Overview of Assumptions for Macro-economic impacts Chapter of the Beyond the Gap South Africa 2022 report

Jules Schers, 7 January 2023

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# Internal Briefing on modelling Assumptions

This briefing consists of the essential assumptions to inform readers of the Macro-economic impacts chapter about key assumptions.

🡪 Based on the Annexes below

Still to be Added: DETAILS FROM EXCEL (Funding Parameters, 2simulation…SDGs)

Still to be DOUBLE-CHECKED/Number-checked for THE SUMMARY/BRIEFING

AND EITHER, KEEP INTERESTING STUFF FROM BELOW FOR AN ANNEX?, or DELETE ANNEXES COMPLETELY!

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## Assumptions for Macro chapter

Our approach assumes that infrastructure has a positive externality. Infrastructure investment creates demand for investment goods and contributes to the efficiency the economy. Productivity is a transmission channel for positive externalities of infrastructure investment. In our approach, these productivity impacts are defined for the national economy based on findings in economic literature.

For **transport** we distinguish impacts from expanded accessibility and from the improvement of road safety. In the former case productivity impacts are estimated for **expansion and rehabilitation** of urban roads, of rural roads, and from expansion of public transport services (BRT and rail networks). These are based on estimated Total Factor Productivity impacts of relative road and rail infrastructure expansion in South Africa by Fedderke and Bogetic (2009).[[1]](#footnote-1) For rural roads the rural access index is used to normalize the additional road network leading to people getting all-weather road access to the major urban centres of South Africa.

Concerning **road safety** the central assumption is that bringing 75% of roads to 3-star rating achieves half of the SDG 3.6 objective for road safety - a reduction in accident-related mortality.[[2]](#footnote-2) The resulting improved adult survival rates are translated to productivity impacts based on Bloom et al (2019), similar to the approach for disease-reducing productivity impacts identified for Water & Sanitation.[[3]](#footnote-3)

For **water and sanitation** two distinct mechanisms for productivity impacts are identified as well. Firstly, **improved access** to safely managed water supply, sanitation, and hand washing hygiene allows to reduce diarrhoea-related disease and mortality. Prüss-Ustün et al. (2014) estimate the total of preventable Water, Sanitation & Hygiene deaths in South Africa. Their estimate translates to 3.8 thousand of these adult diarrhoea-related deaths among people of working age (15-64) in 2020 and a diarrhoea related death rate of 0.096 deaths per thousand persons, and to an increase of 0.57% in adult survival ratio.[[4]](#footnote-4) The increase in adult survival rate leads to a 0.31% higher TFP by 2030 for full achievement of water & sanitation SDG’s in South Africa, based on insights from Bloom et al. (2019), while Universal Basic Service levels would lead to a TFP improvement of 0.22% TFP improvement by 2030.[[5]](#footnote-5)

Secondly, for **reduced demand on freshwater resources & increased water resilience** the key assumption is that reduction of water consumption per capita will allow to avoid structural water shortages. Water shortages would primarily hit agricultural and other productive sectors to spare water supply to citizens. The reference or status quo scenario sees South Africa’s water consumption grow and is expected to lead to an average water deficit of 17%.[[6]](#footnote-6) Based on Ntombele et al (2017)[[7]](#footnote-7). The average structural water shortage is estimated for each scenario based on comparing per capita water consumption levels and this average shortage is equated to a shock pro rata to the economic shock of the 2015/2016 drought.[[8]](#footnote-8) In this way one arrives at a TFP impact by 2030 of: +0.89% for 1BW and 2BW scenarios, and of +0.49% for 2BF vs the No investment Reference.

Concerning **education**, abundant theoretical models about education-driven productivity-wage gaps are not matched by abundance of empirical literature, and evidence for whether education raises productivity and wages is sparse (Kampelman et al, 2018). Nevertheless, Bhorat and Kimani (2017) show that in South Africa educational spending and lower teacher-student-ratios (STRs) lead to higher educational attainment levels. For STRs this would mostly be the case in primary education. Furthermore, a minority of South African pupils enjoys high quality education, while the majority cannot (Spaull, 2013). The conditions therefore seem right for investment in quality of education to contribute not only to better educational levels, but also to an improved economy. However, calibration of such an economic impact remains difficult.

The following approach is applied to estimate productivity gains due to **improvement of basic education**: The Full access and Efficiency scenarios lead to higher enrolment and quality and therefore higher graduation levels for secondary school types relative to the Baseline scenario. A first step quantifies the impact on educational attainment by level of education. [[9]](#footnote-9) Step 2 translates this to a change in school leavers from primary to matric-level educated.[[10]](#footnote-10) Step 3 translates the additional educational attainment in the employed work force to a TFP impact, based on the wage ratio between average secondary educated and primary (or less) educated workers.[[11]](#footnote-11) This leads to an additional TFP growth of additional educational enrolment and quality of 0.22% for the period 2022-2030. The difference relative size of additional capital investment between Baseline and the No investment reference scenario would imply that the TFP impact for the baseline vs the reference scenario is 0.3%, and therefore the TFP impact of Full access and Efficiency scenarios vs Reference are 0.53%.

For **TVET education** the same approach applies: This time the enrolment numbers lead to a shift from learners entering the labour market at the lower-secondary level to the matric/upper-secondary level.[[12]](#footnote-12) Again, based on relative capital expenditure for expansion the impact of the Baseline scenario relative to the Reference scenario is estimated. The result of the estimation is that additional TFP growth for the total period up to 2030 is 0.37% for the NDP scenario, 0.08% for the Baseline scenario, and 0.75% for the PSET scenario.

### Abstract References

Bhorat, H, Kimani, M 2017, The role of post-school education and training institutions in predicting labour market outcomes, LMIP report, no. 23, Labour Market Intelligence Partnership, Human Sciences Research Council, Pretoria, viewed 12 Jan 2023, <http://www.lmip.org.za/document/role-post-school-education-and-training-institutions-predicting-labour-market-outcomes>.

Bloom, D.E., Canning, D., Kotschy, R., Prettner, K. & Schünemann, J.J. (2019), “Health and Economic Growth: Reconciling the Micro and Macro Evidence”, NBER wp 26003, June 2019, DOI 10.3386/w26003, accessed online (august 2022) [https://www.nber.org/papers/w26003](https://www.nber.org/papers/w26003" \t "_blank)

DWS, 2018. National Water and Sanitation Master Plan (NWSMP). Department of Water and Sanitation (DWS), Pretoria.

Fedderke, J.W., and Bogetić, Ž. 2009. Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures, World Development, 10.1016/j.worlddev.2009.01.008, 37, 9, (1522-1539).

Kampelman, S., Rycx, F., Saks, Y., and Tojerow, I., 2018. Does education raise productivity and wages equally? The moderating role of age and gender. IZA Journal of Labor Economics, vol.7:1, DOI 10.1186/s40172-017-0061-4

Ntombele S., Nyhodo, B., Ngqangweni, S., Phahlane, H. and Lubinga, M. 2017. Economy-wide effects of drought on South African Agriculture: A computable general equilibrium (CGE) analysis. Journal of Development and Agricultural Economics. Vol. 9(3), pp. 46-56, March, 2017. DOI: 10.5897/JDAE2016.0769

Prüss-Ustün A, Bartram J, et al. 2014. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. Trop Med Int Health. 2014 Aug;19(8):894-905. doi: 10.1111/tmi.12329. Epub 2014 Apr 30. PMID: 24779548; PMCID: PMC4255749.

Spaull, N. 2013. South Africa’s education crisis: The quality of education in South Africa 1994-2011 (Johannesburg: Centre for Development and Enterprise (CDE)).



## General approach to translating Sector Report scenarios to the CGE model

### Reference scenario calibration, and fixing key economic parameters

The above, reference GDP growth trajectory in SATIMGE is obtained applying SATIMGE’s usual model closure rules which assume a balanced (also called Johanson) closure.[[13]](#footnote-14) This reference provides the trajectories for parameters that will be fixed in scenario runs. Notably:

* Household and enterprise saving ratios
* Government expenditure
* Total investment
* Check 2simulation\_loop-file for further information

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### Public finance

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Finally, for scenario runs, the closure rules is adapted such that ..

### Investment

corresponds to …

### O&M expenditure

…

## Transport scenario assumptions

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Further assumptions are :

1. Urban scenarios have the TFP growth assumptions as before (elastic with LN(km) for roads, and with LN(passgr trips) for rail & BRT;.

2. Rural scenarios (CUG, CUS, CRG, CRS) have higher average TFP per LN(km) growth, leading to an average 4,6% TFP growth in the 4 rural scenarios, but this is now normalized based on passenger trips so the rationalized scenarios come out better.

### Urban Roads

There is a limited extension of urban roads foreseen in all scenarios for urban access & safety. From Fedderke and Bogetic (2009) we use the estimate that the TFP elasticity of (the natural logarithm of) the total length of the **national** road network is **2.8** for manufacturing and industrial sectors, which were the focus of their study. We assume for simplicity half of the same impact for all other (primary and tertiary) sectors, though outside urban areas the impact might be as high for primary sectors as for manufacturing sectors.

Rail and BRT

The Transport scenarios run with a the assumption that 50% of new BRT and Rail capital stock adds to South Africa’s productive K-stock.

In the IRT scenario there is 60 kms added and 651 million more passenger trip per year by 2030 compared to the no investment Reference and the urban BAU scenario.

In the ERT scenario there are 89 kms rail and BRT network added and this combines with 182 million passenger trip more than in the IRT.

### Rural road network extension

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### Safety

All Transport scenarios invest 0.57% of reference GDP into safety-related road capital-stock improvement. Rail and BRT safety investments are part of the regular investments for Rail and BRT expansion of the IRT and ERT scenarios.

The Transport scenarios do not allow for a translation of road safety investment into a reduction of injuries and deceases due to traffic accidents. Therefore, the following assumptions apply:

* All scenarios bring 75% of roads to 3-star rating;
* the SDG 3.6 for road safety is to reduce mortality due to accidents by 50% in 2030;
* I have no indication for whether the above investment achieves the SDG, and thus assumed "middle-off-the-road" that half of the SDG target is achieved
* This would mean that mortality due to road accidents decreases by 25%
* Currently, accidents cause 0,213 deaths per 1000 persons in South Africa
* Decrease by 25% = -0,05325 per thousand persons per year
* On an adult mortality rate of 6,06 per thousand (source Pruss-Ustun et al, supplementary material , used for Water & Sanitation assumptions) this means -0.88% mortality
* SA's adult mortality rate would decrease from 303/1000 to 300.3/1000 - aka SA's adult survival rate would increase from 697/1000 to 699.7/1000, an increase of 0.38%
* Following Bloom et al cited for their estimate of labour productivity impacts of health improvement, L-productivity has a 1% elasticity with the adult survival rate (rate of adults reaching the age of 65)
* Simplifying things for the model, I use the L-share in VA (53.5% in the SAM 2019) and estimate the impact of this improved adult survival rate at 0.2%.
* This would be the TFP impact for the full 2022-2030 road safety improvement, so annually this ends up around 0.02% which is added to the other Transport TFP impacts in the Transport aggregated scenarios.

## Water & Sanitation scenario assumptions

### Translation of scenario Investment and O&M expenditure to SATIMGE

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### TFP impact from achieving better Water, Sanitation and Hand washing hygiene (objective 1)

The 2BF and 2BW scenarios see full achievement of the SDGs for Water and Sanitation. This leads to 0.57% higher labour productivity (by 2030). South Africa’s SAM 2019 shows an average labour share in Value Added of 53%. Simplifying matters, the assumption is that the equivalent increase in TFP is 53.5% of the Labour productivity increase from literature, thus arriving **at a 0.31% higher TFP by 2030**.

In 1BW scenario: I assume that compared to full achievement of the SDGs the achievement of Universal Basic Service levels leads to a 2/3rd reduction of water supply related diarrheal disease burden, and a 1/3rd reduction of sanitation-related disease burden, and 100% of hand washing - Translated to reduced adult mortality the Labour Productivity improvement would be 0.40% by 2030, which I then translate to **a 0.22% TFP improvement by 2030**.

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| ***estimated share in diarrhoeal disease related deaths*** | **Attributed to …** | **Maximum = full SDGs = 0,57% Labour prod (assume TFP) for 2022-2030** | **Medium = Basic servicing for most water clients (2/3rd of full dhiarheal disease reduction), and limited servicing for most sanitation clients (only 1/3rd of full reduction), but full reduction for handwashing hygiene** |  |
| *83%* | Lack of safe Drinking water (SDG 6.1) | 0.25 | 0.17 | %TFP increase |
| *1.7%* | Lack of safe Sanitation (SDG 6.2) | 0.01 | 0.00 | %TFP increase |
| *14.7%* | Lack of Handwashing hygiene | 0.05 | 0.05 | %TFP increase |
| **100%** | **Total** | **0.31** | **0.22** | **%TFP increase** |

Explanation of the labour productivity impact of achieving South Africa’s SDG for water & sanitation

The metrics of the Water and Sanitation Sector Report are the “physical components” to which impacts on macro-economic drivers of the different water and sanitation infrastructure and policy measures scenarios should be linked. Using insights from Bloom et al. (2014), progress on the metrics is translated to a quantified impact on the adult survival rate.

Supplementary Material table from Prüss-Ustün et al. 2014 estimates the total of preventable Water, Sanitation and Hygiene deaths in South Africa **at 6.3 thousand in 2012**, or 0.12 deaths per thousand people. At the same rate the number of deaths would have amounted to 7.2 thousand deaths in South Africa in 2020.

Children under 5 years old made up 43% of these deaths in LMIs (361.000 out of 842.000).[[14]](#footnote-16) Assuming low mortality related to diarrhoea in children aged 6-14 and possibly composition effects with a smaller share of children in South Africa being under 5, the adult mortality in South Africa related to diarrhoea would have amounted to 4.1 thousand deaths in 2020.

On a population of 42.6 million persons aged 15 or older this means a diarrhoea related death rate of **0.096 deaths per thousand persons.** [[15]](#footnote-17) People of working age (15-64) make up 93% of the adult population, and could therefore represent **3.8 thousand** of these adult diarrhoea related deaths in 2020.

Average adult mortality stood at an estimated 303 per 1,000 adults under 65 in South Africa.[[16]](#footnote-18) The latter implies that out of 39.6 million working age people in South Africa in 2020 about 12 million will die before the age of 65 – equivalent to on average 0.24 million per year, or 6.06 per thousand working age persons.

A decrease of 0.096 deaths per 1,000 persons would thus mean a 1.6% decrease in death rate and thus decrease mortality from 303 per 1,000 to 298 per 1,000 – and increase the adult survival rate from 697 per 1,000 to 702 per 1,000 – an increase of 0.57%. With Bloom et al. (2019)’s average elasticity of 1.0 (0.67 to 1.3) of labour productivity to adult survival rate, this would mean **a 0.57% increase of labour productivity** of achieving the SDG’s for water, sanitation and hygiene in South Africa, relative to 2020.

### TFP impact from Reducing water demand/increasing water resilience (objectives 3 and 4)

The key assumption is that reductions of water consumption per capita will allow to avoid structural water shortages, which would primarily hit agricultural and other productive sectors (to spare water supply to citizens).

I derive that reducing water consumption per capita leads to an 0.48% TFP growth for the 2BF, and - 0.89% TFP growth for the 1BW and 2BW scenarios. Details are presented in the table below, but in brief, assumptions are the following[[17]](#footnote-19):

* The reference / 0SQ / status quo scenario sees SA water consumption grow by about 25% from 5.14 million Mlitres per year to 6,43.
* This is expected to lead to an average water deficit of 17%
  + See sector report Water & Sanitation, p.24: "3.4 Objective 4: Increased water resilience … The scarcity of resources and the increase in service levels increases the risk of water shortages during droughts. The NWSMP (DWS, 2018) warns of a 17% water deficit by 2030."
* Ntombele et al (2017) estimated (with a counterfactual CGE model scenario) the impact of the 2015/2016 drought on SA's GDP to have reduced the potential GDP by 1,49% through its impact on agricultural output (-7% to -20% for different sectors, some staples needing to be imported, and some prices, e.g. maize increased by 50%, while food expenditure makes up a third of poor household budgets in non-drought years).
* The 2015/2016 drought saw rainfed water supply decrease by a third compared to the long-term average, meaning a shortage of 29%.
  + The implied long-term average (combining the NWSMP (DWS, 2018) and Ntombele et al (2017) is a 6% structural water supply surplus (meaning unused and not “lost” water supply)
* To simplify matters the average *structural* water shortage is assumed to equate to a shock that is a pro rata of the 2015/2016 drought’s 29% water shortage. The shock was estimated at negative GDP impact of 1.49% by Ntombele et al (2017)
* The GDP impacts is assumed to equate to an equivalent average TFP impact (for non-energy sectors).
* Reality is more complex of course:
  + Adaptive behaviour would reduce the negative economic impact of long-term water deficits;
  + But, on the other hand, an average water shortage will likely make the negative consequences of a drought - when it happens - more severe;
  + also, Ntombele et al only look at the impacts for 1 year, whereas fruit crops (citrus, wine) and livestock take many years to return output to pre-drought levels as plants and animals will have been sacrificed to save water, see a report by SA's Water Research Council (attached)
  + Also, Ntombele et al (2017) seem to consider only agricultural impacts, whereas other sectors (mining, tourism) are probably affected too, and they might have underestimated agricultural output impacts, see the report by SA's Water Research Council.
* Because the reference growth has already been set, and one cannot impose the reference resulting in a lower TFP due to expected structural water shortage. Therefore, here the assumption is that the scenarios without or with *less water shortage than the Status Quo scenario* will lead to *higher* TFP than the no investment reference -).
* In 1BW and 2BW scenarios South Africa resp. maintains recent historic 5% average national water supply surplus (my estimate, based on 25% growth leading to a 17% water deficit) or steer just clear of having no shortage (a 1% surplus)
* while in the 2BF scenario the water shortage will be limited to 8% on average.

Thus one arrives at a water deficit/shortage reduction TFP impact by 2030 of: +0.89% for 1BW and 2BW scenarios vs Ref, and of +0.49% for 2BF vs Ref.

### Combined TFP impacts Objectives 1, 3 and 4

With the combined impact of of objectives 1, 3 and 4 the total TFP impact by 2030 becomes for each scenario: 1BW: = +1.11% ; 2BF = +0.78%; 2BW = +1.19% (see Table X)

*Table X*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Water demand in million Ml pa (\*):** | | **Growth 2020 - 2030** | ***2030 sce Diff with 0SQ*** | ***2030 avg Water shortage*** | **Pro rata economic shock (\*\*)** | **Economic development relative to 0SQ** | **Added TFP impact of reduced dhiareoal disease** | **Total TFP impact by 2030** |
|  | **2020** | **2030** |  |  |  | **, by 2030** |  |  |  |
| **Status Quo** | 5,14 | **6,43** | 25,1% | *0%* | 17% | -0,88% | **0** | **0,00%** | **0,00%** |
| **1BW** | 5,14 | **5,23** | 1,8% | *-19%* | -5% | 0,00% | **0,89%** | **0,22%** | **1,11%** |
| **2BF** | 5,14 | **5,93** | 15,4% | *-8%* | 8% | -0,41% | **0,48%** | **0,31%** | **0,78%** |
| **2BW** | 5,14 | **5,46** | 6,2% | *-15%* | -1% | 0,00% | **0,89%** | **0,31%** | **1,19%** |
| *Notes: (\*) See Fig E3 Water & Sanitation sector report (\*\*) following Ntombele et al (2017), assuming a linear evolution between 2022 and 2030 from 0 to the value Ntombele et al find for the GDP impact of the of 2015/2016 drought and translating this directly to TFP change.* | | | | | | | | | | |

## Basic Education

Abundant theoretical models about education-driven productivity-wage gaps is not matched by abundance of empirical literature, and evidence for whether education raises productivity and wages is sparse (Kampelman et al, 2018)[[18]](#footnote-20). They indicate several reasons why statistical analysis of such economic impacts can be complicated, yet achievable, as they have observed for Belgium.

Nevertheless, Bhorat and Kimani (2017)[[19]](#footnote-21) show that in South Africa educational spending and lower teacher-student-ratios (STRs) lead to higher educational attainment levels, though for STRs this is mostly the case in primary education. Bhorat and Kimani also discuss reasons why statistics on education spending and STRs might be skewed in South Africa. Another important issue to keep in mind is that South Africa has a gap in educational quality inherited from the Apartheid era, which it has not yet overcome. A minority of South African pupils enjoys high quality education, while the majority cannot (Spaull, 2013).[[20]](#footnote-22) This limits the benefits South Africa’s educational system can have for its people and its economy. South Africa’s labour market is furthermore constrained by a skill shortage (Daniels, 2007)[[21]](#footnote-23).

The conditions therefore seem right for investment in quality of education to contribute not only to better educational levels, but also to an improved economy. However, calibration of such an economic impact is difficult. The objective of the estimation steps detailed below is therefore not to calculate the exact impact which additional enrolment would have, but to arrive at **a plausible magnitude of an impact on economic drivers of educational investment. This is developed through the estimation of a proxy for such an impact**:

**Step 1 – quantify the impact of enrolment on educational attainment**

* Higher enrolment levels of the full enrolment scenario lead to higher levels of educational attainment meaning more people reaching matric (secondary), more people reaching middle-school (lower secondary); and less people being uneducated.
* We furthermore assume that the increase in enrolment per educational year, thanks to upgrading and all other investments, leads to an equally sized increase in students reaching matric, and thus that the number of school drop-outs does not change compared to the BAU scenario;
  + South Africa has significant drop out rates especially in secondary education. Drop-out rates hovered around 1% for primary school cohorts, and increased to almost 12% for the last two cohorts of high school according to the NIDS 2007/2008 (RSA, 2011)[[22]](#footnote-24). By 2020 they still ranged between 3% and 9% for high school students.[[23]](#footnote-25) Higher quality education (lower TSRs, better facilities, less distant schools) likely reduces school drop-out rates, but it is unknown to what extent (Hartnack, 2017)[[24]](#footnote-26).
* Furthermore, improvement of Teacher-Student-ratios also lead to improved educational attainment, but this is already accounted for by the assumption that all additional enrolment translate to an increase of educational output (people finishing a schoolyear successfully and passing to the next year/school type) for each cohort.
  + For example, if enrolment increases by 12,000 pupils in a given year, then this means that 1/12th or 1,000 learners (as there are 12 cohorts in the total school system), pass from GR to primary school, ditto from 1st year to 2nd year, etcetera up to a 1,000 learners more obtaining their Matric (successful completion of high school).
* …

The Table below shows how increased enrolment, which we assume takes place across the board (for all years of schooling) leads to higher educational attainment in the labour market.

*Table X*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Future enrolment in basic education under the full access scenario - All schools** | **percent public** | **Enrollment Diff Full vs Baseline** | **Enrollment diff per cohort (Full vs Baseline)** |
| ***thousands of pupils/students*** | ***thousands of pupils/students*** |
| 2020 | 13 543 | 92.5% | 0 | 0,0 |
| 2021 | 13 654 | 92.5% | 25 | 2,1 |
| 2022 | 13 770 | 92.5% | 52 | 4,3 |
| 2023 | 13 890 | 92.5% | 80 | 6,7 |
| 2024 | 14 014 | 92.5% | 110 | 9,2 |
| 2025 | 14 143 | 92.5% | 141 | 11,8 |
| 2026 | 14 276 | 92.5% | 174 | 14,5 |
| 2027 | 14 414 | 92.5% | 210 | 17,5 |
| 2028 | 14 557 | 92.5% | 247 | 20,6 |
| 2029 | 14 705 | 92.5% | 286 | 23,8 |
| 2030 | 14 858 | 92.5% | 328 | 27,3 |

*…*

**Step 2 – Quantify the impact of educational attainment on labour market participation by level of skill based on educational attainment.**

SATIMGE has a skill-differentiated labour market model. This concerns segmented labour markets, with skills based on the level of educational attainment.[[25]](#footnote-27) The four categories are primary or less-educated, middle-school (lower secondary) educated, matric/completed secondary educated, and tertiary/higher educated. Each skill segment is modelled through an upward-sloping labour supply curve. The model therefore does not take into account latent labour supply, e.g. in the form of the officially unemployed. The impact of educational attainment is thus calibrated through increased productivity of workers in a segment. The following assumptions are used to model this:

* All students, and not only the additional students thanks to the investments, will benefit from improvements in Student-Teacher- ratios (STRs) and improved facilities, hence we can expect the average learner to enter the labour market with slightly improved skills.
* **There is no quantitative basis for a calibration of this impact, so to simplify matters the labour productivity impact is concentrated within a group of learners equal in size to the additional amount of learners (i.e., the 1,000 from the example).**
* We furthermore assume that this only concerns “will-be-employed” school leavers, and that the net effect is that the amount of additional learners in one cohort would move from being a primary/less-educated worker to becoming a secondary/matric-educated worker.
* Table X above gives the amount of annual additional learners in a cohort for the Full scenario vs the Baseline education scenario. Table Y below shows the No\_investment Reference projected labour supply per projection year and shows how the additional educational attainment from Table X would increase secondary labour supply, by decreasing primary labour supply, given as a percentage of the total labour supply in a given year.

*Table Y*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Reference 2019 labour supply by skill, SAM 2019 (thousands)** | | | | | | **Shift from Primary to Secondary** | |
| tertiary | secondary | middle | primary or less | **Total** | **Pct of labour supply** | |
| 2020 | 3 025 | 4 348 | 4 887 | 2 923 | **15 183** | **0,00%** | |
| 2021 | 3 112 | 4 510 | 5 091 | 3 033 | **15 745** | **0,01%** | |
| 2022 | 3 198 | 4 659 | 5 262 | 3 128 | **16 247** | **0,03%** | |
| 2023 | 3 277 | 4 793 | 5 404 | 3 211 | **16 686** | **0,04%** | |
| 2024 | 3 356 | 4 920 | 5 539 | 3 290 | **17 105** | **0,05%** | |
| 2025 | 3 438 | 5 048 | 5 675 | 3 371 | **17 532** | **0,07%** | |
| 2026 | 3 523 | 5 179 | 5 817 | 3 453 | **17 971** | **0,08%** | |
| 2027 | 3 611 | 5 314 | 5 965 | 3 540 | **18 429** | **0,09%** | |
| 2028 | 3 695 | 5 444 | 6 117 | 3 636 | **18 892** | **0,11%** | |
| 2029 | 3 789 | 5 588 | 6 283 | 3 740 | **19 400** | **0,12%** | |
| 2030 | 3 890 | 5 740 | 6 454 | 3 847 | **19 931** | **0,14%** | |

**Step 3 – Translate the additional educational attainment in the employed work force to a TFP impact**

From the SAM 2019 we furthermore obtain differences in average pay by level of skill. We assume for convenience perfect or rational average labour markets, and we thus assume that the ratio of wage differences between educational labour market categories corresponds to increased labour productivity.

Table Z below calculates the average increase in wage rent for a person moving from being an average primary-school educated skilled worker to becoming an average secondary-school educated skilled worker. The average for the presented years is a ratio of 2,41.

*Table Z1*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Relative wage-rents in No\_Investment Reference (wfx in satimge)** | | | | **Wage rent ratio of Secondary labour over Primary Labour** | | | |
| **Year (2019 is calibration)** | **tertiary** | **secondary** | **middle** | **primary** | **tertiary** | **secondary** | **middle** | **primary** |
| 2019 | 0,3543 | 0,1439 | 0,0751 | 0,0574 | n/a | **251%** | **<---** | **<---** |
| 2020 | 0,3698 | 0,1513 | 0,0806 | 0,063 | n/a | **240%** | **<---** | **<---** |
| 2021 | 0,3739 | 0,1506 | 0,0794 | 0,0623 | n/a | **242%** | **<---** | **<---** |
| 2022 | 0,3729 | 0,1488 | 0,0782 | 0,0614 | n/a | **242%** | **<---** | **<---** |
| 2023 | 0,3702 | 0,1468 | 0,0773 | 0,0608 | n/a | **241%** | **<---** | **<---** |
| 2024 | 0,3696 | 0,1459 | 0,0769 | 0,0606 | n/a | **241%** | **<---** | **<---** |
| 2025 | 0,3701 | 0,1457 | 0,077 | 0,0606 | n/a | **240%** | **<---** | **<---** |
| 2026 | 0,3712 | 0,1459 | 0,0772 | 0,0608 | n/a | **240%** | **<---** | **<---** |
| 2027 | 0,3722 | 0,1461 | 0,0774 | 0,061 | n/a | **240%** | **<---** | **<---** |
| 2028 | 0,3699 | 0,1452 | 0,0773 | 0,0614 | n/a | **236%** | **<---** | **<---** |
| 2029 | 0,3714 | 0,1457 | 0,0776 | 0,0616 | n/a | **237%** | **<---** | **<---** |
| 2030 | 0,3728 | 0,1461 | 0,0778 | 0,0616 | n/a | **237%** | **<---** | **<---** |
| **Average** |  |  |  |  |  | **241%** |  |  |

Using this Labour productivity increase and applying it to the percentage of total labour supply that would shift from primary to secondary educated labour, this leads to an average L-productivity increase presented in Table Z2 below. This impact is converted to a Total Factor Productivity impact to simplify the representation in the SATIMGE, leading to an average annual TFP growth in the Full Education scenario compared to Baseline scenario.

*Table Z2*

|  |  |  |
| --- | --- | --- |
|  | **L-productivity growth Full vs Baseline** | **TFP growth Full vs Baseline** |
| 2020 | 0,00% | 0,00% |
| 2021 | 0,03% | 0,02% |
| 2022 | 0,06% | 0,03% |
| 2023 | 0,10% | 0,05% |
| 2024 | 0,13% | 0,07% |
| 2025 | 0,16% | 0,09% |
| 2026 | 0,19% | 0,10% |
| 2027 | 0,23% | 0,12% |
| 2028 | 0,26% | 0,14% |
| 2029 | 0,30% | 0,16% |
| 2030 | 0,33% | 0,18% |
| **annual avg TFP addition** | **0,20%** | **0,11%** |

**Conclusion on TFP impact for Basic Education scenarios**

For Baseline versus No\_Investment the assumption is that the TFP impact is pro-rata of the investment compared to the additional investment of Full vs Baseline. The reason is that the BAU TFP impact (likely negative) due to lack of investment or implementation thereof is unknown. As this is unknown, the preferred approach is to assume that the Baseline scenario has improved TFP relative to the No\_Investment reference. As Bhorat and Kimani (2017) estimate, spending per student would on average have a positive impact on educational attainment. Hence the overall TFP impacts of all 3 Basic Education scenarios becomes:

* The additional capital expenditure in the Baseline scenario is on average 16 bn ZAR per year (2022-2030), while in the Full access scenario compared to the Baseline scenario additional capital is 6.2 bn ZAR per year. The Baseline/No-investment over Full access/Baseline investment ratio therefore is 2.56.
* The TFP impact of **Baseline vs No\_Investment** would then be **0.27% per year** on average.
* The **Full access scenario** has 0.11% additional TFP growth, thus total annual average TFP growth from 2022-2030 is 0.27+0.11 = **0.38% relative to the No Investment baseline**.
* The **Efficiency scenario** leads to the same enrolment improvement as the Full Access scenario and will thus achieve the same productivity improvement.

## TVET Education

TVET scenarios:

* There is a single estimate for upgrading/rehabilitating existing campuses.
* There are 3 scenarios for campuses expansion and two of them include expansion of student housing.
* Add up cost of upgrading, cost of expansion of campuses and housing to get aggregate scenarios
* The preferred aggregate scenario is the one that includes the NDP expansion scenario

Potentially useful reference: “This research aims to shed light on the factors that differentiate those who transition from higher education into employment from those who transition into unemployment.” (Bhorat et al, 2017)[[26]](#footnote-28)

**Table National Qualification Framework links to other qualification types - Source: www.skillportal.co.za**

Table

Description automatically generated

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Ntombele et al (2017)

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# Annex A: Modelling approach

## A.1 The SATIMGE model

**(The source for the text of this section = Ahjum, F. et al (2022), “Green hydrogen and TVET employment prospects: An assessment in a context of ambitious decarbonization for South Africa towards 2050”, ESRG (Dept. of Chem.Eng., UCT) working paper & SAIIA UKPACT paper Workstream 6)**

In this analysis, the linked energy-economic model SATIMGE, described by Arndt et al. and Merven et al. is used.[[27]](#footnote-29) The SATIMGE model provides cost optimal sectoral pathways for technology options and economic activity. These are underpinned by assumptions of the future costs of options and constraints to activity. Constraints to unbridled activity can be either regulatory or policy based (e.g. air quality or GHG emissions), economic (e.g. national growth expectations and capital availability) or physical (e.g. material and labour).

SATIMGE comprises two hard-linked models[[28]](#footnote-30), namely:

The South Africa TIMES (SATIM) energy systems model is an instance of the international TIMES modeling platform[[29]](#footnote-31). TIMES is a so-called partial equilibrium linear optimization modelling platform that facilitates a detailed full-sector representation of supply and demand components of national energy systems from extraction to end-use services (e.g., heating, cooling, lighting, passenger and freight transport, industrial processes). For example, the model includes extraction, transmission and distribution of gas and coal for electricity generation; the transmission and distribution of electricity; and the consumption of electricity by end-use technologies to supply. SATIM tracks flows of energy, materials, emissions, and energy demand services, and determines capital requirements for all technologies embodied in the system, and their full economic costs.

In the analysis for this study only one scenario for South Africa’s future energy system is used to inform the CGE part of SATIMGE about energy costs and investment needs.

The South Africa General Equilibrium (SAGE) model is a macro-economic computational general equilibrium (CGE) model that describes the national economy not only in monetary flows but also in the physical flow of energy (e.g., measured in PetaJoules), such that these flows match those of the SATIM model’s projected energy balances. As a CGE model SAGE is a full sector representation describing production and purchase of intermediate and end-use commodities across the economy. Labour and capital as primary economic drivers are endogenously modelled. Labour is typically modelled through separate labour markets in four groups according to level of education-based skill categories: 1. primary or less, 2. middle-school, 3. completed secondary, and 4. tertiary educated. Key outputs of the SAGE model are sectoral growth, employment by educational category, growth in household income and expenditure, and the national balance of payments.

Figure 2‑1 schematically depicts the linked models. The SATIM and SAGE models are linked in a way that retains the best features of both models, i.e., one that captures detailed energy investment options, as well as detailed information on economic structure and behaviour. Within our linked framework, SATIM computes a least-cost energy system investment pathway based on forecasted demand and fossil fuel prices from SAGE. SAGE replicates energy investments and the full set of energy prices from SATIM, and then revises its GDP forecast and fuel price forecasts, which are used by SATIM to re-determine future energy demand and run a new least-cost energy system pathway. Iteration is continued until economic growth converges in both models.



Figure 2‑1: Illustration of the iterative exchange of data between the energy and economic model of SATIMGE

For the present study SATIMGE was run according to its most recent calibration parametrised for “Existing Policies” and “Reference growth”, as fully described in a recent technical report by UCT[[30]](#footnote-32) prepared for informing the South African government’s process of updating its NDC before the COP26 conference in Glasgow 2021. Compared to the latter, the model version used for the present study includes additional descriptions of hydrogen use technologies in industry and transport, as well as an added description of hydrogen, fuel cell, electrolyser, and ammonia industrial sectors in the economy part of the model. Those additions are described in the next section.

## General characteristics of the CGE Model (Source: ZAF BtG Inception Report)

Each year of a scenario is solved as a static equilibrium. Dynamics in the model derive from changes in resource allocations from year to year principally reflecting exogenous population growth and endogenous capital accumulation where the savings of a year are transformed into investment in the following year. Productivity growth is typically set exogenously.

Both demand and supply decisions in the model are derived from micro-founded optimization problems. Production is modelled using a series of nested constant-elasticity-of-substitution (CES) functions designed to capture the substitutions and complements across the different inputs, notably capital and labour. The model will represent energy as a near-complement to capital in the short-run, but as a substitute in the long-run. Thus, rising energy prices tend to lead to rising production costs in the short run when substitution is low, but as time passes new more energy efficient capital is employed bringing down the cost-push factor.

Labour and capital income are largely allocated to households with pass-through accounts to enterprises. Government revenue is derived from both direct and indirect taxes and non-tax revenue. Household demand is modelled in such a way that consumption of households shifts towards luxury goods as income increases allowing for a more realistic evolution in economic structure as development progresses.

Goods are evaluated at basic prices with tax wedges. The model incorporates trade and transport margins that add an additional wedge between basic prices and end-user prices. The relatively large number of goods and services and detailed information on tax revenues earned on the sales of different goods makes the model of tax policy much more realistic than other more aggregated models.

Import demand is modelled using the Armington assumption, i.e., goods with the same nomenclature are differentiated by region of origin. This allows for imperfect substitution between domestically produced goods and imported goods. The level of the CES elasticity determines the degree of substitutability across regions of origin. Domestic production is analogously differentiated by region of destination using a constant-elasticity-of-transformation (CET) function. The ability of producers to switch between domestic and foreign markets is determined by the level of the CET elasticity. At the limit, as the elasticity approaches infinity, the model allows for perfect transformation, in which case the law-of-one price holds.

Market equilibrium for domestically produced goods sold domestically is achieved through market clearing prices. By default, the small country assumption is assumed for export and import prices and thus they are exogenous, i.e., export levels do not influence the price received by exporters and import demand does not influence import prices.

The supply of labour is segmented and assumed to increase exogenously, although upward sloping labour supply curves are assumed for all four skill categories, given the long-term nature of the analysis, which means that increases in wages resulting from higher labour demand increases the labour force participation rate.

Closure of the capital markets depends on the nature of the simulation. In the dynamic simulations, within the context of the present study, new capital, i.e., that which is generated by recent investments, is allocated across sectors so as to equalize the rate of return across sectors. Old capital in expanding sectors earns the same rate of return as new capital.

Supply side dynamics in the CGE model are composed of three elements. Population and labour supply (which also includes people without employment) are defined exogenously. The aggregate capital stock grows according to the overall level of saving (enterprises, households, public and foreign), but will also be influenced by the investment price index and the rate of depreciation. The third component relies on productivity assumptions. By default, total factor productivity is calibrated dynamically to achieve a per capita growth. Alternatively, labour productivity can also be assumed/calibrated which allows one to calibrate inter-sectoral labour productivity to historical trends (either domestic or international).

## A.2 Model input / calibration data

**(Complete with a brief description of all data used. Move details to an Annex.)**

### 2019 SAM and energy balances for Calibration of the CGE model

The CGE model is calibrated to a SAM for 2019, which consists of an update of South Africa’s (I-O/SAM for 2017 ??). Three published SAMs in the same tradition of SAM data generation (for 2012, 2015 and 2016), have been published by UNU-WIDER under the umbrella of the SA-TIED project (Van Seventer et al., 2016; Van Seventer et al., 2019; Van Seventer and Davies, 2019). The authors of these SAMs have prepared a SAM for 2019, which came available to UCT for CGE modelling for this project. The SAM 2019 present the South African economy disaggregated into XY sectors and YZ commodities (products and services). The SAM provides disaggregation of household revenue and consumption for XY household income/expenditure classes and 4 educational labour categories.

Trade, production, and consumption function elasticities for South Africa are based on a combination of economic literature about South Africa and Global Trade Analysis Project (GTAP) databases.

### TIMES energy system model Net Zero scenario

An exogenous scenario for energy system characteristics of the SATIM feeds into the recursive (myopic) CGE model run.

Description of NZP1

Overall assumptions:

The key assumptions included in the analysis are outlined below.

-          ***Available technologies***: In addition to standard available technologies considered in the analysis for South Africa, the analysis also includes the potential for hydrogen for hard to decarbonize sectors although no major hydrogen-based products or economy is included in the scenarios presented here.

-          ***Technology costs:*** Moderate assumptions on solar PV and wind costs are included in line with the costs used in the Integrated Resource Plan (IRP2019). Learning is assumed for renewable energy (12% decline by 2030 for PV, 2% for wind relative to 2020), battery costs (45% decline by 2030) and electric vehicles. This means that the cost of the technology decreases as the global cumulative installations increase, due to factors such as learning-by-doing and economies of scale. Electric vehicles are assumed to reach cost parity with traditional internal combustion engines by 2030.

-          ***Retirement of existing capacity***: Existing power capacity is assumed to retire as per IRP 2019. Endogenous retirement is also possible for refinery capacity although this is limited to after 2028 for crude oil refineries and after 2035 for the coal to liquid plant.

-          ***Fossil fuel exports***: Coal exports are assumed to moderately decline by 4% per annum in line with the change in global preference for cleaner energy fuels.

-          ***Economic***: The Reference scenario assumes a real economic growth rate of 2.8% per annum on average. The underlying assumptions leading to this growth rate (e.g. total factor productivity, foreign investment) is kept the same across scenarios, although in the 7GT scenario changes in the energy sector resulting from the emissions cap affect prices and behaviour affecting the resulting growth rate in the economy. The population is assumed to grow by 0.8% per annum (average) from 59 million in 2020. Population projections are based on data from StatsSA (2020) and the United Nations (2019). Energy investment is assumed to be financed from existing funds available in the country.

-          ***Non-energy emissions:*** A 10GT CO2 sink is assumed to be provided by the land sector by 2050.

-          ***Other***: A real discount rate of 8.2% is assumed as per government planning documents. The international oil price is taken from the 2020 IEA World Energy Outlook (IEA, 2020) and is assumed to reach US$50 per barrel in 2050.

Energy Efficiency:

Energy efficiency measures modelled in the Planned policies scenario are, in the absence of a finalised energy efficiency policy and/or strategy, based on the draft post-2015 National Energy Efficiency Strategy (NEES) (DoE 2016), which proposes sectoral targets for 2030. These are included as follows:  
  
•Residential. A 30% improvement in the efficiency of household energy appliances by 2030, and a 20% improvement in the energy efficiency of residential buildings is achieved by 2030.  
•Commercial. A 37% reduction in energy intensity in commercial buildings, including government buildings, by 2030.  
•Mining. The 40 PJ savings identified by the NEES translates into a 4% energy savings by 2030.  
  
•Manufacturing. 35% improvement in energy efficiency in all applications other than furnaces and kilns, which improve by 5%, by 2030.

The Green Transport Strategy (GTS) (DoT 2018) consists of a number of long-term qualitative goals, and a number of very ambitious quantified short-term goals. These have been implemented conservatively in the current analysis as follows:  
  
•A shift from road to rail for corridor freight transport. By 2030, the rail share of corridor freight transport will be 30%, and by 2050, 50%.  
•A shift from private to passenger transport. A 20% relative shift to public transport by 2030.  
•Alternative vehicles. A minimum of 10% of the vehicle population will comprise EVs and hybrid vehicles by 2030, reaching at least 40% by 2050.  
•Minibus conversion to bifuel (CNG/petrol) vehicles. 10% of the minibus taxi fleet will be converted to be bifuelled by 2030, reaching 40% by 2050.  
•The GTS also contains references to biofuels – 2% blending with petrol and 5% blending with diesel by 2030 have also been included in the Planned policies scenario.

EVs:

•Charging infrastructure is assumed to be part of distribution network which is costed in power sector (under EDist). Smart charging behaviour is assumed across all sectors, such that the charging profile is evenly spread across the day.  
•Investment Cost parity with ICE for new EVs is achieved in 2030 in all scenarios  
•In the CGE, the car manufacturing sector is assumed to follow trends in the vehicle parc with no additional investments

## A.3 Infrastructure investment and growth (Source: Inception report / Other / New writing)

### Introduction (source: Own writing / Summaries of refs)

For the South African economy to create prosperity, generate jobs, and improve public finances and debt dynamics, there is only one path—higher growth. South Africa’s peers have been showing the way. Since 2000, the typical middle-income economy had almost doubled its per capita income before the COVID-19 pandemic. South Africa’s economy grew relatively more slowly in the past two decades, its labour market outcomes worsened in the last decade, and its public finances had been deteriorating rapidly before the pandemic.

Economic growth is forecasted to have rebounded by 4.8% year-on-year in 2021, according to National Treasury’s Budget Review 2022 (NT 2022), but the medium-term outlook is uncertain. The global recovery, until recently, helped South African economic growth, especially given a commodity price boom and strong performance by China and the United States, two of its main trading partners. With deeper economic reforms, including infrastructure investments, South Africa could benefit even more from the high growth in its trading partners and build the foundations for long-term growth.

Economic infrastructure—such as water and sanitation, electricity, and transport—is clearly necessary for the functioning of modern economies and the well-being of populations. However, it does not necessarily follow that more infrastructure will bring more growth or greater prosperity. The constraints may lie elsewhere—with human or private capital or with weak institutions and the rule of law. And, of course, infrastructure is expensive to build and maintain, much of it financed through costly and often distortive taxation, implying heavy trade-offs.

A large body of literature has developed over the last 25 years to assess the impact of infrastructure on growth. While the majority (though not all) of the studies tend to find a positive causal relationship between infrastructure and growth, the magnitude of the relationship varies widely. A meta-analysis of 78 studies (covering developed and developing countries) found that elasticities of output with respect to infrastructure range from −0.06 to 0.52 (Holmgren and Merkel 2017), meaning that infrastructure investments sometimes have a slightly negative impact on growth and sometimes have a significantly positive impact.

### More potential text on an Approach (for how applied to the model)

Investment is distinguished between public and private, and ideally the model is adapted to treat infrastructure and other investments distinctively. Infrastructure investment is distinguished from other types of investments in the model as it can have positive externalities. It is a policy variable, which is exogenously determined and therefore does not vary with total savings. Private investment, other than infrastructure, is driven by savings from domestic and foreign sources. The model is run for each year from the calibration year, e.g., 2015 to 2030, or beyond.

The focus is on how investments increase productivity. Starting with Total Factor Productivity for the entire economy, followed by productivity gains in specific sectors, notably those receiving the investments.

* The sector-specific investments might be calibrated from SARB QB capital formation statistics by sector. Alternatively, literature is consulted to arrive at estimates.
* Literature is needed to estimate TFP impacts

**Macro fiscal closures** are such that the government budget balance closure determines government savings. We adopt an endogenous budget balance and fixed tax rates. Government consumption and investment are fixed in real terms as a share of base year GDP and calibrated in the baseline to reflect past performance and projections. Any surplus is used to pay off debt, and any deficit is funded by debt. The level of investment in the economy is determined through a savings-driven closure with exogenous propensity to save for households and firms. We assume exogenous foreign savings in foreign currency calibrated to match historical data and projections. The real exchange rate adjusts to maintain the current account balance.

The drivers of growth in this model are key to understanding the growth effects of infrastructure investment. The level of GDP in this analytical framework depends on three factors: i) the supply of workers, ii) investment, and iii) productivity. Labour supply is affected by labour demand as economic activity picks up due to infrastructure investment. Productivity is a transmission channel of infrastructure investment scenario via positive externalities. Household welfare, measured by household consumption in real terms, depends on changes in employment and wages that raise income. However, infrastructure investment, by creating demand for investment goods, also results in higher prices, which tends to reduce welfare. Hence the final effect would rely on composition of employment, e.g., higher shares of employment in the construction sector would create more jobs as infrastructure investments increase, and households’ income and price elasticities for specific groups of commodities.

Infrastructure investment creates demand for investment goods and contributes to the efficiency of the targeted sectors and the economy in general. Our approach assumes that infrastructure has a positive externality.

We increase economywide total factor productivity (TFP) based on both international and national studies (e.g., Iimi et al., 2015; Perkins et al., 2005; Fedderke and Bogetić, 2009; Wang et al., 2021). Furthermore, we assume that higher investment increases productivity in the targeted sectors, in this case transport, education and water and sanitation. Depending on data availability the scope of sectoral productivity gains can be calibrated based on several factors or estimated by interpreting the investments’ impacts on current primary and secondary input constraints on production (water, transport costs, labour productivity) based on South African and international economic literature.

### Introduction to Productivity impact estimation and data

Our approach assumes that infrastructure has a positive externality. Infrastructure investment creates demand for investment goods and contributes to the efficiency of the targeted sectors and the economy in general. Productivity is a transmission channel of infrastructure investment scenario via positive externalities. These productivity impacts are defined both for the national economy as for sectors. In the former case, this will be based on findings from economic literature on findings for infrastructure investment in South Africa and other countries. The impacts on sectoral productivity will be based on a combination of calibration of past productivity to investment relations, and on predominantly qualitative evaluation of how infrastructure could contribute to increased productivity or reduced costs.

Besides productivity impacts, investment will have impacts on GDP and employment through different mechanisms at play in the modelled national economy. Through investment and productivity increases, household welfare, measured by household consumption in real terms, is boosted by increases in employment and wages that raise income. However, infrastructure investment, by creating demand for investment goods, also results in higher prices, which tend to reduce welfare. Lastly, the investment needs to be financed. In this study we analyse different channels for public finance: namely, increasing public debt and debt repayment and interest payments in later years, or by increasing taxes. These different sources of funding will have different impacts on GDP growth.

For this reason, the remainder of this section first presents findings about TFP impacts of infrastructure from international studies and studies in other countries, followed by findings in literature specific for South Africa, before concluding what values we assign to economy-wide TFP growth with infrastructure investment.

This report will elaborate further on the relationship between infrastructure access and based on the Sector analysis. In brief, Sector analyses find that South African roads and water and sanitation infrastructure has also suffered from a lack of maintenance, and therefore does not provide the quality which could be expected of these infrastructures (REF TO SECTOR REPORTS). These two sector reports therefore emphasize the need to increase Operational expenditure on these infrastructures to recreate or maintain access to certain transport, water and sanitation services.

### The links between infrastructure and growth

Iimi et al find that infrastructure can support GDP growth through …. Different reasons exist why infrastructure does not have the same impact everywhere. Iimi et al mention.. and ….

A summary of reasons for differences in the macro-economic impact of infrastructure is given by Rozenberg and Fay (2019, *Beyond the Gap report)*, who write:

*“Infrastructure services depend on much more than just a stock of capital. Therefore, although a large literature on the impacts of infrastructure on growth, employment, and welfare has developed in the last decades, it is hardly conclusive. Possible explanations include the following:*

* *Most infrastructure is in the form of networks, which creates threshold effects and returns that vary with the stage of completion of the network and the number of users. Thus, the U.S. interstate highway system is believed to have had extremely large impacts on the U.S. economy up to its completion, after which additions to the network had limited effects.*
* *Transport and electricity services depend not only on roads and power plants but also on consumer durables (like cars, buses, trucks, and refrigerators) and machinery. The economic returns to these services are likely to be greater when the household or firm is located close to markets. In part because of this dependence on complementary inputs, impacts can be slow in coming. But because infrastructure is typically long-lived, the impacts may last a long time.*
* *Infrastructure may be built in pursuit of goals other than growth. Investments may be aimed at promoting social equity, environmental preservation, public health, political goals, or even personal enrichment. And in the absence of market signals, notably about future demand, it can be difficult to know where to build what and at what scale.”*

Quality of infrastructure matters as well, like Calderón and Servén (2004)[[31]](#footnote-33) find:

*“The two robust results are: (i) growth is positively affected by the stock of infrastructure assets, and (ii) income inequality declines with higher infrastructure quantity and quality.”*

Calderon and Serven’s literature analysis identifies multiple ways through which infrastructure enhances growth and reduces inequality, though they also point out that circumstances and how infrastructure investment is set up and financed matter. In our present study, specific impacts on equality except those that result indirectly from the macro-economic impacts are out of scope. Yet, the present study only considers public sources of finance for infrastructure, thereby excluding one potential risk factor for equality that Calderon and Serven (2004) identified, namely unequal access and reduced labour intensity (job creation) following privatization.

For the growth impact of infrastructure investment, based on literature in this field, Calderon and Serven propose a number of causal links, schematically depicted here:

… - SCHEME/FIGURE TO BE DRAWN HERE - …

### Estimates of the impact of infrastructure development on productivity (and growth)

Iimi et al (2015) however also point out that infrastructure does not have the same impact everywhere, thus confirming findings of heterogeneity in the impact of infrastructure investment on GDP by Canning and Pedroni (1999): CITE. Another literature review also finds that there are big differences between studies about the relationship between infrastructure development and economic growth (Timilsina et al., 2020) ADD REF. However, the authors, Timilsina et al (2021)[[32]](#footnote-34) ADD REF then perform their own estimate based on more recent data, and also evaluate more kinds of infrastructure than previous studies, and the difference between developing and industrialized countries. Their focus is labour productivity, and they find a very significant positive relationship between output per worker and their first two principal components of composite infrastructure per worker indicators. Their first two principal components give a combined elasticity of 0.115 to 0.303 of output to infrastructure (per worker), with the elasticity varying with the choice of estimation model (Timilsina et al (2021, see Table 7).

Calderon and Serven (2004) also perform PCA to compose their infrastructure aggregate and perform several additional analyses to control for endogeneity of infrastructure and growth. They conclude that there is a robust impact of infrastructure quantity increase (telecommunications, energy and roads) on the GDP growth rate of a country. They find that a one standard deviation increase in their index of capital stock can be linked to a 1.7 to 3.1 percent increase in GDP growth rate.

For quality of infrastructure Calderon and Serven (2004) find a positive but less robust relation with growth than for quantity, though they mention that correlation with quantity or the choice of quality indicators might could explain that the relationship of GDP growth with infrastructure quality is less pronounced than for infrastructure quantity. They apply their estimated model to historic data to estimate how much of past growth in Latin American countries could be contributed to infrastructure quantity and quality:

*“From these estimates, we can also assess the contribution of infrastructure development to growth across the regions in the world. For example, the average growth rate in Latin American countries increased by 2.8% per year in the period 1996-00 relative to the period 1981-85. Our empirical growth model predicts an increase of 2.5% in the growth rate – slightly short of the observed increase.*

*During this period, the average increase in the synthetic index of infrastructure across Latin American countries exceeded 40% (with Chile’s increasing almost 60% during this period). On the other hand, the synthetic index of quality in 1996-00 was 30% lower than in 1981-85 period (with Brazil exhibiting the largest decrease). Using the estimated regression coefficients, we find that the faster accumulation in infrastructure stocks accounts for an increase in the growth rate of 0.9% per year. However, declining quality in the provision of infrastructure services explains a decrease in the growth rate of 0.2% per year. In sum, infrastructure development accounts for 0.7% of the acceleration of growth in Latin America in the period mentioned – about one-fourth of the actual increase.” (Calderón and Servén, 2004, p.19)*

The lesson from Calderon and Serven (2004) for the present study is that they prove that there is a quantitative effect, likely caused by the causal relationships between infrastructure and growth. This causal relationship, also taking into account quality of infrastructure, of course deals with access to infrastructure which gives access to markets, productive opportunities, and improved productivity.

However, to translate and quantify their results to the analysis of SDG gaps for South Africa only the road capital stock index can be useful, but it is out of scope to estimate where South Africa would be in the … percentile on the road index… unless published by Calderon and Serven. /?/ We propose to replace it with a road access index….?!?

The most significant issue with most literature about the impacts of infrastructure on total factor productivity (and labour productivity) is that they by great majority do not include water & sanitation infrastructure, neither education.[[33]](#footnote-35)

### Discussion

CALDERON AND SERVEN ALSO MAKE a CRITICAL NOTE ABOUT THEIR FINDINGS:

*“While the magnitude of these growth effects is quite substantial, we should keep in mind that they refer to the long run, and that transition toward the increased level of infrastructure stocks assumed in these calculations would demand large sustained increases in infrastructure investment – particularly in the scenario of catch-up with the East Asia median country. This would likely pose tough policy choices to the authorities, as they would have to reconcile these large investment increases with the maintenance of adequate spending on other growth-enhancing items (such as education) while at the same time preserving macroeconomic stability and keeping in check the overall burden of government, which in light of our regression results are also significant drivers of long-run growth.” (Calderón and Servén, 2004, p.21)*

The underlying but not analysed principle might be that the observed relation between infrastructure and growth depends on infrastructure investment that has been timely, meaning on average, applied wisely – due to financial and political constraints. For instance, we think that it would be hard to imagine stable long-term growth if one would trade-off at a large-scale infrastructure investment with spending on education.

# Annex B. Scenario assumption details

## B.1 Total factor productivity gains from infrastructure investment in South Africa

The factors on which productivity impacts could be calibrated include past expenditure in the sector, average annual growth of sectoral GDP over the past 10 years, and the share of the sector in new infrastructure investment.

Fedderke and Bogetic (2009) **[[34]](#footnote-36)** (add to ref list!) present one of the rare elaborate studies for South Africa on the relationship between infrastructure investment and manufacturing sector labour productivity, and on Total Factor Productivity (TFP). Their study finds that after correction for endogeneity between productivity measures and infrastructure a significant positive impact is found for the latter on the former. The disadvantage of their study is that their estimate only considers impacts on what could be called industry and manufacturing sectors, requiring additional assumptions to translate their estimates to national TFP growth values is therefore complicated.

## B.3 Assumptions for Transport sector

…

### Introduction

Internationally, grey and scientific literature mostly finds positive impacts on GDP growth for infrastructure investments, but there is no unanimous picture about the size of these impacts (Binder and Smith , 1996; add more… see Julie’s global SDG gap report). Sometimes this is related to methodological differences in estimation methods (Fedderke and Bogetic, 2009), but it also lies in the line of expectations that macro-economic impacts of infrastructure depend on local contexts and set-ups.

For example, Wang et al (2021) find a complicated non-linear relationship between transport infrastructure investment and Total Factor Productivity growth for different cities in China. They relate this to local differences in circumstances for, and implementation of, infrastructure investments. Nevertheless, this section presents a methodology to overcome this ambiguity about the order of magnitude of transport infrastructure investment impacts on macro-economic development, based on a limited number of advanced studies on this topic.

The Transport Sector Report underlined that South Africa is facing problems with both the quantity and the quality of roads. The quality impact is often related to past shortcomings in maintenance of transport infrastructure and could be a reason to base macro-economic impacts on the measures used for measuring SDG impacts. However, from the literature there is no clear method for linking impacts on macro-economic drivers to accessibility or road quality aspects. Therefore, this chapter sticks to the use of more conventional approaches, namely linking growth impacts to the extension of road, rail, and other networks - are preferable.[[35]](#footnote-37) Nevertheless, due to a lack of literature about growth impacts of especially bus infrastructure and to a lesser extent rail extension, a simplifying assumption has been made to quantify macro-economic impacts of these two types of transport infrastructure.

The solutions to quantify impacts on macro-economic drivers for rail and BRT networks presented in this section can be summarized as …

### Approach for urban access and safety

The studies on which we base our quantitative link between transport infrastructure development and impacts on macro-economic drivers of growth are Fedderke and Bogetic (2009), who estimated growth impacts from infrastructure for South Africa, and Calderón and Servén (2004) who evaluate whether and how much quantity and quality of main infrastructures have affected growth and inequality in especially Latin American and East Asian countries. Several studies discuss how road infrastructure could contribute to long term the macro-economic growth (Calderón and Servén, 2004; Fedderke and Bogetic, 2009; Fedderke and Garlick, 2008), e.g. following from reduced transport time and costs, increased safety and educational participation, and improved access to markets.[[36]](#footnote-38) However, the services obtained from transport infrastructure are often difficult to quantify, especially at the large national scale of our current analysis.[[37]](#footnote-39) Similar to Calderón and Servén we therefore use road extension as a proxy for GDP growth related to such improved transport services.

Another consideration to be aware of is that a large part of the improvements analysed in the Transport Sector Report concerns improvement of existing roads. Nevertheless, the investments proposed would turn (or return) these roads to being all-weather roads, and they will therefore be counted as extensions of the South African road network.[[38]](#footnote-40) The quantification of impacts of increased transport infrastructure on macro-economic drivers is therefore limited to the estimation of productivity impacts of expansion of physical infrastructure (summarized in Table 3‑2), with additional productivity gains to be derived from estimates of time gains in urban transport.

The accessibility parameter used in the Transport Sector Report suffered from a lack of granularity in data and modelling. The report therefore does not acknowledge that in many cases rail investments not only add rail networks but also re-create rail networks, while the accessibility impact of BRT could not be modelled with sufficient detail given data constraints. For this reason, we assumed that the extension of rail and BRT networks should have a similar type of impact as the extension of urban roads.

Here we discuss how the productivity impacts are obtained per category of scenario impacts (see Table 3‑2 before).

### Scenarios and impacts for area 1: Urban access, and Safety

Metrics for scenario evaluation in Sector Report are Rapid Transit to Resident Ratio, Median Accessibility, and Affordability, Decarbonisation, and Safety. However, the last three types of impacts are not reported on by the Transport Sector Report. The scenario interventions per type of transport, as well as their impacts on the two main metrics are summarized in Table XYZ below. Additionally, the Table summarizes the changes in physical infrastructure, which are considered relevant for the evaluation of macro-economic impacts (section XYZ below provides an in-depth discussion on this).

Table 3‑2 Scenario options and impacts for Urban access and Safety (Source: Transport Sector Report)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **For Baseline socio-economic scenario** | **BAU policy** | **IRT policy** | **ERT policy** | **Land-use planning policies** |
| **Scenario options** | | | | |
| Roads | Metropolitan and municipal road networks are strengthened based on Kannemeyer (2016)[[39]](#footnote-41), maintenance backlogs are addressed. | Same as in BAU | Same as in BAU | IRT + a joint land-use and transport policy is implemented. Such a land use intervention aims to capture the effect that “take the opportunities to the people".  In brief, the assumption is that 2% of the populated (1x1 km) cells in urban area receive a mixed-use facility with all opportunity types except for a hospital. |
| BRT, busses and minibuses | Ongoing maintenance supports road-based transport & minibus taxis. | Same as in BAU; and start of BRT operations in eThekwini and Nelson Mandela Bay. | IRT + 120 km expansion of the BRT in Gauteng, eThekwini, Cape Town, &Nelson Mandela Bay. |
| Trains | No improvement of urban rail. | Improvement of the quality of urban rail - bringing it to full capacity with 20 min. headways, and 75 km/hour effective speed. | IRT + 55 km expansion of urban rail in Gauteng, Cape Town, & Nelson Mandela Bay. |
| **Changes in physical infrastructure** | | | | |
| Roads – km and pct growth | 2,102 km paved roads strengthened, or resp. 1.35% and 0,54%\* of resp. urban and national all-weather roads | as in BAU | as in BAU | as in BAU |
| BRT – quality improvement for RTR | 80.7 km (existing operational network) | 140.4 km (existing network incl. non-operational) | as in IRT | as in IRT |
| BRT – expansion, km. and pct growth | None (59.7 km of newly added BRT lanes remain out-of-use) | Purchase of busses and adding O&M for not yet operational lanes | 120.3 km - adding to 140.4 km existing BRT, or 86%)\*\* | as in IRT |
| Train – km and pct growth | Lack of O&M will render trains incapable of providing RTR. | O&M to maintain /renovate existing urban rail lines for RTR. | as in IRT + 28.3 km, adds 1.7 % to 1,619 km in urban Gauteng, KZN, EC and WC. | as in IRT |
| **Impacts on metrics** | | | | |
| RTR |  |  |  |  |
| Median Accessibility |  | “Both improvement and expansion of rail have a negligible effect on accessibility in the four metropolitan areas by 2030.”  “Therefore, improving minibus services, which does not require large infrastructure investments, has the potential to improve urban access and the experience of urban commuting.” | | “Land-use planning allows for higher accessibility per rand spent on transport.” |
| Affordability | impacts of scenarios not reported | impacts of scenarios not reported | impacts of scenarios not reported | impacts of scenarios not reported |
| Decarbonisation |
| Safety |

*Notes to Table: \* Based on Transport Sector Report modelling, according to which 2102 km of metropolitan and secondary city roads need strengthening. This corresponds to 1.35% of the metropolitan and secondary city road network and 0,54% of the national road network that do not need strengthening,; \*\* Source: Transport Sector Report.*

The main metric impacted by the choice between the Urban access scenarios above is the **Rapid Transit to Resident ratio (RTR)**. Another metric “median accessibility” is by far and large determined by population size and income (GDP per capita), and there is therefore no difference between the policy options for the accessibility metric.

*“The reasons for the limited impact of the infrastructure investments in formal urban transport are the spatial structure of the metropolitan areas, the location of the rail corridors, and minibuses dominating urban rail over short to medium distances. The South African rail service was designed and planned to move large groups of (displaced) workers from peripheral townships far from the economic centres. The improvements could reduce travel time and costs along those rail corridors, but they are not large enough to lead to higher accessibility.” [[40]](#footnote-42)*

On the contrary, minibuses allow people to reach a broader range of activities at a lower generalized transport cost and do not require large infrastructure investments. Minibuses therefore have the potential to improve urban access and the experience of urban commuting (Source: Transport Expert report).

**Fedderke and Bogetic (2009) summary**

Labour Productivity and Total Factor Productivity elasticity of growth of a selected number of infrastructure stocks and flows[[41]](#footnote-43) for manufacturing (and heavier industry) as estimated by Fedderke and Bogetic (2009):

* All infrastructure : ln(GFCF) : Gross fixed capital formation in infrastructure
  + Manufacturing labour productivity elasticity (instrumented): 0.20
  + *Or,* Manufacturing TFP elasticity (instrumented): 0.038
* All infrastructure : ln(FCS) : Fixed capital stock of infrastructure
  + Manufacturing labour productivity elasticity (instrumented): 0.19
  + *Or,* Manufacturing TFP elasticity (instrumented): *insignificant*
* Rail: ln(RPASS) : number of passenger railway journeys *,* Manufacturing TFP elasticity (instrumented): 0.159
  + Manufacturing labour productivity elasticity (instrumented): 0.43
  + *Or,* Manufacturing TFP elasticity (instrumented): 0.159
* Roads: ln(TRDS): total distance
  + Manufacturing labour productivity elasticity (instrumented): 2.95
  + *Or,* Manufacturing TFP elasticity (instrumented): 2.802
* Roads: ln(PRDS/RDSSHT): Paved road distance/alternative measure
  + Manufacturing labour productivity elasticity (instrumented): 1.08
  + *Or,* Manufacturing TFP elasticity (instrumented): -0.445 / 4.940

### Changes in physical infrastructure: Roads

There is a limited extension of urban roads foreseen in all scenarios for urban access & safety. From Fedderke and Bogetic (2009) we use the estimate that the TFP elasticity of (the natural logarithm of) the total length of the **national** road network is **2.8** for manufacturing and industrial sectors, which were the focus of their study. We assume for simplicity half of the same impact for all other (primary and tertiary) sectors, though outside urban areas the impact might be as high for primary sectors as for manufacturing sectors.

To Be Continued – e.g. to explain details of Rural approach

### Changes in physical infrastructure: BRT & Rail

… STILL TO BE EXPLAINED BASED ON EXCEL CALCULATIONS

### Discussion of alternative estimates

Tsivanidis (2022)[[42]](#footnote-44) discusses welfare gains and benefits for Bogota’s GDP due to the development of its BRT system “TransMilenio”, which suggests that BRT could possibly be qualified for higher economic gains than rail, with door-to-door travel times approaching those of cars in Bogota. These gains notably concerns reduced travel time translating into more hours worked or spend as leisure time, and decreases in transport costs (relative to their alternatives). These gains lead to direct and indirect benefits for GDP growth and welfare. The improvement of the transport system is also estimated to have translated into an increased migration towards Bogota from the rest of Colombia, meaning that per capita welfare gains have been more limited, though they have possibly been constrained by a lack of co-evolution of urban zoning policies with the development of BRT stations. Repeating Tsivanidis study for South Africa’s metropolitan BRT systems is out of scope for the present study. Also, GDP impacts of over the growth of Bogota’s BRT system are likely not applicable to South Africa, due to a wholly different functioning of the two systems within their urban (transport) environments (Hook and Weinstock, 2021).

### Scenarios and impacts for area 2: Rural access, and Safety

Metrics for scenario evaluation in Sector Report are Rapid Transit to Resident Ratio, Median Accessibility, and Affordability, Decarbonisation, and Safety. However, the last three types of impacts are not reported on by the Transport Sector Report.

The scenario interventions per type of transport, as well as their impacts on the two main metrics are summarized in Table XYZ below. Additionally, the Table summarizes the changes in physical infrastructure, which are considered relevant for the evaluation of macro-economic impacts (section XYZ below provides an in-depth discussion on this).

Table 3‑4 Options and impacts for CUG, CUS, CRG, CRS scenarios for Rural access (Source: Transport Sector Report)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Data for Baseline socio-economic scenario* | **Stay within budget X, no prioritisation/rationalisation** | | **Stay within budget X, coordination for efficiency & rationalising road use** | |
| **Unrationalised gravel (CUG)** | **Unrationalised sealed (CUS)** | **Rationalised gravel (CRG)** | **Rationalised sealed (CRS)** |
| **Scenario Options** | | | | |
| Roads | Rehabilitate all strategic roads and 51% of basic access roads with existing surface. | Rehabilitate all strategic roads, and convert 31% of basic access roads to sealed ones. | Rehabilitate all strategic roads, and 94% of basic access deemed as surplus roads with existing surface. | Rehabilitate all strategic roads, and 57% of basic access deemed as surplus roads to sealed ones. |
| **Change in physical infrastructure** | | | | |
| Roads – km and pct growth | 8,649 km paved, and 50,779 km unpaved roads – adds 15.3% to national all-weather roads | 8,649 km paved, and 30,862 km unpaved roads – adds 10.1% to national all-weather roads | 8,649 km paved, and 50,765 km unpaved roads – adds 15.3% to national all-weather roads | 8,649 km paved, and 30,783 km unpaved roads – adds 10.1% to national all-weather roads |
| **Impacts on metrics** | | | | |
| Rural Access Index | +5.4 pct points to 63.6% | +4.5 pct points to 62.8% | +7.2 pct points to 65.5% | +5.7 pct points to 63.9% |
| Safety gap | n/a | TBC | n/a | TBC |
| Cost-effectiveness (costs per person) | ? | ? | ? | ? |

*Notes to Table: \* Based on Transport Sector Report modelling.*

### Safety

… TBC

## B.4 Assumptions for Water & Sanitation sector

…

### Water and Sanitation SDG gap investments by scenario

Scenarios for SDG gap investments from the Water & Sanitation Sector Report were based on a combination of either of 3 socio-economic development assumption, 2 service level goals, and 4 technology options. The following naming convention was decided in the Water & Sanitation Sector Report (Table XYZ):

*Table: Naming convention for scenarios of the Water & Sanitation sector expert report[[43]](#footnote-45)*



Each of these 24 scenarios were modelled using two models: A Water Services Model and a Water Resources Model to estimate the impacts on Water and Sanitation access, service levels, and conservation metrics.

**From these 24 scenarios the following 3 are the focus of the macro-economic impact analysis:**

* **1BW, the minimum spending scenario;**
* **2BF, the maximum spending scenario;**
* **2BW, the preferred scenario with medium spending.**

### Literature on macro-economic impacts of Water & Sanitation infrastructure

Address the links between metrics (see below) and TFP ! (how links work / the “technics”)

The types of investments necessary to achieve the water-related SDGs are in the domain of the provision of safe drinking water and sanitation. These will likely have positive health impacts and potentially reduce expenditure on certain items by poor households. While productive impacts are not the main goal of water-related SDG investments, certain investments, like investments for safe wastewater treatment could have positive impacts on other sectors’ productivity. This also counts for health-related impacts of water and sanitation infrastructure, for which Calderón and Servén provide a short discussion of literature (2004):

*“Infrastructure development can also have a disproportionate impact on the human capital of the poor, and hence on their job opportunities and income prospects. This refers not only to education, but most importantly to health. A number of recent papers has focused specifically on the impact of expanding infrastructure services on child (and maternal) mortality, and educational attainment.[interesting footnote!]* ***This literature shows that policy changes that enhance the availability and quality of infrastructure services for the poor in developing countries have a significant positive impact on their health and/or education and, hence, on their income and welfare as well****.*

*Brenneman and Kerf (2002) summarize some recent evidence on these impacts. Regarding education, a better transportation system and a safer road network help raise school attendance. Electricity also allows more time for study and the use of computers (Leipziger et al. 2003).* ***Regarding health, access to water and sanitation plays a key role.*** *Several studies have identified instances in which access to clean water has helped significantly to reduce child mortality (Behrman and Wolfe, 1987; Lavy et al. 1996; Lee et al. 1997; Jalan and Ravallion, 2002).13 In Argentina, for example, a recent study by Galiani et al. (2002) concludes that expanded access to water and sanitation has reduced child mortality by 8 percent, with most of the reduction taking place in low-income areas where the expansion in the water network was the largest.” (Source: Calderon and Serven, 2004)*

That these health impacts could be translated to macro-economic impacts can be found from a recent publication by Bloom et al (2019)[[44]](#footnote-46) which presents an overview and a renewed assessment of the validity of differing predictions from micro-founded and macro-estimated productivity impacts of improved health. It finds:

*“The growth literature has used micro-based and macro-based approaches to assess the macroeconomic return to health. Micro-based approaches aggregate the return on health obtained from Mincerian wage regressions to derive the macroeconomic return to health, whereas macro-based approaches estimate generalized production functions decomposing human capital into its components. Macro-based approaches tend to find estimates that are negative and close to zero or 2.5 to 18.5 times larger than micro-based estimates, thereby raising a micro-macro puzzle of the macroeconomic return to health. Our study shows that macro-based estimates of the macroeconomic return to health are compatible with micro-based estimates when we control for the indirect effects of health, which macro-based approaches usually capture but micro-based approaches omit by design.* ***Our estimate indicates that an increase in the adult survival rate of 10 percentage points increases labor productivity by 10.6 percent.*** *This estimate is consistent with the calibrated values of Weil’s micro-based approach, which range from 6.7 percent to 13.4 percent when averaging over all microeconomic studies on which his results are based (Weil, 2007). Our results confirm the validity of the micro-based approach and justify its use when estimating the direct economic benefits of health interventions at the macro level.”(Source: Bloom et al (2019))*

### Approach

The analysis of macro-economic impacts of water and sanitation infrastructure and policy measures will focus on the impacts on macro-economic drivers through improved health, thereby disregarding potential benefits of not facing water scarcity or of avoided negative environmental externalities.[[45]](#footnote-47)

As found by Bloom et al (2019), we assume a **1 percentage point increase in labour productivity for each percentage point increase in adult survival rate** (the probability of surviving from age 15 to 60), using 0,67 to 1,3 percentage point changes per percentage change in survival rate as values for sensitivity analysis.

### Objective 1: Universal access to safe and reliable water and hygiene services

The metrics of the Water and Sanitation Sector Report are the “physical components” to which impacts on macro-economic drivers of the different water and sanitation infrastructure and policy measures scenarios should be linked. Using insights from Bloom et al. (2014), progress on the metrics is translated to a quantified impact on the adult survival rate.

Supplementary Material table from Prüss-Ustün et al. 2014 estimates the total of preventable Water, Sanitation and Hygiene deaths in South Africa **at 6.3 thousand in 2012**, or 0.12 deaths per thousand people. At the same rate the number of deaths would have amounted to 7.2 thousand deaths in South Africa in 2020.

Children under 5 years old made up 43% of these deaths in LMIs (361,000 out of 842,000).[[46]](#footnote-48) Assuming low mortality related to diarrhoea in children aged 6-14 and possibly composition effects with a smaller share of children in South Africa being under 5, the adult mortality in South Africa related to diarrhoea would have amounted to 4,1 thousand deaths in 2020.

On a population of 42.6 million persons aged 15 or older this means a diarrhoea related death rate of **0,096 deaths per thousand persons.** [[47]](#footnote-49) People of working age (15-64) make up 93% of the adult population, and could therefore represent **3.8 thousand** of these adult diarrhoea related deaths in 2020.

Average adult mortality stood at an estimated 303 per 1,000 adults under 65 in South Africa.[[48]](#footnote-50) The latter implies that out of 39,6 million working age people in South Africa in 2020 about 12 million will die before the age of 65 – equivalent to on average 0,24 million per year, or 6,06 per thousand working age persons.

A decrease of 0.096 deaths per 1,000 persons would thus mean a 1,6% decrease in death rate and thus decrease mortality from 303 per 1,000 to 298 per 1,000 – and increase the adult survival rate from 697 per 1,000 to 702 per 1,000 – an increase of 0,57%. With Bloom et al.(2019)’s average elasticity of 1.0 (0,67 to 1.3) of labour productivity to adult survival rate, this would mean **a 0.57% increase of labour productivity** of achieving the SDG’s for water, sanitation and hygiene in South Africa, relative to 2020.

### Objectives 3 & 4: Reduced demand on freshwater resources & Increased water resilience

**Objective 3: freshwater resources**

Quantification of water resource use on GDP to be considered.

Metrics:

* potable water consumption per capita.
* non-revenue water (NRW) as a percentage of system input volume (SIV)

**Objective 4: water resilience**

Metric: The total volume of potable water projected to be used in 2030

The conservation of freshwater resources and water resilience will allow for avoiding future water shortages. Water shortages will limit economic output in many sectors, in a similar manner as droughts have already done temporarily[[49]](#footnote-51),[[50]](#footnote-52),[[51]](#footnote-53),[[52]](#footnote-54). One can also expect droughts to incur additional costs on households seeking more expensive or time-consuming solutions for their water supply, and negatively affect household welfare, and possibly even increase mortality.

# Annex C. Basic & TVET education background material

**From The South African Green Hydrogen TVET Ecosystem Just Transition Strategic Framework Synthesis report (SAIIA, 2022)**

# Annex C. References

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1. We use the estimate by Fedderke and Bogetic (2009) that the TFP elasticity of (the natural logarithm of) the total length of the national road network is 2.8. For Rail (also applied to BRT) Fedderke and Bogetic estimate that the elasticity of the (natural logarithm of) the number of passenger railway journeys to TFP would be 0.159. [↑](#footnote-ref-1)
2. The SDG 3.6 objective for road safety is a reduction in mortality due to road traffic accidents by 50% in 2030. [↑](#footnote-ref-2)
3. their estimate of labour productivity impacts of health-related improvement of adult survival rate is that L-productivity has an elasticity of 1 with the adult survival rate – based on the L-share in VA (53.5% in SAM 2019 data) and estimate the impact of this improved adult survival rate at 0.2%. [↑](#footnote-ref-3)
4. Based on authors own calculations, taking into account the following: Prüss-Ustün et al. (2014, Supplementary Material) estimate the total of preventable Water, Sanitation and Hygiene deaths in South Africa at 6.3 thousand in 2012, or 0.12 deaths per thousand people. In 2020, at the same rate, the number of deaths would amount to 7.2 thousand deaths. Children under 5 years old made up 43% of these deaths in LMIs (361.000 out of 842.000). Assuming low mortality related to diarrhoea in children aged 6-14, the adult mortality in South Africa related to diarrhoea would have amounted to 4.1 thousand deaths in 2020. On a population of 42.6 million persons aged 15 or older this means a diarrhoea related death rate of 0.096 deaths per thousand persons. People of working age (15-64) make up 93% of the adult population, and could therefore represent 3.8 thousand of these adult diarrhoea related deaths in 2020. Average adult mortality stood at an estimated 303 per 1,000 adults under 65 in South Africa. The latter implies that out of 39.6 million working age people in South Africa in 2020 about 12 million will die before the age of 65 – equivalent to on average 0.24 million per year, or 6.06 per thousand working age persons. A decrease of 0.096 deaths per 1,000 persons would thus mean a 1.6% decrease in death rate and thus decrease mortality from 303 per 1,000 to 298 per 1,000 – and increase the adult survival rate from 697 per 1,000 to 702 per 1,000 – an increase of 0.57%. [↑](#footnote-ref-4)
5. With Bloom et al. (2019)’s average elasticity of 1.0 (0.67 to 1.3) of labour productivity to adult survival rate, this would mean a 0.57% increase of labour productivity of achieving the SDG’s for water, sanitation and hygiene in South Africa, relative to 2020. The 2BF and 2BW scenarios see full achievement of the SDGs for Water and Sanitation. This leads to 0.57% higher labour productivity (by 2030). South Africa’s SAM 2019 shows an average labour share in Value Added of 53%. Simplifying matters, the assumption is that the equivalent increase in TFP is 53.5% of the Labour productivity increase from literature, thus arriving at a 0.31% higher TFP by 2030. For the 1BW scenario, the achievement of Universal Basic Service levels are assumed to lead to a 2/3rd reduction of water supply related diarrheal disease burden, and a 1/3rd reduction of sanitation-related disease burden, and 100% of hand washing. Translated to reduced adult mortality the Labour Productivity improvement would be 0.40% by 2030, which I then translate to a 0.22% TFP improvement by 2030. [↑](#footnote-ref-5)
6. See sector report Water & Sanitation, p.24: "3.4 Objective 4: Increased water resilience: … The scarcity of resources and the increase in service levels increases the risk of water shortages during droughts. The NWSMP (DWS, 2018) warns of a 17% water deficit by 2030." [↑](#footnote-ref-6)
7. Ntombele et al (2017) estimated (with a counterfactual CGE model scenario) the impact of the 2015/2016 drought on SA's GDP to have reduced the potential GDP by 1,49% through its impact on agricultural output. The 2015/2016 drought saw rainfed water supply decrease by a third compared to the long-term average, meaning a shortage of 29%. Combining this with the NWSMP implies that current long-term structural natural water supply of South Africa has an average 6% surplus compared to water use. [↑](#footnote-ref-7)
8. Because the reference growth has already been set, the assumption is that the scenarios with less water shortages than the Status Quo scenario see their TFP impact as higher TFP growth than the no investment reference. [↑](#footnote-ref-8)
9. While Full Access and Efficiency scenarios improve educational quality with a different focus, this means that the Efficiency scenario increases upper secondary educational output more before 2030, whereas Full Access spends more on all educational levels, and reaches higher matric graduation levels only later on. Yet, we assume that the labour market impact of full access broad quality impuls would be the same as that of the additionally obtained matric graduations in the Efficiency scenario. [↑](#footnote-ref-9)
10. All students, and not only the additional students thanks to the investments, will benefit from improvements in Student-Teacher- ratios (STRs) and improved facilities, hence we can expect the average learner to enter the labour market with slightly improved skills. To simplify matters the labour productivity impact is concentrated within a group of learners equal in size to the additional amount of learners. We furthermore assume that this only concerns “will-be-employed” school leavers, and that the net effect is that the amount of additional learners in one cohort would move from being a primary/less-educated worker to becoming a secondary/matric-educated worker. [↑](#footnote-ref-10)
11. The wage ratio between upper-secondary educated, and primary or less educated workers would be on average 2.41 for the 2022-2030 reference projection. [↑](#footnote-ref-11)
12. The corresponding wage ratio between upper-secondary educated and lower-secondary educated workers would be on average 1.89 for the 2022-2030 reference projection. [↑](#footnote-ref-12)
13. Balanced closure is modelled in SATIMGE as Investment and Government expenditure being fixed shares of total absorption, with household and enterprise saving ratios uniformly adjusting to allow for the right amount of savings. Government savings are fixed, and direct taxes adjust to allow for government revenue to cover expenditure and savings. [↑](#footnote-ref-14)
14. Globally water-sanitation-hygiene preventable diarrhoea deaths represent 1.5% of the disease burden. For children under 5 diarrhoeal disease represents 5.5% of the disease burden globally. [↑](#footnote-ref-16)
15. Population share aged 0-14 in South Africa: 30% (2012), 29% (2021); Population share aged 15-64: 66% (2012), 66% (2021). [↑](#footnote-ref-17)
16. Based on World Bank data (from UN Population division World Population Prospects and work by UC Berkeley and Max Planck Institute for Demographic) Male adult mortality rate stood at 368 per 1,000 in South Africa in 2020 (aka survival rate of 0.632) while female adult mortality rate stood at 241 per 1,000 persons (aka survival rate of 0.759). The population share male: 49% both in 2012 and 2021 (hence female 51% as no other genders are registered). This means an average adult mortality rate of 303 per 1,000. [↑](#footnote-ref-18)
17. These assumptions replace an out-of-scope (bottom-up) sector-by-sector quantification of water shortage impacts on economic output. [↑](#footnote-ref-19)
18. Kampelman, S., Rycx, F., Saks, Y., and Tojerow, I., 2018. Does education raise productivity and wages equally? The moderating role of age and gender. IZA Journal of Labor Economics, vol.7:1, DOI 10.1186/s40172-017-0061-4 [↑](#footnote-ref-20)
19. Bhorat, H, Kimani, M 2017, The role of post-school education and training institutions in predicting labour market outcomes, LMIP report, no. 23, Labour Market Intelligence Partnership, Human Sciences Research Council, Pretoria, viewed 12 Jan 2023, <http://www.lmip.org.za/document/role-post-school-education-and-training-institutions-predicting-labour-market-outcomes>. See also Kimani and Bhorat (2015), and Kimani’s PhD thesis of UCT (2015). [↑](#footnote-ref-21)
20. Spaull, N. (2013). South Africa’s education crisis: The quality of education in South Africa 1994-2011 (Johannesburg: Centre for Development and Enterprise (CDE)). [↑](#footnote-ref-22)
21. Daniels, R.C. (2007). Skills Shortages in South Africa: A literature review (Cape Town: Development Policy Research Unit (DPRU)). [↑](#footnote-ref-23)
22. RSA (2011). Report on Dropout and Learner Retention Strategy to Portfolio Committee on Education. Dep. of Basic Education, Republic of South Africa, Pretoria, June 2011 [↑](#footnote-ref-24)
23. https://www.statssa.gov.za/?p=15520 [↑](#footnote-ref-25)
24. Hartnack, A., (2017). Background document and review of key South African and international literature on school dropout. DGMT Foundation, Claremont [↑](#footnote-ref-26)
25. Segmented labour markets do not interact, meaning there is no flow of labour between the skill segments based on labour-market conditions. Non-segmented labour market models in which labour can move between skill levels are difficult to calibrate, often facing lacking existing literature or data to estimate or calibrate such a model. They are furthermore complex to solve within the context of a (multi-sector) computable general equilibrium model. [↑](#footnote-ref-27)
26. Bhorat, H, Lilensteing, A, Lilenstein, K, Oosthuizen, M, (2017) youth transitions from higher education into the labour market. HSRC LMIP Report 36-06. Cape Town [↑](#footnote-ref-28)
27. Arndt, C. Davies, R., Gabriel, S., Makrelov, K., Merven, B., Hartley, F. and Thurlow, J. 2016. A sequential approach to integrated energy modelling in South Africa. Applied Energy, 161:591–599. DOI: https://doi.org/10.1016/j.apenergy.2015.06.053; and Merven, B., Arndt, C. and Winkler, H. 2017. The development of a linked modelling framework for analysing the socioeconomic impacts of energy and climate policies in South Africa. WIDER Working Paper, No. 2017/40, ISBN 978-92-9256-264-9, The United Nations University World Institute for Development Economics Research (UNU-WIDER), Helsinki. [↑](#footnote-ref-29)
28. The term hard-linked refers to distinct models that are programmatically coupled such that a subset of outputs are exchanged in an iterative data input-output loop, until an exit boundary condition is satisfied. [↑](#footnote-ref-30)
29. It is developed, promoted and used under the auspices of the International Energy Agency’s Energy Technology Systems Analysis Program (IEA-ETSAP), see <http://iea-etsap.org/web/index.asp> [↑](#footnote-ref-31)
30. Andrew Marquard, Faaiqa Hartley, Bruno Merven, Jesse Burton, et al. ‘Technical Analysis to support the update of South Africa’s First NDC’s mitigation target ranges’. University of Cape Town. Report. https://doi.org/10.25375/uct.16691950.v2 [↑](#footnote-ref-32)
31. Calderón, César, and Luis Servén. 2004. “The Effects of Infrastructure Development on Growth and Income Distribution.” Policy Research Working Paper No. 3400. Washington DC: The World Bank. [↑](#footnote-ref-33)
32. Timilsina et al.,2021. “How much does physical infrastructure contribute to economic growth?” WB Policy Research Working Paper No. 9888. Washington DC: The World Bank [↑](#footnote-ref-34)
33. However, in some papers human capital’s role for GDP growth is estimated within the same model. [↑](#footnote-ref-35)
34. J.W. Fedderke, Ž. Bogetić, Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures, World Development, 10.1016/j.worlddev.2009.01.008, 37, 9, (1522-1539), (2009). [↑](#footnote-ref-36)
35. For other sectors, like water and sanitation, and education, there is no clear literature about the potential growth impacts of expansion of access to these infrastructures or services, and more indirectly estimated, ad hoc solutions had to be used – see the respective chapters for more information. [↑](#footnote-ref-37)
36. This concerns macro-economic impacts beyond the short-term impacts of a road’s construction works. [↑](#footnote-ref-38)
37. See also Fedderke and Garlick (2008) for a discussion of the relationships between infrastructure and growth and the role of measurement and of the choice of measures. [↑](#footnote-ref-39)
38. These roads have also been deducted from our estimate of South Africa’s road network, for which we have only included roads that are considered of “fair”, “good”, or “very good” quality. [↑](#footnote-ref-40)
39. Consider Slide 10/20 of Kannemeyer (2016). [↑](#footnote-ref-41)
40. In Gauteng only 0.7% of areas show rail as providing the greatest accessibility, in eThekwini the percentage is 0.4%, in Nelson Mandela Bay 0.6% and in Cape Town, with its more extensive rail network, only 1.1%. (Source: Expert report) [↑](#footnote-ref-42)
41. Some are defined in more detail by Perkins, P., et al. (2005). [↑](#footnote-ref-43)
42. Tsivanidis, Nick (2022) Evaluating the Impact of Urban Transit Infrastructure: Evidence from Bogotá’s TransMilenio. Haas School of Business and Department of Economics, University of California at Berkeley [↑](#footnote-ref-44)
43. DRAFT “Water & Sanitation sector report” of the study “Going beyond the Infrastructure Funding Gap: A South African Perspective” [↑](#footnote-ref-45)
44. Bloom, D.E., Canning, D., Kotschy, R., Prettner, K. & Schünemann, J.J. (2019), “Health and Economic Growth: Reconciling the Micro and Macro Evidence”, NBER wp 26003, June 2019, DOI 10.3386/w26003, accessed online (august 2022) https://www.nber.org/papers/w26003 [↑](#footnote-ref-46)
45. For water scarcity impacts there is no basis to assess the economic constraint in a business-as-usual scenario in which no additional investment is made or additional policy measures would be taken. Concerning the indirect impact of avoiding negative environmental externalities also no robust quantified estimates were found in our limited exploration of literature on the topic. [↑](#footnote-ref-47)
46. Globally water-sanitation-hygiene preventable diarrhoea deaths represent 1.5% of the disease burden. For children under 5 diarrhoeal disease represents 5.5% of the disease burden globally. [↑](#footnote-ref-48)
47. Population share aged 0-14 in South Africa: 30% (2012), 29% (2021); Population share aged 15-64: 66% (2012), 66% (2021). [↑](#footnote-ref-49)
48. Based on World Bank data (from UN Population division World Population Prospects and work by UC Berkeley and Max Planck Institute for Demographic) Male adult mortality rate stood at 368 per 1,000 in South Africa in 2020 (aka survival rate of 0.632) while female adult mortality rate stood at 241 per 1,000 persons (aka survival rate of 0.759). The population share male: 49% both in 2012 and 2021 (hence female 51% as no other genders are registered). This means an average adult mortality rate of 303 per 1,000. [↑](#footnote-ref-50)
49. https://theconversation.com/how-droughts-will-affect-south-africas-broader-economy-111378#:~:text=Declining%20agricultural%20production%20could%20lead,produce%20could%20push%20up%20prices. [↑](#footnote-ref-51)
50. https://academicjournals.org/journal/JDAE/article-full-text-pdf/C7A813862849 [↑](#footnote-ref-52)
51. https://www.wrc.org.za/wp-content/uploads/mdocs/2604%20Vol%201.pdf [↑](#footnote-ref-53)
52. https://www.emerald.com/insight/content/doi/10.1108/DPM-05-2018-0155/full/html [↑](#footnote-ref-54)