrialised countries.

2.8 Strategy

The key strategic focus of the firm is internationalisation. It focuses on this in order to be more successful in export markets and more cost-competitive by sourcing inputs. Expanding the export markets requires considerable marketing and tendering expenses, given that, according to Gunric's own estimate, they win fewer than the 1% of sales bid for.[4] Quotes for export business are typically given one to two years in advance, as they concern supplies for major projects (dams, mines etc.). This lag, together with the volatility of the exchange rate, increases the risk associated with the returns from exporting.

Gunric is pursuing alliances and joint ventures with firms in India and Brazil to market one another's products. It is also exploring the sourcing of machined components from India.

The internationalisation therefore relates to market access, the marketing costs of exporting, and cost competitiveness. In the technology literature on developing countries, international linkages are usually understood as important, as they enable firms to learn, copy and adapt technologies from more advanced countries. The Gunric case is a little unusual in that improving technological capabilities is not the aim of the internationalisation developments.

The second strategic thrust has been black economic empowerment through the formation of a separate company, Isizwe Valves, targeted at refurbishing operations and business from government and the mines. This company is owned by a black investor and by a trust of black employees who had worked for Gunric for more than ten years.

[3] For example, Gunric uses TUV Rhineland, an international company based in Germany.

[4] This is very low, and the firm confirmed that it really was its estimated success rate.

2.9 The role of institutions and policies

In the past, Gunric Valves has drawn on institutions like the CSIR and DTI. The CSIR has been used specifically for fire-testing, and Gunric has also received support from the DTI under the General Export Incentive Scheme. More recently, DTI support was given for attending an exhibition in Holland. A government grant has also been received for obtaining ISO environmental certification.

The firm is thus well aware of the operations of different institutions and what is on offer. The use of incentives, however, masks the lack of deeper interactions with a network of institutions to support research and development, and the improvement of skills and technological capabilities. For example, at the most basic level all the testing (apart from fire-safe testing) has to be done in-house. R&D takes place in-house with apparently few, if any, links with universities and other research institutions.

Like any other firm, Gunric is affected by the range of policies related to employment, trade liberalisation, investment, etc. It is beyond the scope of the present project to explore the impacts of these policies, except for the impact on the firm's innovative activities. The greater openness of the South African economy is perhaps the most important factor here. As already noted, the firm does also draw back the skills development levy, and the new skills development framework has been one consideration in its employment of a trainee from a technikon, in supporting increased training at the artisan/operator level, and providing more in-house training to support its product testing.

The significance for the firm of policies directly aimed at supporting technological development is that there are no such policies.

2.10 Obstacles

The main obstacles identified were related more to commercialisation and competitiveness than to research or innovation. These obstacles were the difficulties and costs of building export markets, and of gaining access to large projects. Both of these obstacles, and also the effect of input costs on competitiveness, highlight the importance of a trade and industrial policy which is consistent with exploiting technological capabilities.

The main issues in exporting are:

- Export marketing costs (which are being addressed through joint ventures, although these themselves are risky, and rely on the parties to the agreement differentiating their products to reduce overlap);
- Risks in returns due to volatility of exchange rates and input costs; and
- Export finance.

Exports also have an important role to play in sustainable growth, by ameliorating the effects of highly cyclical local demand. Expanding and reducing capacity by large amounts is difficult and costly: exports provide a means for maintaining steadier output levels.

The main obstacle to supplying large projects is that such projects are generally managed by international turnkey contractors, often linked to international sources of funding. Turnkey contractors receive support from their home governments on condition that they source inputs from their home country as far as possible. This has had major and direct impacts on South African firms:

- For Saldanha Steel, the turnkey contractor was an Austrian company, First Alpine. As First Alpine was 'required' to source within its region, Gunric eventually supplied valves for Saldanha via a German company.
- A similar thing happened with Mozal, for which the turnkey contractors were French and Canadian companies. They also supported producers from their home countries.
- In the case of an Algerian refinery built by the French company Technik, business went to another French company, even though Gunric was technologically better and cheaper.

Inducements to use South African materials could be specified by financers like the IDC. Rand Water is notable for using South African suppliers, for example, in tendering for a contract for a pumping station in Jordan.

3. RGR Valves

RGR won a prize in the Technology Top 100 for its innovations in developing high-pressure ball valves. The company manufactures a range of ball valves and piston-type non-return valves. These valves are used for pipes approximately 22 cm in diameter in high-pressure pumping systems. The company started as a general engineering shop that was taken over by two brothers in 1990, and now employs 24 people.

The innovation was mainly due to meeting local requirements, particularly those of deep-level mines, which wanted to replace imported valves that did not meet specific South African needs. The developments started as the repair of imported valves followed by reverse engineering and the development of prototypes. RGR is now custom-making valves for the chemicals and pulp and paper industries, continuing to focus on high-pressure systems. It developed three new products for the pulp and paper industries in 2003.

3.1 The innovation

The valve developed does not disrupt the water flow when open, lasts much longer than substitutes, and meets the requirements for:

- Working at depth (and being able to cope with the consequent pressure);
- Coping with corrosive and abrasive substances, like the waste water from these industries;
- Coping with extremes of temperature; and
- Coping with large volumes of water.

The two major steps taken were the development of a high-pressure ball valve (isolating valve), and a non-return valve designed specifically for the particular conditions in South African mines. These developments prevent 'water hammer' from pressure surges which damage pipe work. The imported valves used by South African mines were in fact made for the oil industry, and not specifically for the needs of deep mines.

In addition to engineering, design and development, an important step was the process developments that arose from the decision to buy CNC machinery, even although the company was doing customised jobs that required many changeovers, and which traditionally were seen as unsuitable for CNC. This decision to invest in expensive machinery despite not having long production runs meant that changes had to be made in the organisation of production.

Essentially, RGR has followed a multi-skilling route in order to introduce processes that halve the changeover times between jobs and maximise the time for which the CNC machinery is working, even although there are many small jobs being done.

3.2 Incentives and drivers of innovation

The innovation has been driven almost entirely by a niche opportunity arising from the specific needs of deep-level mines (in which South Africa is the world leader) for high-pressure valves. This opportunity was seized by two entrepreneurial brothers, one with an engineering background, who had been working in mines, and the other with a financial background. Initially RGR undertook repair work on imported valves: the opportunity arose from this. The main incentives were the relatively high prices that South African mines were paying for imported valves and the relatively cheap costs of manufacture compared to the USA and Europe. This is a classic entrepreneurial story: for working capital both brothers had to mortgage their homes.

In the reverse-engineering and innovative design the work was done in-house, including the building and testing of prototypes. Pressure testing is done in-house but more extensive testing is done by installing valves on site. The company has developed very close working relationships with the mines in order to do this. This was made possible by its existing relationships with the major mines, and its reputation for success, which means that mines would install untested variants for *in situ* studies. Mine decision-making on such equipment is localised, and much of RGR's marketing is done through and with consulting engineers responsible for delivering systems to the mines.[5]

The core capabilities in making ball valves for very-high-pressure systems have provided a foundation for diversification, so that the company now produces customised valves for other industries. As discussed, the constraints due to small orders and the cost of machinery forced RGR to make innovations in its work organisation. RGR can now set up CNC machines in less than one hour, while most other firms take between two and three hours to do this. This focus on work organisation and efficiencies in producing small batches is further reflected in the stability of the workforce and the high rates of pay (by South African standards) to staff such as the senior setter. More than 80% of the workforce have been with RGR for above five years. Furthermore, an estimated three months is spent on retraining recruits from other firms.

The strong focus on product development has meant that the R&D spend has remained relatively high at 3% to 5% of turnover.[6]

[5] This is changing as the mining companies centralise their procurement.

3.3 Strategic choices, commercialisation and competitiveness of the firm

As RGR has replaced imported valves (which were very expensive), it has good margins and a competitive edge owing to the cheap costs of manufacture in South Africa relative to the EU and the USA. After a financially difficult period during which RGR was developing the product it is now established as the leading local manufacturer.

Competitors import or make under license, which means that price competition is keen. Increases in materials prices have also affected RGR's costs. For example, the price of forged bar from Iscor increased by 50% over 18 months, and even though the rand has appreciated, the price has not decreased.

It is RGR's ability to deliver to particular specifications, and its ongoing product development, that places it in a strong competitive position. This allows it to earn a return from those of its competitive advantages that are not related to prices.

Because of the company's narrow focus on valves for deep-level mines, exports have also been limited to these users. Most deep-level mining takes place in South Africa. In recent years RGR has delivered large orders to Konkola Deep in Zambia, and to gold mines in Ghana.

3.4 Certification

RGR has faced similar issues with regard to certification to those faced by Gunric. At a similar cost it has obtained ISO 9000 certification and is currently going through the process for PED with the help of the same international firm, TUV of Germany. It is also planning to apply for certification from the American Petroleum Institute in 2004.

While SABS used to test products and certify that they complied with standards, RGR believes that it is cheaper and more effective to go the international route of EU and USA certification.

Fire-safe tests have been done at CSIR in the past but the effective privatisation of the CSIR facilities means that RGR is looking at other options.

[6] This is fairly close to Gunric's spend, as it is measured out of turnover, while Gunric's R&D spend was given as a proportion of costs.

3.5 Strategy

As already discussed, RGR's strategy can be characterised as flexible, high-value manufacture for a quality niche. This strategic approach is reflected in its decision to buy sophisticated CNC machinery early and to train employees to use the machinery effectively. It is also reflected in the employment retention and pay levels noted above.

3.6 The role of institutions and policies

Little direct support has been received in recent years. As a member of the Capital Equipment Export Council, RGR has been contacted by the DTI. However, little of practical value has come from the interactions to date. The Small and Medium Enterprise Development Programme was explored but rejected on the grounds that it does not support incremental growth, but only discrete investments in new and expanded production capacity. The firm did receive support from the Small Business Development Corporation initially.

As with Gunric, state institutions could play a major support role by helping RGR to overcome obstacles connected with testing, certification, and obtaining finance for exports. The DTI's export credit facility at interest rates of 2% per month is viewed as expensive, and it does not effectively provide support for exports when payment terms are sometimes 60 days after delivery.

In terms of the broad policy framework, the major effect has been greater openness resulting from trade liberalisation.

3.7 Obstacles

The main obstacles to growth are cited as:

- Obtaining export finance;
- Obtaining finance for expansion; and
- The expense of certification.

Notwithstanding the success of RGR, financing the working capital has been difficult, in particular for a business where the time from order to design and delivery is long. Commercial banks have lent money for the purchase of machinery as the machinery itself constitutes collateral; but the working capital was only obtained by borrowing against the owners' private property.

Export finance is very expensive, especially as some deliveries to EU firms are on payment terms of 60 days after delivery. The importance of exporting for firms that are learning and upgrading, coupled with the risks, the high transaction costs and the high information costs strongly suggests that it would be sensible to provide ways of

supporting or subsidising exporting for small firms entering export markets. Export finance is an obvious way of doing this.

There are more fundamental obstacles, which are illustrated partly by RGR's success in overcoming them. These are the lack of supporting institutions for building capabilities, the fact that many South African firms are dependent on technologies controlled by multinational enterprises, and the weak value-chain linkages, particularly with suppliers of raw materials.

4. Comparative analysis

The two cases highlight the relatively well-known gaps in research support under the apartheid system. The apartheid government's strategy was to support fundamental research, research in upstream production capabilities and research in specific strategic industries, notably defence and petrochemicals; it largely ignored support for industrial research. An important part of a broad-based manufacturing strategy is building capabilities in value-added items and developing the engineering skills base which can be applied to many different product groupings.

Valves were, and remain, largely imported. Yet their cost competitiveness depends on materials, mainly metals, in which South Africa is internationally competitive, and mainly mid- to low-skilled labour, which the case studies here do not suggest is a constraint. The necessary manufacturing capabilities are certainly not beyond South Africa's power, as it has demonstrated very successfully in industries such as defence, chemicals and, more recently, automobiles.

A major issue is certainly the economies of scale necessary to be internationally competitive. While there is significant demand in South Africa, the local market remains small by international standards. Economic growth in the southern African region will add to local demand for valves, especially in areas like water supply.

The premise underlying the studies is that a key constituent for industrial development is the development of technological capabilities. Case studies provide insights into specific firms and their developments. By studying success stories, the cases can illustrate the importance of different factors in technological capabilities. The cases also point to weaknesses. The comparison of the cases here seeks to identify similarities and differences, and also to relate the cases to broader questions of innovation and technological capabilities.

4.1 Innovation and commercialisation

There are striking similarities between the experiences of the two firms described here. They are as follows:

The importance of the specific nature of local demand. Demand-side inducements have been the single most important impetus for the innovation and the reason for the niche competitiveness of the firms. The specific requirements of deep-level mining and the fact that the demand is not big enough for the major global manufacturers to target the market directly have provided a window of opportunity for infant valve manufacturers to grow.

International linkages and exposure. In each firm, interaction with international manufacturers was an important element. In the case of Gunric this included a close relationship with a leading Swedish manufacturer. It highlights the importance of

international relationships for access to technological know-how, alongside local advantages enabling the learning-by-doing to take place, sheltered to some extent from international competition. These local advantages are specifically those referred to above: the combination of specialised local demand and a requirement for small volumes only.

Reverse engineering was in both cases the second step (after valve repair) in developing particular products which would be leaders in their specific applications.

Research and design capabilities are of a general engineering nature. In both cases, while experience in the industry was crucial, the internal design capabilities reflected the willingness to pursue an opportunity, rather than skills of a unique nature.

Testing strategies are similar in both cases, with firms investing in the internal systems necessary for international certification and testing of products as part of ongoing innovations being done largely in-house (due to the lack of other facilities) and by customers themselves.

Products have been successfully sold to *export markets*, despite a lack of particular advantages in terms of *cost competitiveness*. This is highlighted by South Africa's comparative disadvantage, a trade deficit in valves, which it has in common with many downstream manufacturing sectors. The recent huge increases in the price of steel illustrate the fact that the steel-using firms do not benefit from low steel production costs in the form of competitively priced steel. When the rand depreciated at the end of 2001, import parity pricing led to sharp increases in local steel prices. With the recovery of the rand, prices have not come down, however.

4.2 Firm capabilities and strategies

There are similarities in the capabilities of the firms, each being centred around an owner/manager with the necessary engineering and design skills. These individuals have innovated by using their own resources and facilities. The firms' strategies have also differed in important respects, although it is not clear that one approach is necessarily superior to the other. The key features of the different strategies and their implications are described in the following paragraphs.

Gunric's avoidance of the expense of CNC equipment on the grounds that it was not viable given the scale of operations and small orders in turn led it to focus on valves with very large diameters, for which CNC is not appropriate.

RGR's approach placed it on reinforcing circular dynamic, although it made the opposite choice to that of Gunric. Early purchase of CNC machinery coupled with the fundamental problem that was also faced by Gunric, that of low economies of scale, led to radical and internally driven changes in workplace organisation, including an approach to training. Organising the workplace to ensure rapid changeovers between jobs, achieving high efficiency levels while producing small batches, means

that shop floor workers and tool setters will assume greater responsibility and initiative; it also means that there will be a need for teamwork and greater flexibility. This is strikingly similar to the flexible specialisation and multi-skilling models which are associated with Japanese production systems and small firms in Germany or the 'Third Italy' region. The strategy appears not to have been influenced by exposure to these types of organisation but instead to be an internal response to production challenges.

The changes in workplace organisation and production systems instituted by RGR represent major and fundamental elements in its production capabilities. As explained in the case study, they are integral parts of the firm's ability to undertake product development and can be viewed as process innovations in their own right. RGR was, indeed, more innovative in this case as the production systems changes were not instituted as an explicit copying of 'best practice' or 'world class' processes from elsewhere but as a result of internal innovation in response to a key challenge facing the firm.

4.3 Institutions, policy and implications for RBTC

Quite concrete findings emerge from the two cases in terms of obstacles and related institutional issues.

Certification is an important barrier to entry to international markets. It imposes a cost on firms (the cost is fixed, and hence is more onerous for small firms) and highlights weaknesses in terms of local institutional support for developing the appropriate production systems and advice on obtaining the certification itself. An important gap is the availability of facilities for testing products. This is necessary for ongoing incremental product development and is also important for marketing to local customers.

Risks and market failures in integrating with the international economy (for example, through a greater export orientation) suggest the need for targeted support measures. Exporting requires access to finance and a willingness to take risks. In the absence of direct measures, exports are therefore likely to cause firms' capabilities to lag rather than to move forward, notwithstanding the incentive schemes already in place. It is evident that interaction with international firms is also important for ongoing technological development. This is reflected in the reverse engineering undertaken by both firms. South African firms may be falling behind international developments once more. While learning from international firms is part of catch-up it does not prevent falling behind. Measures that help firms to draw on international developments on an ongoing basis are important.

The existing institutions have been drawn on by the firms, but they are generally not seen as responsive to the practical needs of firms undertaking continuous incremental product development. Nor does the shift towards an approach which makes more use of consultancy help deal with the intrinsic issues of technology (including positive externalities and informational problems) which are briefly outlined below.

These issues suggest a possible gap in the institutional framework, namely technical centres of exactly the type envisaged in the AMTS. Given the 'public good' dimension to much of what they would do, with government support, such centres could address the lack of shared facilities for testing, and the need for support for certification if it is to be readily overcome as a barrier to exporting. They could also serve as a source of information on best practice in work organisation, production systems and approaches to exporting.

It is important to be clear that there are separate and reinforcing rationales for such facilities arising from economies of scale and scope (avoiding the duplication that would result if each firm sets up its own in-house testing equipment and machinery) and from the positive externality and public-good aspects of technology and information. The latter point refers to the fact that the gains to the economy from a firm investing in improving technological capabilities are greater than the gain to the firm itself as there are spill-over effects – other firms learn and copy. There is therefore a tendency for private agents to under-invest relative to the economic gains. Public funding to support such activities (for instance, by providing information) is one solution. A private fee-for-use approach does not provide the support (or subsidy) to remedy the intrinsic problem of private under-investment.

The cases reinforce the rationale for the RBTC programme. In both firms, the role of local demand from mining and energy was crucial in developing manufacturing capabilities. These insights are important for a strategy for broader-based industrialisation, as such an approach needs to build on existing strengths. At the same time, a changed orientation in itself will stimulate new areas of capabilities – just as demand from mining stimulated a production response, so may different sources of demand going forward stimulate appropriate responses. However, the development of production capabilities is evidently dependent on the path chosen. To put it as simply as possible, what we can do in manufacturing now depends on what we aimed to do in the past. A new trajectory cannot start from a clean slate.

The cases also point to the need for consistency between industrial and technology policy, such as is envisaged when a value matrix is used. The cases examined show that technological developments at the level of the firm are part of production strategies. These strategies in turn have evolved owing to the position of the firm in terms of markets, main competitors, availability of competitively priced inputs, etc.

The industrial policy concerns from a firm perspective are effectively indistinguishable from the technology policy concerns. If there is not a 'joining up' of policy from the government side then there is a risk that the policy instruments will not be well coordinated from the point of view of the users (firms).

5. Conclusions

The development of capabilities in valve manufacture is a very good illustration of the production capabilities that have been driven by mining demand. It is the particular requirements of deep-level mining which have served as the platform for both of the firms studied here. In a sense this local demand advantage provided a level of natural protection for the firms. The development of capabilities in both cases involved reverse engineering, learning and innovation.

The decision of both firms to focus on specific niches also illustrates the importance of demand-side factors in driving technology. Neither firm has the levels of exports necessary to achieve the economies of scale which would allow them to lower production costs and move beyond quite narrowly defined product niches. There are several reasons for this, including the difficulties and risks involved in exporting, as well as relatively expensive material inputs. At a broader level this is manifested in the very large ongoing trade deficit in valves and related products.

The different strategies adopted by the two firms in response to the same core difficulty of achieving effective usage of expensive machinery are reflected in each firm's innovations. RGR has made important process innovations in its work organisation. These are additional to the particular product developments which have been stimulated by the problems faced by South African mines. Gunric chose a niche in which it could build on its ability to customise without the necessity of CNC machinery.

In both cases there are also indications of significant challenges. Internationalisation of standards means that firms are being required to invest in certification. A separate but related issue for firms involved in incremental product development is the availability of testing facilities and appropriate institutional support. These weaknesses in the local environment pose a threat to the improvement and retention of capabilities as large multinationals increasingly outsource production to low-cost destinations and provide full installation and after-sales support in markets like South Africa.[7] This is a reversal of the pattern which underpinned the development of both of the cases here, where the firms started up by providing repairs and support for foreign-manufactured valves.

The policy implications of such patterns are relatively clear. There is a strong rationale for government-supported programmes and institutions to ensure that firms' activities in upgrading technological capabilities reflect the returns to the wider economy from such activities. In the presence of narrow private incentives alone, firms will under-invest in such activities, as they will not take the positive externality effects into

[7] The FRIDGE study (2003) noted these patterns and a shift to firms becoming importers and agents for local sales by multinationals.

account. In addition, information on different production systems, better work organisation, etc., can be provided as a 'public good' through such programmes and institutions. This can be thought of as analogous to public parks, which are available to all, while each individual is also free to plan his or her own private garden. Public investment in the park provides everyone with a large, shared benefit.

Lastly, the cases illustrated that the ability to access export markets for capital equipment like valves often requires breaking into the organisation of large projects. Turnkey contractors providing total project management solutions are very influential in the sourcing of machinery and equipment. There is a need to foster local project management capabilities, which will enable greater linkages with local firms manufacturing machinery and equipment. A second level of influence is the conditions often imposed by governments on projects for which there are public funding or other support.

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