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COMPARING R&D: WHAT SOUTH AFRICA CAN LEARN FROM OTHER COUNTRIES*

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Introduction

This brief looks at how South Africa compares to other countries that are active in research and experimental development (R&D). It aims to provide useful insights to South African policymakers by showing what has worked and what has not worked in other countries.

Understanding R&D in other countries can help South Africa improve its own efforts. When countries invest in R&D, they create new areas of expertise or strengthen existing ones, leading to the development of innovative products that can boost economic growth. Prominent examples include the surge in IT technology in the United States post-WWII and South Korea's ascent as one of the "Asian tigers" where a strategic emphasis on R&D fuelled its economic expansion.

What this brief provides

This brief explores which countries are best suited for comparison with South Africa in terms of patterns of R&D funding. It offers a bird's-eye view of the socio-economic and R&D landscapes of three other countries and highlights the importance of researcher intensity in transitioning to a developed economy. Socio-economic and STI indicators provide insights into how these areas may be related. The brief raises questions about the movement of researchers between sectors and its impact on R&D intensity and economic development.

The comparative analysis done in this brief aligns with modern theories of growth, which considers Research and Development expenditures as investments aimed at generating technological knowledge. This knowledge, cultivated through the R&D process, serves as a pivotal factor in production, as proposed in endogenous growth models. As a result, the contribution of this knowledge to long-term GDP per capita growth can be examined. The effectiveness of this process depends on the robust industrial capabilities of the workforce and its capacity to adapt to evolving technologies.

* A list of definitions of key terms used in this brief appear on pages 18 and 19.

Science, Technology and Innovation Statistics South Africa

HSRC Human Sciences Research Council

R&D SURVEY
Investment ▪ Insight ▪ Impact

Herein lies the importance of a strong private sector equipped with industrial capabilities and adequate technological infrastructure, essential for translating R&D investments into economic performance. However, factors that contribute to successful R&D-driven economic growth are not straightforward and can vary widely. For instance, the South Korean government's systematic approach was pivotal in cultivating an innovative economy able to translate laboratory concepts into tangible products and industries. Also, cultural attitudes in South Korea are believed to foster innovation, as noted by Martin Hemmert (Dayton, 2020). But in a developing economy context, the paradigm in which R&D leads to innovation, which leads to productivity gains, falls short when providing empirical evidence which, at best, can be described as mixed (Fedyunina and Radosevic, 2022).

South Africa has been caught in a middle-income trap for decades, struggling to find a development pathway to higher income status. What lessons can we learn from countries with similar historical contexts that have successfully achieved this transition? Conversely, what can we learn from other countries that have not escaped the middle-income trap?

While innovation policy may help countries emerge from a middle-income trap, it cannot do so in isolation; and must be part of a larger economic and industrialisation strategy. This brief identifies successful strategies that South Africa can potentially adapt or adopt to stimulate new industries and expand into global markets.

Middle-income trap

When middle-income countries remain middle income for "too long" this is referred to as a middle-income trap. To move from this category, the economic growth rate must be high enough. This may depend on factors such as the changing structure of the economy, the role exports play, and the diversification of the economy (Felipe, et al., 2012).

The brief presents a comparative analysis of countries with similarities to South Africa, looking at their history, science technology and innovation (STI) profiles, and R&D efforts. The intention is to highlight data and indicators that are comparable using the international standard provided by the Frascati Manual (OECD, 2015).

Comparator country candidates

Due to the reliance on R&D and economic metrics, comparison is confined to a select group of nations with comparable statistical data and indicators. Table 1.1 compares South Africa's spending on R&D to that of other countries, using purchasing power parities (PPPs) to show how much R&D activity each country performs.

Table 1.1 Gross Domestic Expenditure on R&D for selected countries (millions in current price PPP$), 2018/19 to 2020/21

COUNTRY	2019	2020	2021
[1] Czechia	57 915	57 091	61 087
[1] Finland	8 126	8 643	9 569
[1] France	75 682	76 073	80 917
[1] Germany	153 293	150 789	161 232
[1] Italy	118 152	130 426	147 797
[1] Poland	17 830	19 080	21 869
[1,2] Russian Federation	47 413	50 746	-
[1] Spain	25 776	26 008	29 188
[2] China	545 461	607 601	701 115
[1] Japan	173 928	174 926	183 467
[1] South Korea	105 064	112 221	123 460
[1] Israel	6 880	6 680	7 120
Malaysia	-	15 127	-
[1] Türkiye	31 015	32 703	37 327
[1] United States	677 286	730 241	821 811
Mexico	7 493	7 361	7 562
Chile	1 684	1 646	-
Argentina	5 057	5 480	6 186
Egypt	2 646	3 389	3 653
Mauritius	470	490	457
[2] South Africa	4 881	4 627	5 177

Legend:
- Europe
- Asia and Middle East
- North, Central and South America
- Africa

Note: [1] OECD member states, [2] BRICS member/observer states.
Source: Czechia, Mexico, Egypt, Malaysia, Mauritius: The World Bank (n.d.); South Africa: South African National Survey of Research and Experimental Development: Statistical Report 2021/22; remaining countries: OECD (n.d.).

The selection of countries for comparison with South Africa includes African, Latin American, OECD and BRICS countries (Table 1.1). This includes middle- and upper-income countries, developed and developing countries, and world leaders in R&D performance. However, some countries lack comparable data based on Frascati standards e.g., India and Brazil in the BRICS grouping, while data for some countries is not available for certain years. Countries were selected based on the availability of data, but this begs the question: What are the most appropriate countries for comparison with South Africa in an evidence-led manner?

This is not easy to answer because of the many reasons why a country may or may not succeed in growing their R&D intensity to levels that are associated with economic success. Evaluating South Africa's advancement in STI against high-intensity R&D performers such as the United States of America (USA) or South Korea inevitably highlights our perceived shortcomings and underperformance. However, these nations may not serve as suitable benchmarks for various reasons. For example, while the USA is a significant trading partner for South Africa, the socio-economic challenges addressed through R&D

promotion in the USA differ significantly from those facing South Africa. Additionally, disparities in knowledge capabilities and economic standing exist, with South Africa largely reliant on imports, including high-tech goods. Similar considerations arise with China, and concerns regarding comparability extend to several Scandinavian countries. Are there more suitable comparator nations that offer insights into our emerging strengths and potential for upward progression? This brief attempts to shed light on this question by contrasting countries with similar histories to South Africa – that have experienced national challenges in the recent past – but with different economic outcomes. We have also selected science and technology indicators that are indicative of success in modernisation strategies and may be useful for benchmarking South Africa's national innovation system.

Histories and socio-economic factors in brief with a focus on STI policies

Argentina, Malaysia, and Czechia share several similarities with South Africa including the diversity of their economies, dependence on natural resources, and intended transitions toward more knowledge-based modes of production and products. Moreover, they have experienced significant socio-political events, including turbulent political changes.

Argentina

Until the mid-twentieth century, Argentina followed a development path similar to more developed countries. Its population density was relatively low and abundant natural resources enabled export-driven growth. However, since the 1930's Argentina experienced cycles of dictatorship and democracy, undermining institutional development and growth-enhancing economic policies, condemning Argentina to decades of stagnant productivity and poor economic growth (Spruk, 2019). Poverty rates are high and informal economic practices widespread in urban areas. In addition, education has been underfinanced and has lacked coherence for many years (Bertelsman Stiftung, 2024).

STI policies

Over the past two decades, Argentina has implemented various policies to promote STI with a focus on economic development. The foundation of Argentina's STI policies was established in 2001 with a framework to promote scientific and technological activities by integrating STI policies with national development plans, to enhance the country's technological competitiveness (Flanzbaum and Balbo, n.d.). Subsequently, the National Plan for Science, Technology, and Innovation (PNCTI) was launched in 2004, to boost Argentina's scientific capabilities and innovation systems. This plan emphasised the need for increased public and private investment in R&D, improvement of research infrastructure, and promotion of international cooperation (UNESCO, n.d.).

"In 2007, Argentina's System of Science, Technology and Innovation (STI) underwent a re-structuring process that resulted in the creation of the Ministry of Science, Technology and Productive Innovation (Ministerio de Ciencia, Tecnología e Innovación Productiva - MINCYT)" (UNESCO, n.d). This was integral in coordinating national STI policies, managing funding programmes, and strengthening the connection between scientific research and productive sectors.

In 2010, the Argentine Technology Fund (FONTAR) was created to provide financial support for technological innovation projects, particularly for small and medium-sized enterprises (SMEs), thereby encouraging private sector investment in R&D (UNESCO, n.d.). The same year, the Scientific and Technological Research for Strategic Areas (PICT) initiative was launched to support research in critical areas such as biotechnology and nanotechnology, aligning scientific research with national economic goals (UNESCO, n.d.).

STI Indicator trends

Argentina's expenditure on R&D, while lower than most developed countries, is greater than many other South American countries (except Brazil) and has increased resource allocation to R&D in the past several years. But, compared to its regional peers, Argentina spends less on private R&D. Labour productivity is also low (Arza et al., 2020). Argentina closely resembles South Africa in terms of the volume of their R&D activities, which are approximately equivalent (Table 1.1). Additionally, both countries boast workforces of around 20-25 million people. Of the three countries chosen for comparison, Argentina and South Africa exhibit the highest degree of similarity at a coarse-grained level.

Middle-income trap

Pessino et al. (2012) provide insights into Argentina's challenges with the middle-income trap, discussing how economic reforms aimed to address structural issues and promote sustainable growth amidst persistent income disparities and economic volatility. Argentina has remained trapped in a cycle of economic stagnation, characterised by macroeconomic instability and short-term populist policies, which hinder long-term growth and competitiveness (Levy Yeyati, 2021). Argentina's middle-income trap is further exacerbated by weak institutions, poor education and an underdeveloped financial sector, making it difficult to transition to a higher income level (International Growth Centre, 2017).

Malaysia

Malaysia, like South Africa, emerged from resource-based economic growth post-1900s as a former British colony. Post-World War II independence marked a period of significant economic change, with increased investment in infrastructure and human capital. Economic diversification since 1970 reduced poverty through labour-intensive manufacturing and urban service provision. Despite progress, Malaysia's growth was constrained by dependence on a few export sectors, limiting innovation-driven growth. After 2000, economic growth slowed due to export manufacturing competition from China. Malaysia has also been subject to declining labour productivity over the last decade.

STI policies

In the past decade, Malaysia initiated ambitious reforms through the Government Transformation Program (GTP) and Economic Transformation Program (ETP). Launched in 2010, the GTP aimed to enhance governance, targeting crime, corruption, educational improvement, poverty alleviation, rural infrastructure, and urban transport (Government of Malaysia, 2010). The Economic Transformation Program focused on restructuring Malaysia's economy across 12 areas to increase gross national income (GNI) per capita and create millions of jobs through public-private partnerships (Economic Planning Unit, 2010).

By the 2010s, Malaysia reported significant gains: improved crime rates, public transport, rural infrastructure, increased private sector investment, job creation, and global competitiveness (Malaysia Productivity Corporation, 2020). Challenges persisted, including governance issues and income disparities, prompting ongoing refinement and consolidation into the 2020s. The GTP focused on sustaining gains and enhancing public service delivery, while the ETP underwent evaluations to ensure economic resilience and equitable development (Government of Malaysia, 2021).

STI indicator trends

Over the past decade, Malaysia has shown a steady increase in research and development (R&D) expenditure, reflecting a commitment to enhancing its innovation capabilities. The Malaysian government played a pivotal role in funding R&D through agencies and initiatives aimed at fostering scientific research and technological advancements. Concurrently, there has been a notable rise in private sector investment in R&D, encouraged by government incentives and partnerships with academic and research institutions. Focus areas for R&D have included biotechnology, ICT, manufacturing technologies, and renewable energy, aligning with national strategic objectives (Malaysian Innovation Agency, n.d.). Moreover, Malaysia has increasingly engaged in international collaborations to leverage global expertise and resources (Tey and Idris, 2012), further enhancing its R&D capabilities.

Middle-income trap

To escape the "middle-income trap", Malaysia needs to increase funding for education, especially in science and mathematics, and innovation systems, including more funding for R&D (Sachs, n.d.).

Czechia

The 1990s represented a notable era of political transformation for Czechia, as the country shifted from its previous economic frameworks as part of the USSR to embrace greater openness to global corporations. This transition resulted in significant societal disruption. The peaceful split, often referred to as the "Velvet Divorce," led to the creation of two independent countries: the Czech Republic and Slovakia, effective January 1, 1993. This transition followed the end of Communist rule and the Velvet Revolution of 1989, which marked the end of the Communist regime in Czechoslovakia and ushered in a period of democratic reforms and economic transition (Kučera, 1993; Open Society Foundations, n.d.). This period was marked by economic restructuring, privatization, and the establishment of new political and social institutions. The challenges included high unemployment rates, inflation, and a sharp decline in industrial production, which affected the livelihoods of many citizens.

Historically, Czechia has had a well-educated, highly skilled labour force, with educational attainment among the highest in Europe (Novokmet, 2018). It has a long tradition of manufacturing across various industries. Initially, the economy was textile-based but later shifted to heavy industry and engineering, along with the development of commercial agriculture (Novokmet, 2018). By 1996, Czechia had established success in mining and manufacturing sectors such as steel, trucks, small aircraft, arms, electricity, cement, coal, oil refining, and shoes. Since then, it has grown its high-technology exports to be above the average for European Union countries in 2022 (World Bank, n.d.).

STI policies

Czechia has strategically directed its policy attention towards advancing STI to drive economic growth and competitiveness. The country has significantly increased its investment in R&D through public funding initiatives and incentives for private sector participation. This focus aims to stimulate innovation across various sectors and foster technological advancement. The development of innovation ecosystems has been a key priority, involving the establishment of technology parks, innovation hubs, and incubators. These initiatives support startups, facilitate collaboration between academia and industry, and accelerate the commercialisation of research outcomes. Investments in digital infrastructure and cybersecurity measures have enhanced the country's digital capabilities ensuring a secure environment for businesses and individuals. Additionally, education and skills development in STEM fields have received attention, with reforms aligning education curricula with industry needs. This strategic focus equips the workforce with necessary skills to thrive in the digital economy and support technological advancements. Sector-specific policies target key industries such as healthcare, renewable energy, manufacturing, and information technology, aiming to enhance their competitiveness through innovation-driven strategies and technological advancements (Goglio, 2006).

STI indicator trends

Czechia is classified as a moderate innovator compared to other European countries. It underperforms in intellectual assets, including patent, design, and trademark applications, venture capital investments, and opportunity-driven entrepreneurship relative to the rest of the EU. Innovation activities are highly concentrated, with a small percentage of R&D-performing enterprises accounting for the majority of expenditures. Czechia is also highly dependent on international funding for R&D.

Middle-income trap

The nation has exhausted previous growth factors and lost competitive advantages, falling into a "middle-income trap," characterized by long-term economic stagnation, slower wage growth, and declining living standards. Stronger support for higher value-added production could reverse this trend (Radio Prague International, 2023; Prague Forum, 2023).

Comparing key R&D indicators

This section analyses economic and STI indicators for Argentina, Malaysia and Czechia and identifies lessons from their STI performance and its correlation with economic development, in comparison to South Africa. Czechia shows progress towards a knowledge-based economy with significant exports of high-technology goods, contrasting with Argentina and Malaysia, which mirror South Africa's incomplete transformation in STI development. By analysing data for each country, we seek insights to guide South African policymakers and provoke questions to achieve STI-led growth.

GDP per capita is commonly used as a measure of socio-economic wellbeing. While all four countries had similar GDP per capita in the 1990s (Figure 1.1), Czechia's grew more rapidly than Argentina, Malaysia and South Africa from the early 2000s, when it joined the EU. By 2022, Czechia's GDP per

capita was more than double that of Argentina, followed closely by Malaysia. South Africa's GDP per capita was less than half that of Argentina in 2022.

Czechia has historically had a higher GERD to GDP ratio than Argentina, Malaysia and South Africa (Figure 1.2), reaching 1.5% in 2011, continuing to increase to just under 2% in 2020. Malaysia's GERD to GDP ratio was the lowest of the four countries in the 1990s, but increased steadily to 1.5% in 2016, but declined to just below 1% by 2020. Argentina and South Africa have had significantly lower ratios of GERD to GDP than Czechia and Malaysia since the late 2000s.

In 2001, business expenditure on R&D as a percentage of GERD was above 50% in Malaysia, Czechia, and South Africa, whereas Argentina was below 50%, where it remained for the next 20 years (Figure 1.3). South Africa and Malaysia have had similar growth trends. Both started above 50% but dropped to below 50% by 2020. An interesting feature exhibited by Malaysia is the 2016 value of BERD/GERD, which was above 50%. Czechia's BERD to GERD ratio was consistently above 50%, with a value of 61% by 2020. A value above 50% is indicative of developed economies, and an indicator of economic wellbeing, such as GDP per capita.

The high R&D intensity (Figure 1.1) and high technology exports (Figure 1.5) that Czechia exhibits go hand-in-hand with a higher percentage of researchers per million than the other three countries (Figure 1.4). While the numbers of researchers grew slowly but steadily in Argentina and South Africa between the late 1990s and 2020, Malaysia experienced a rapid increase in the number of researchers from 2008 reaching a peak of 2,396 per million population in 2016 that coincided with the single value of BERD/GERD ratio of over 50%, but this was not sustained, and the number of researchers declined from that point.

High-tech exports

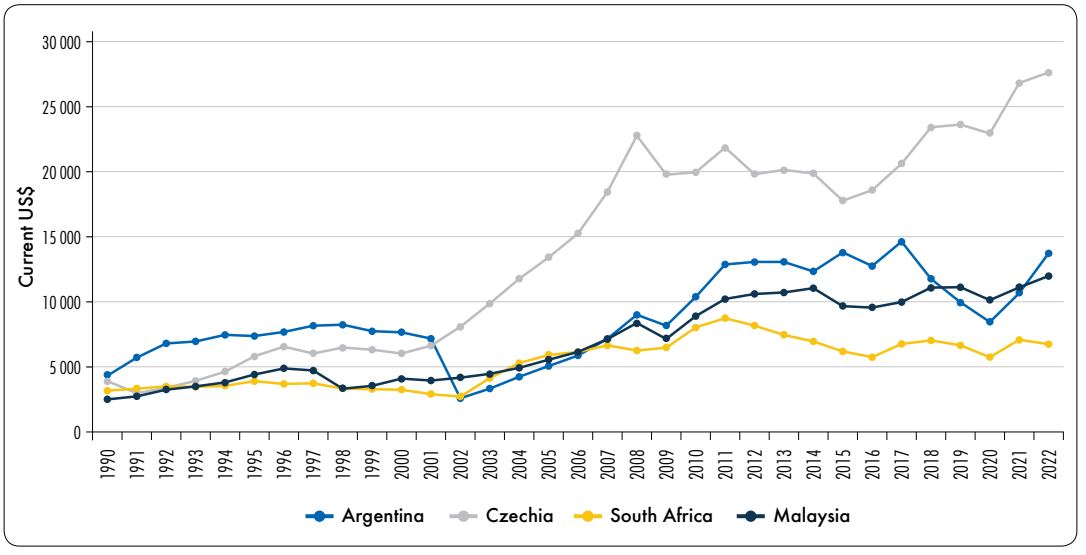
High-technology exports are products with high R&D intensity, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

Source: World Bank (n.d.)

South Africa has had the least researchers per million of the four countries since the late 2000's—approximately 500 or fewer. It is interesting to note that, while Argentina has almost double the number of researchers per million than South Africa over the 20-year period, it has only recently exhibited higher R&D intensity. There appears to be a growing trend in BERD/GERD for Argentina starting in 2014.

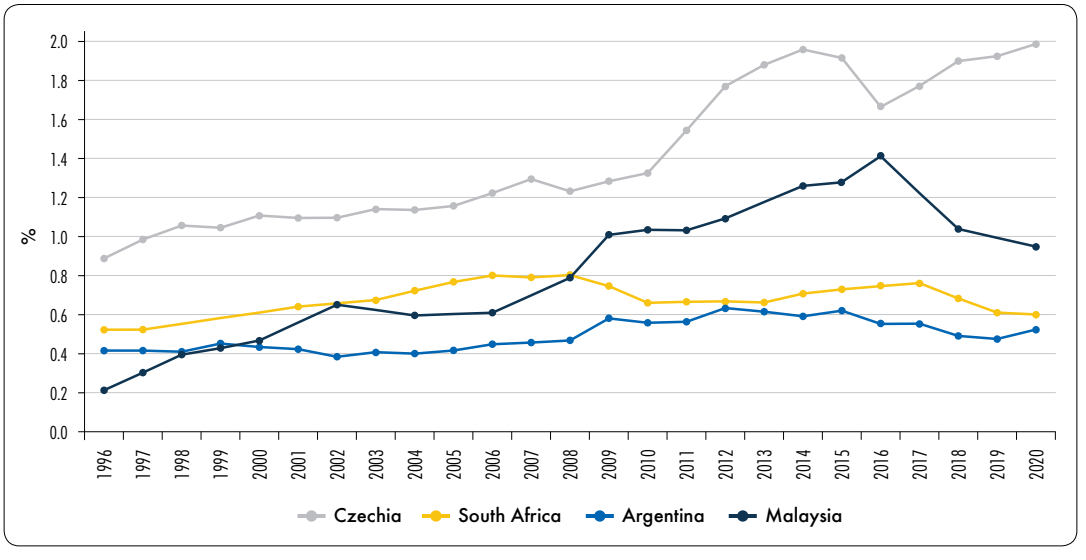
Although empirical analyses on these variables have not been conducted, preliminary data suggests a correlation between robust R&D capabilities and strong economic performance among South Africa's comparator countries.

Figure 1.1 GDP per capita (current US$) in South Africa, Malaysia, Argentina and Czechia, 1990 to 2022



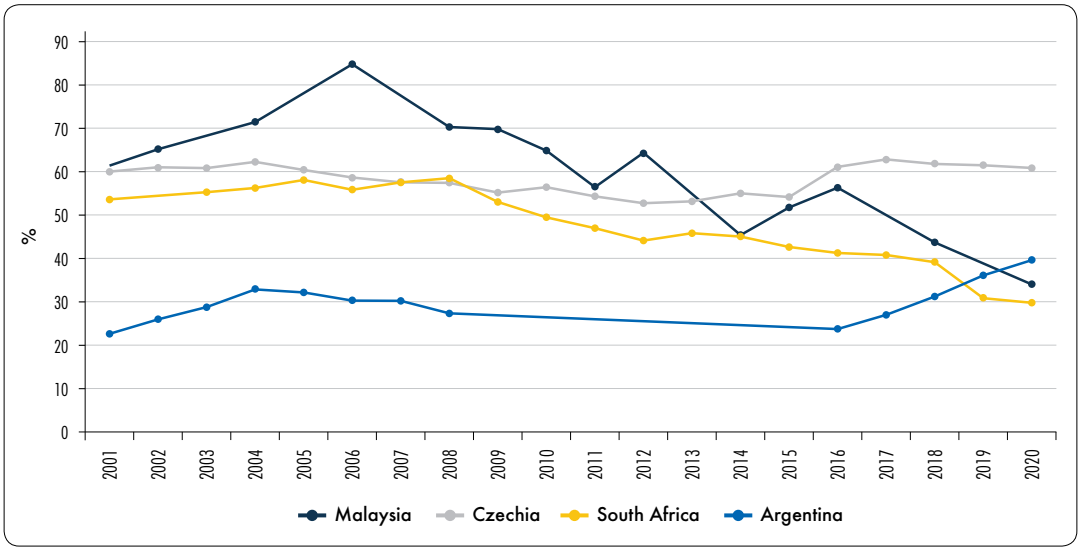
Source: OECD (n.d.); Stats SA (2023).

Figure 1.2 GERD as a percentage of GDP in Argentina, Czechia, Malaysia and South Africa, 1996 to 2020



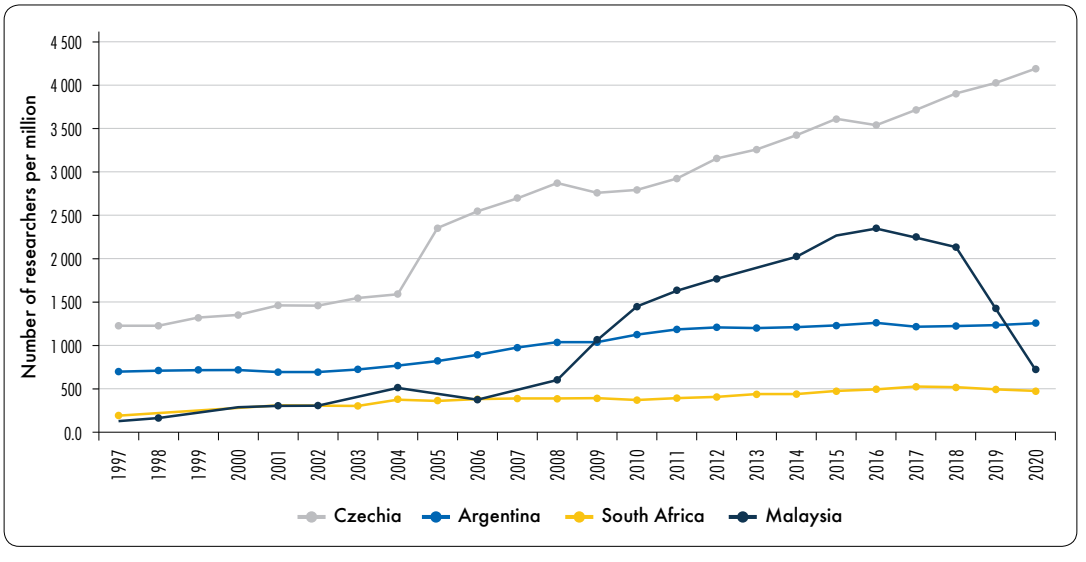
Source: World Development Indicators (n.d.); UNESCO Institute for Statistics (n.d.).

Figure 1.3 Business expenditure on R&D as a percentage of GERD in Argentina, Czechia, Malaysia and South Africa, 2001 to 2020



Source: OECD (n.d.); Knowledge Resource for Science and Technology Excellence, Malaysia (n.d.).

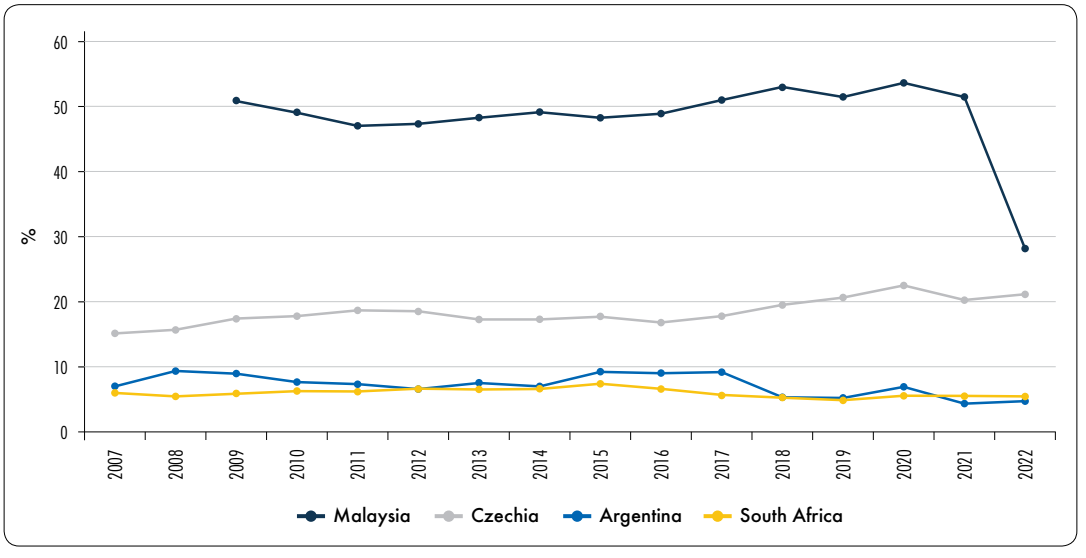
Figure 1.4 Researchers per million population in Argentina, Czechia, Malaysia and South Africa, 1997 to 2020



Source: World Development Indicators (n.d.); UNESCO Institute for Statistics (n.d.).

The data trend regarding high-technology exports as a proportion of manufacturing exports offers intriguing insights. Of the four countries, Malaysia stands out with the highest value in this metric, which may seem unexpected given its relatively low research and development (R&D) intensity. This anomaly becomes clearer when considering that a significant portion of Malaysia's high-tech exports is attributed to a single dominant player. The Electronics and Telecommunications (E&E) product group, "continued to be the top contributor to Malaysia's high-tech exports in 2022, amounting to USD96.38 billion or 77.08 per cent of export value" (MIGHT, 2023). High exports and low R&D might equate to dominance of assembling activity with a minimum of global R&D conducted in Malaysia (Letaba and Pretorius, 2021). Compared with South Korea, Malaysia gained comparative advantage in electronics only, whereas Korea had a comparative advantage in a significant number of sophisticated products and was well connected, demonstrating the importance of diversity in escaping the middle-income trap (Felipe et al., 2012).

Figure 1.5 High-tech exports as a percentage of manufactured exports, 2007 to 2020



Source: The World Bank (n.d.).

Moreover, the notable presence of high-tech exports in developing economies like Malaysia may be due to a statistical artefact. It's plausible that the majority of high-tech exports are linked to the international fragmentation of production value chains in the electronics sector (Srholec, 2007). That is to say, companies and countries specialize in particular segments of the production process where they have comparative advantages. For example, a country with advanced technology capabilities may focus on designing components, while another with lower labour costs may tend to handle assembly. On the one hand, the implication is that Czechia may be on the less valued end of such global value chains; that is the assembly end. On the other hand, Czechia demonstrates substantial proportions of high-tech exports in manufacturing alongside high researcher per population intensity values and R&D intensity

values surpassing 1% of GDP. This suggests that Czechia's export performance manifests in export strength of *diverse* products, notwithstanding that the export dominance of its electronics sector may indeed be a statistical artefact due to international trade contributions to technology intensity in that sector.

Comparative Analysis of R&D Performance and Economic Indicators in Czechia, South Africa, Argentina, and Malaysia

Our intention is to open suggestions for further inquiry, rather than make definitive pronouncements.

Although all four countries had comparable GDP per capita figures in the 1990s and early 2000s, Czechia significantly outperformed the others since then. South Africa's GDP per capita growth appears to be like that of Argentina and Malaysia, although Argentina has shown a slight hint of an upward trend in the most recent two years (2021 and 2022) displayed. Moreover, the Business Expenditure on Research and Development (BERD) to Gross Expenditure on Research and Development (GERD) ratio for Argentina has been consistently increasing recently from 2017 to 2020.

Of the four countries, Czechia has consistently maintained the highest R&D intensity. Historically, countries with a GERD to GDP ratio of 1.5% or more have demonstrated greater competitiveness, leading to the production of high-value exports. Czechia was the only country among the four to reach this critical threshold (in 2011) and has continued to surpass it since. Additionally, a BERD to GERD ratio exceeding 50% typically indicates developed economies. By 2020, Czechia was the only country of the four to achieve this benchmark.

Table 1.2 Summary trends in STI indicators for South Africa, Argentina, Malaysia and Czechia between 2016 and 2020

COUNTRY	BERD/GERD		RESEARCHERS PER MILLION POPULATION		GERD/GDP	
	2016 BERD/GERD < 50%	2020	2016	2020	GERD/GDP < 1%	2020
South Africa	41% ↘	30%	490 →	490	0.75% ↘	0.60%
Argentina	24% ↗	40%	1 260 →	1 230	0.56% ↘	0.53%
	2016 BERD/GERD > 50%	2020	2016	2019	GERD/GDP > 1%	2020
Malaysia	57% ↘	34%	2 350 ↘	1 430	1.42% ↘	0.95%
Czechia	61 % →	61%	3 620 ↗	4 030	1.67% ↗	1.99%

Source: Authors' own calculations from data in the body. Numbers rounded to the nearest ten.

The inferences made in the ensuing analysis acknowledge that we have considered only a small sample. The four countries selected in this investigation all started the 1990s with a BERD/GERD value below 50%. The recent STI performance of the four countries can be summarised using several key indicators, as in Table 1.2. Notably among the four, when researcher intensity declined or remained stagnant, R&D intensity followed suit, and the same applied conversely. This behaviour persisted regardless of fluctuations

in BERD/GERD. Furthermore, the number of researchers is notably higher in Czechia compared to the other countries and has been steadily increasing. In contrast, the numbers have seen sluggish growth in Argentina and South Africa and experienced a sharp decline in Malaysia in recent years.

Argentina and South Africa exhibit similar performance trends. Firstly, both countries have business expenditure on research and development (BERD) to gross expenditure on research and development (GERD) ratios below 50%. Secondly, their R&D intensities are notably below 1%. While Argentina's researcher intensity appears to be double that of South Africa, South Africa's unemployment rate is approximately double that of Argentina, suggesting similar researcher intensities when viewed in terms of the labour force instead of population size. These indicators reflect typical STI behaviours or outcomes for these countries. Interestingly, R&D intensity declined regardless of whether the business sector's contribution to R&D increased during the interval considered.

In contrast, Malaysia and Czechia stand out with recent BERD/GERD values exceeding 50%. Both countries boast significantly higher researcher intensities compared to South Africa, ranging from five to eight times larger. Most evident from the trend data between 2014 and 2020 is that Malaysia experienced growth and decline in BERD/GERD in tandem with increasing and decreasing researcher intensity, respectively. In contrast, Czechia distinguished itself by maintaining consistently higher levels of both researcher intensity and the BERD/GERD ratio compared to other countries. Associated with these indicators is a relatively higher level of high-tech export capacity (Figure 1.5). Malaysia's R&D intensity recently declined from 1.42% to 0.95% (Table 1.2) as its BERD/GERD ratio dropped below 50% (Figure 1.3), indicating that an R&D intensity of around 1% might not sufficiently be associated with substantial business sector-led R&D performance, whereas 1.5% appears to be a more robust indicator of such behaviour. Czechia's R&D intensity values fall between 1.5% and 2%, underscoring the importance of a robust business sector driving R&D performance. Note that, while Czechia has a GDP per capita level that's consistently higher than the other three countries (Figure 1.1), Malaysia is consistently at a level that compares with South Africa and Argentina, even though Malaysia has a high level of high-tech exports.

Taking all of this into account, it appears that growing researcher intensity is perhaps a necessary but not sufficient condition to transition from a developing to a developed economy. It is perhaps a result we expected, even though this may not be evident from the overall R&D intensity at first. Witness Argentina, which has a consistently low R&D intensity, but high researcher intensity (compared to South Africa) over many years (Figures 1.2 and 1.4). Even though its R&D intensity is low (relatively), in recent years its BERD/GERD ratio has been steadily climbing (Figure 1.3). Could it be that the overall researcher capability is not as important in this respect, but rather the movement of researchers between business sector and other sectors that matters more?

The data that we have examined do not make it clear if there is any one sector where researcher capabilities drive such a transition. However, the dominance of the business sector in R&D activity is naturally associated with a greater proportion of experimental development, which is expected to lead to novel products being generated in that sector, which in turn shows up in a greater number of high-tech exports. This is borne out for the four countries that we have selected.

Conclusion

In South Korea, government initiatives encouraged collaboration between industry and academia, positioning R&D as a catalyst for economic growth and societal change. Notably, Czechia's success can be attributed to strategies implemented since the 1990s. Like South Korea, Czechia leveraged its textile manufacturing industry with a skilled workforce. In contrast, Malaysia and South Africa, despite having strong textile manufacturing bases in the 1990s, have struggled to localise technological strength, remaining primarily in the assembly segment of global value chains for high-tech products. That is not to say that a history of textile manufacturing determines R&D driven growth performance. Rather the point is to illustrate the importance of leveraging the productive abilities of the economy, rooted in capabilities, as espoused in modern theories of economic growth as being driven by factors within the economy itself, such as innovation and human capital, rather than external forces.

Malaysia's economy continued to rely on a limited range of export sectors specifically electronics, potentially hindering self-sustaining innovation driven by science and technology. South Africa faced similar challenges immediately following the advent of democracy, marked by sluggish GDP growth, limited industrial competitiveness, and inadequate infrastructure funding, partially due to development under high tariff barriers and extensive apartheid-era subsidies. Adopting a neo-liberal trade policy akin to the Washington Consensus (Gantz, 2021), South Africa achieved export strength, notably in automotive manufacturing, but primarily through component assembly rather than indigenous technological advancement, similar to Thailand and Malaysia.

For the small set of comparator countries we have considered, we have confirmed that a high economic wellbeing (indicated simply by GDP per capita) is associated with a value above 50% for BERD/GERD. Furthermore, this is also associated with high values of R&D capability (proxied by researchers per million of the population). When we take the trend data into consideration, it appears that the growth in R&D intensity is associated with increasing the intensity of researchers.

Are South Africa's workforce and infrastructure sufficiently equipped to accommodate these changes if local production or strategic importation of technological knowledge proves successful? Is SA's economic strategy adequate to harmonise the various production factors, including the technological knowledge developed through R&D investments, in order to drive structural transformation and achieve a higher productivity capable of the economy from the middle-income trap? These are pertinent questions raised through such comparative analyses, which aid in identifying issues that South Africa, as well as other countries in the past, have encountered, and potential solutions to address them.

The **South African National Survey of Research and Experimental Development data** for the period 2001/02 to 2021/22 that is cited in this report was created by the Centre for Science, Technology and Innovation Indicators at the Human Sciences Research Council. Data is available for download and use by readers in different formats on the HSRC's website (hsrc.ac.za). For specialised data requests from CeSTII, visit https://data-request.hsrc.ac.za/

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DEFINITION OF TERMS

Applied research is original investigation undertaken to acquire new knowledge. It is directed primarily towards a specific practical aim or objective.

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

BERD refers to business expenditure on research and experimental development.

Biotechnology is an application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.

Capital expenditure is the annual gross expenditure on fixed assets used repeatedly or continuously in the performance of R&D programmes for more than one year. Such expenditure is reported in full in the period in which it took place and is not registered as an element of depreciation. Capital expenditure includes expenditure on land, buildings, instruments and equipment.

Constant 2015 (Real) Rands is the value of goods and services of a given year using the prices of a determined base reference year, which is 2015 in this case. These values were obtained by deflating with the GDP deflator using data published in the Statistics South Africa GDP survey P0441, Fourth quarter 2021 (Stats SA 2021).

Current expenditure is composed of labour costs of R&D personnel and other current costs used in R&D. Services and items (including equipment) used and consumed within one year are current expenditures. Annual fees or rents for the use of fixed assets is included in current expenditures.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems or services, or to improving substantially those already produced or installed.

Full-time equivalent (FTE) refers to the number of hours (person-years of effort) spent on R&D activities.

FTE per 1 000 in total employment is the number of professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as in the management of these projects during a given year expressed as a proportion of 1 000 employed people. It is calculated by number of researchers during a given year divided by the total employed people and multiplied by 1 000.

Gross domestic product (GDP) is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports.

Gross domestic expenditure on research and experimental development (GERD) covers all expenditures for R&D performed on national territory in a given year. It thus includes domestically performed R&D that is financed from abroad but excludes R&D funds paid abroad, notably to international agencies.

Headcount refers to the actual number of people directly involved in or supporting R&D (i.e. the total number of R&D personnel).

New materials refer to the technology and R&D activities of high-technology companies particularly in the aerospace, construction, electronic, biomedical, renewable energy, environmental remediation, food and packaging, manufacturing and motorcar industries. New materials include multi-functional materials, advanced materials, nanomaterials, nanocomposites and nanotechnology.

Other support staff includes skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

Research and experimental development (R&D) comprises creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge.

Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned.

Research field (RF) refers to a branch of science, either natural or social and humanities sciences.

R&D intensity refers to gross expenditure on R&D as a percentage of GDP.

R&D personnel include all persons (irrespective of nationality) employed directly on R&D activities, as well as those providing direct services, such as R&D managers, administrators, technicians and clerical staff. These include emeritus professors, honorary fellows and research fellows.[1]

R&D-performing sectors comprise the government, higher education, business and not-for-profit institutional sectors.

Standard Industrial Classification (SIC) are codes used by Statistics South Africa for all economic activities of industries.

State-owned enterprises (SOEs) are public corporations owned by government units mainly engaged in market production and sale of the kind of goods and services often produced by private enterprises.

Technicians and equivalent staff are persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences, or social sciences, humanities and the arts.

Total employment is the total employment in the economy. This statistic is obtained from the Statistics South Africa Labour Force Survey series P0211 (Stats SA 2022), where employed persons are those aged 15-64 years who, during the reference week, did any work for at least one hour, or had a job or business but were not at work (temporarily absent).

Year-on-year changes are calculated as follows: (current year's figure - previous year's figure) / previous year's figure × 100%.

[1] Prior to 2016/17, emeritus professors, honorary fellows and research fellows were not required to be explicitly included in the estimates of R&D personnel.

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DISSEMINATION

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- https://hsrc.ac.za/about-cestii/measuring-rd-activity-in-south-africa/

Data extractions in response to users' special data requests are generally provided free of charge, unless substantial analytical work is required to meet any such request. Such data extractions are done in accordance with the approved data access protocol, and requests should be sent to CeSTII via the Data Request Management System.

Companion publications

- Centre for Science, Technology and Innovation Indicators (CeSTII). (2024). *South African National Survey of Research and Experimental Development: Statistical Report 2021/22.* Pretoria: Human Sciences Research Council (HSRC).
- Centre for Science, Technology and Innovation Indicators (CeSTII). (2024). *Main Trends in South African R&D 2021/22.* Pretoria: Human Sciences Research Council (HSRC).

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