

# Infrastructure and Growth in South Africa: Benchmarking, Productivity and Investment Needs\*

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## Abstract

The paper provides three principal results. First, we benchmark South African infrastructure performance in terms of access, pricing and quality against international comparator groups of countries. International benchmarking suggests that, overall, South Africa's utilities report solid service at reasonable quality and, in some cases, competitive cost. But there remain significant shortfalls relative to the benchmark of upper middle-income countries, largely related to incomplete access and less than expected quality, especially in rural areas. Second, we establish clear empirical links between infrastructure and productivity. Specifically, infrastructure affects output directly, while it exerts more limited impact on factor productivity. Finally, the paper forecasts infrastructure investment needs to 2010. We project an average annual electricity generating investment requirement for the period 2003-2010 of US\$ 0.5 billion or 0.2% of GDP, and US\$ 1.98 billion or 0.75% of GDP for telephony.

## 1 Introduction

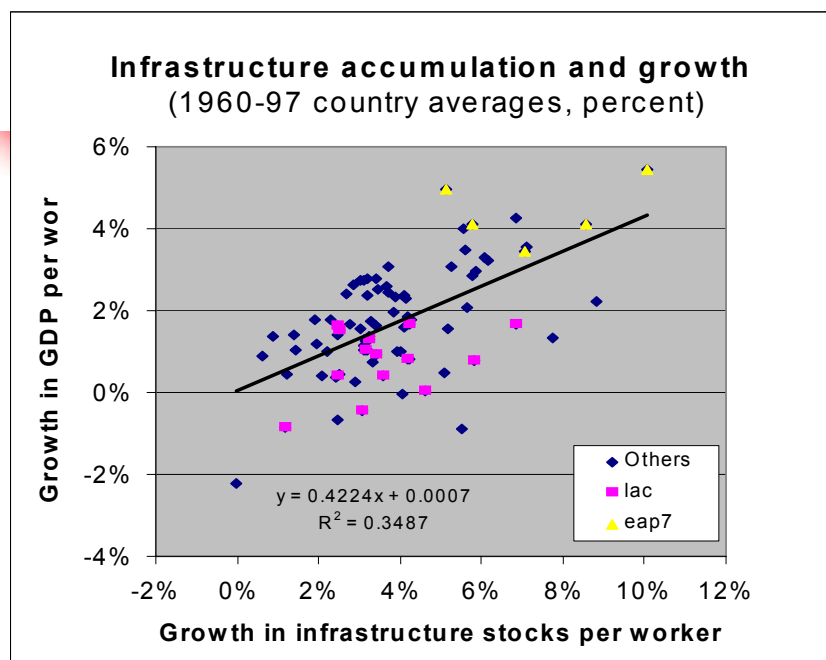
Infrastructure investments have long been recognized in the development literature as an influential factor of economic growth, working through at least two of the three classic drivers of economic growth: directly via capital accumulation and indirectly via total factor productivity gains. Infrastructure investments facilitate private investments by lowering production costs and opening new markets, thereby creating new production, trade and profit opportunities. Roads reduce transport costs and ports reduce transaction and trade costs. Both expose local firms to the innovative pressures of international competition. Aschauer (1989) for example, finds that road building helped increase economic growth in the United States. The World Bank's landmark World Development Report 1994 highlighted multiple links between infrastructure and development and emphasized how policy can improve not only the quantity, but also the quality of infrastructure services in developing countries. Most recently, infrastructure investments were explicitly linked with child health, human capital accumulation, and the achievement of the Millenium Development Goals (Leipziger et al. 2003). The positive and significant correlation between infrastructure accumulation and growth at the macro level is now well established (Figure 1; also see Leipziger, 2001). At the microeconomic level, better infrastructure is associated with greater firm competitiveness, lower poverty, and better health and education outcomes of the poor. Conversely, infrastructure under-investments may lead to significantly lower growth and worsening social indicators.

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Source: Easterly, Calderón and Serven

3

Figure 1: Infrastructure and Growth.

There are several reasons why infrastructure investments in a developing country may be below levels required for dynamic growth. Many infrastructure investments have characteristics of public goods—non-exhaustive and non-exclusive in consumption—and, therefore, may be undersupplied by the private sector in certain circumstances. Macroeconomic and political instability may effectively cut off the source of private finance and the public sector may not be strong enough to pick up the slack. Moreover, pressures for fiscal consolidation often result in cuts in public capital expenditures: infrastructure investments or maintenance is delayed, making rehabilitation and new investments more costly in the future. Cutting public capital expenditures is less politically costly than resisting public wage increases. But excessive and lasting cuts in infrastructure investments can be an inefficient fiscal adjustment strategy that may lead to lower capital stock in the future and, therefore, lower growth (Easterly and Serven 2002). As a result, infrastructure bottlenecks may develop, becoming binding constraints to growth (Hausmann et al 2005).

Recent comparative experience from the 1990s shows serious consequences of such underinvestment in infrastructure for economic growth. For example, Easterly and Serven (2004) show that about one-fifth of Latin American growth underperformance relative to East Asia was directly related to underinvestment in infrastructure. Also shown was that sub-Saharan Africa's poor growth performance was in part related to underinvestments in electricity and telecom infrastructure (Esfahani and Ramirez 2003). It is estimated that if Africa had enjoyed Korea's quantity and quality of infrastructure, it would have raised its annual growth per capita by about 1 percentage point (Eustache 2005).

Finally, infrastructure directly affects human welfare and equity across community and income groups. Urban and rural households in Sub-Saharan Africa—South Africa included—experience widely different access to basic infrastructure services (Figure 2). The lowest household income groups have no or extremely limited access to electricity, improved water and sanitation, or basic telephone services. (Figure 3).

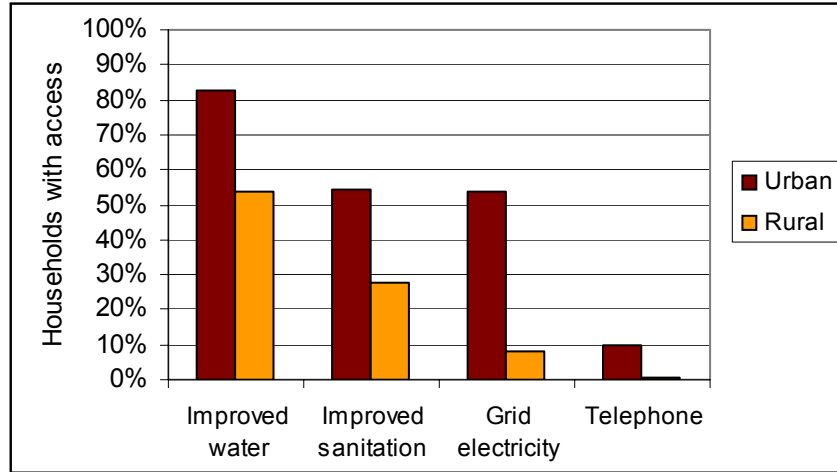


Figure 2: Different Access of Urban and Rural Households in Sub-Saharan Africa. Source: Estache (2005).

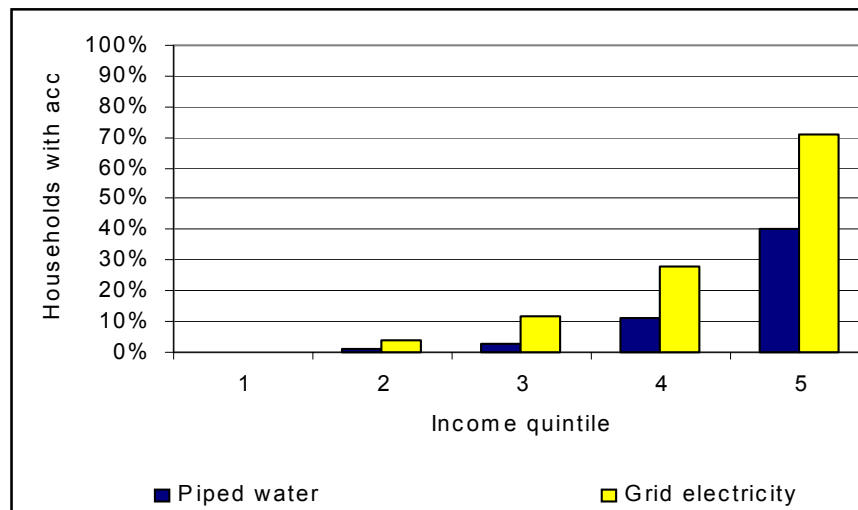


Figure 3: Access Across Income Quintiles in Sub-Saharan Africa. Source: Estache (2005).

The international evidence is mirrored in South Africa. Fedderke, Perkins and Luiz (2005) find a positive impact of infrastructure on aggregate economic growth for South Africa employing time series analysis. Electricity appears to exert the largest and most robust impact on aggregate growth. Investment in infrastructure does appear to lead economic growth in South Africa and does so both directly and indirectly (the latter by raising the marginal productivity of capital); there is also weak evidence of feedback from output to infrastructure.

In this context, developments surrounding infrastructure in South Africa over the past three decades are of particular concern and have been the subject of a debate.<sup>1</sup> The South African Reserve Bank (SARB) publishes the economic infrastructure component of South Africa's gross fixed capital formation and fixed capital stock of the public sector (both general government and public corporations). Figure 4 shows both indices measured per capita, and both demonstrate a long-term deterioration: from the mid-1970s in the case of investment, and from the mid-1980s in the case of fixed capital stock. Specifically, the investment per capita fell from R1 268 in 1976 to R356 in 2002 (1995 prices), a collapse of 72%! As a percent of GDP, investment fell from 8.1% of GDP to 2.4% of GDP, which lies below the international benchmark of approximately three to six per cent identified by Kessides (1993: ix). In 2002, 72% of public-sector infrastructure investment consisted of transport, communication, power and water. The short-lived recovery of infrastructure investment in the 1990s and the subsequent slump were mainly the result of expansion programs by the telephone (Telkom) and electricity (Eskom) utilities to extend telephone lines and electricity to areas which were under-served, and the purchase of new aircraft by the national carrier (South African Airways) (SARB annual economic reports, 1996–2000). In recognition of these trends, the 2005 budget provides for significant expansion of investment in infrastructure, at central government, local government and public enterprise levels.

It is also useful to bear in mind a longer-term history of infrastructure development in South Africa. Perkins et al. (2005) provides a comprehensive description of particular economic infrastructural developments in South Africa since 1875. Figure 4, which shows the long-term development of selected infrastructure measures in the form of indices, provides a summary account, and suggests a series of sequential periods of infrastructure roll-out in South Africa. The first wave of infrastructural development was railways over the 1875–1930 period, after which there was little change in the route-kilometer railway line distance – though rolling stock continued to increase. The second take-off in infrastructure investment was in inter-city roads, which reached a plateau around 1940, after which the focus was on the paving of national and provincial roads. In the 1920s and 1930s growth in road traffic far exceeded growth in rail transport, and with the paving of roads after 1940 road traffic continued to grow faster than rail for the rest of the century. While ports constitute South Africa's oldest form of infrastructure, substantial expansion in port capacity was constrained up to the 1970s, at which point two new ports were constructed, doubling the volume of cargo handled. The final phase of infrastructural development was in telephones and electricity. While the average growth rate for fixed phone lines dropped in the 1960s, it rose again in response to the introduction of information and cell phone technology.

## 2 Organization of the Paper

The objective of this paper is threefold. First, we benchmark South African infrastructure development against international comparator groups of countries. Objective of the analysis is to place the level of infrastructure in South Africa in a broader context, in order to be able to provide an assessment of South Africa's comparative performance. To our knowledge, no such comparative assessment for South Africa has taken place to date.

Second, we confirm that infrastructure has a long-term growth impact in South Africa. Our

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<sup>1</sup>The following evidence essentially draws from the findings of Perkins, Fedderke and Luiz (2005) and Fedderke, Perkins and Luiz (2005).

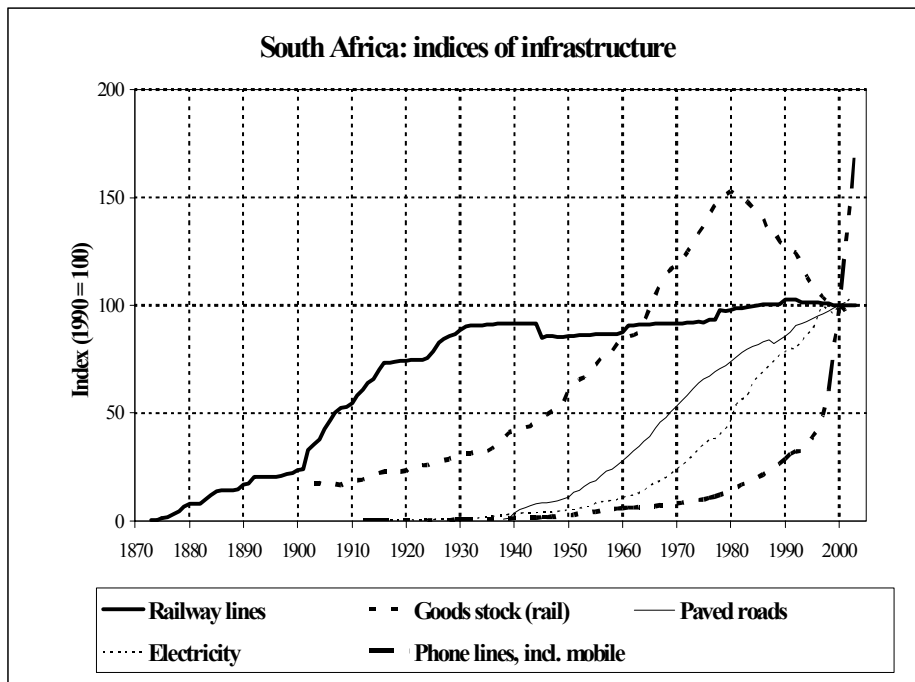
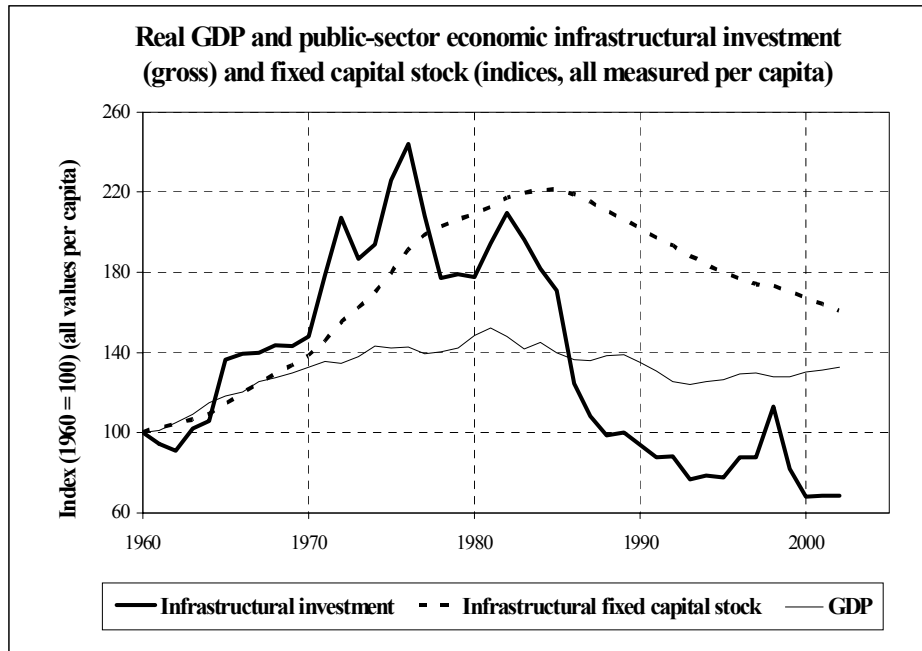


Figure 4: Historical Evolution of Infrastructure in South Africa. Source: Fedderke, Perkins and Luiz (2005).

analysis proceeds by assessing the impact of infrastructure on South African productivity. This represents an advance on previous findings in several ways. The paper assesses the productivity impact not only across a wide range of infrastructure measures, but also at a disaggregated level of 3-digit manufacturing sectors. Our sectorally disaggregated evidence finds clearer, and more robust findings of an infrastructure impact on development than does the aggregate evidence. The paper also innovates by investigating the impact of infrastructure both on labour productivity, and on total factor productivity growth. Finally, we employ panel estimators that present an advance on the literature, since they test both for homogeneity of long-run associations across groups included in the panel, allow for heterogeneity in the short-run dynamics, also allowing for dynamic rather than instantaneous adjustment of stocks to long-run equilibrium values.

Third, we forecast future infrastructure demand in both electricity generation and telecommunications. The forecast of estimated demand for electricity generation and telephony is based on international panel data (52 countries, period 1980-2002) in order to establish long-run equilibrium forecasts of infrastructure requirements in South Africa, implicitly benchmarked against comparative international evidence. Using appropriate, available measures of cost, we conclude by forecasting the investment flows required in order to meet projected infrastructure needs in South Africa in these two sectors.

Section 3 of the paper presents the international benchmark evidence. Sections 4 and 5 present the theoretical and econometric frameworks employed in the remainder of the paper. In section 6 we present the empirical evidence Section 7 concludes.

### 3 Benchmarking South Africa's Infrastructure Performance

The purpose of this section is to benchmark South Africa's infrastructure performance against the relevant group of comparator countries. How does South Africa compare on major indicators of infrastructure sector performance against the relevant country groups? What do outcome indicators tell us about the relative strengths and weaknesses of South Africa's infrastructure vis-à-vis various income and geographic comparator groups of countries? Where are the largest deviations—positive and negative—from the benchmarks and other comparators? And how does one interpret some of these comparisons in order for them to be useful for policy purposes? The answers to these questions are likely to provide important building blocks towards a more complete assessment of the state of infrastructure in South Africa, its performance, and any need for reform. It would also help frame the ongoing discussion in South Africa in a comparative perspective based on well-defined and widely accepted performance indicators. We hope to contribute to these efforts by focusing here on the first step—international comparison and benchmarking along key dimensions of infrastructure performance. The benchmarking covers all four major infrastructure sectors: electricity, water, telecom, and transport. Infrastructure performance is measured using a series of quantitative and qualitative (technical and perception-based) indicators. Data details are provided in Appendix A.

The data used for comparing South Africa's performance comes from the World Bank research data base that was recently developed with a specific objective to be used for this type of benchmarking exercise (Eustache and Goicoechea, 2005). The data base pulls together the latest available observations from a number of well documented, specialized data sources that contain more detailed data with longitudinal information. The data base aims to measure sector performance by focusing on sector *outcomes*—access, affordability/pricing, and quality (technical or perceived). It also provides information on sector institutional reform. Data covers 207 countries (although coverage varies by sector and indicator)<sup>2</sup> with a limited number of variables<sup>3</sup> measuring sector outcomes.

<sup>2</sup>The percentage of available country observations from the total number of countries (207) varies by indicator from close to 90% for measures of access to roads, 85-95% for ICT access and pricing measure, 75-85% for access to water, and 60% for access to electricity. The number of quality indicators is generally lower than those of access.

<sup>3</sup>The numbers of indicators in each sector are the following: 7 in energy, 4 in water & sanitation, 12 in ICT, and 12 in transport.

For the purpose of benchmarking South Africa, we compare it with all the world geographical comparator groups—Sub-Saharan Africa, OECD, South Asia, East Asia & Pacific, Middle East & North Africa, Latin America & the Caribbean, Europe and Central Asia, and the world—and four groups of countries clustered by level of income per capita—low-income, middle-income, upper middle-income, and OECD countries. Therefore, both region and income level are used as comparator criteria. The main benchmarking group on which much of the analysis is focused is South Africa’s per capita income group of *upper middle-income countries*. Because of the strong association between infrastructure and income level and because this is also South Africa’s main competitor group of countries, this is economically the most meaningful group comparator for South Africa. This is supplemented by relevant comparisons with other income groups and major regions of the world to provide a wider, geographical comparison of South Africa’s infrastructure performance. Finally, we use from the aforementioned data base the available indicators for electricity (7), water & sanitation (4), and most of the broader group of indicators for information communication technology (13) and transport (10). For our purpose, the benchmarking is limited to sector performance indicators. Detailed benchmarking is presented in Tables 1 through 4. We do not use nor discuss institutional reform indicators that are also available in the database.

As with any comparative indicators summarizing performance in a vast number of different countries, interpretation of comparisons must be made carefully and taken with caution. Some of the variations among the indicators may reflect other factors that may make single indicator comparison less revealing, or even misleading. The database itself has its limitations detailed in the cited World Bank analysis by Estache and Goicoechea. Where appropriate, we explain or qualify how specific circumstances in South Africa may affect a specific indicator comparison. Nevertheless, since the indicators presented here are widely accepted and fairly unambiguous representations of major dimensions of sector performance, we believe that the benchmarking and comparisons are sufficiently meaningful and could prove useful in both analytical and policymaking studies of South Africa’s infrastructure performance.

### 3.1 Energy: Electricity

Overall, South Africa’s performance in the electricity sector (measured by the seven indicators discussed below) compared to the upper middle-income country benchmark is relatively weak in terms of access, but favorable in terms of technical efficiency (i.e. percentage of losses), pricing, and perceptions of service. The relatively low access reflects in large part the legacy of Apartheid, that left large segments of the population—especially the poor—outside the network of basic service provision. Since then, service access has been increasing, but the level remains behind what would on average be expected, given South Africa’s income level. Low losses reflect solid internal technical efficiency of the electricity network. Low prices reflect the comparatively low cost of South Africa’s electricity (produced almost exclusively from coal) and the fact that a good part of the capital stock has already been depreciated as there has been little investment in the sector over the past two decades. With significant new investments being planned by the state electricity company (ESKOM) over the coming years, prices are bound to increase. Finally, local perceptions of service have been rather favorable, but this may reflect selection bias in that only customers that do have service provision responded to this question. The overall picture, therefore, suggests that the main weakness in South Africa’s electricity sector lies in access which remains limited, and service delivery to the poor.

The following paragraphs detail the benchmarking of South Africa’s electricity sector according to specific dimensions of performance: access, pricing, technical efficiency, and perceptions. The main comparative benchmark remains the group of upper middle-income countries. Comparisons are also made with OECD countries, Sub-Saharan Africa, and other major regions of the world. Figure 5 illustrates.

- **Access.** Not surprisingly, South Africa’s access to the *electricity* network is superior to the

	South Africa	SSA	Mid. East & S. Africa	South Asia	East Asia Pacific	Latin America & Carib.
Access to Electricity Network (% of Pop)	66	15	88	31	54	79
Households Reporting Access to Electricity (% of Households)	65	23	80	39	62	72
Energy Use Per PPP GDP (kg of oil equivalent/1000 PPP dollars, constant 2000)	259	364	249	184	212	207
Electricity average End-user prices (US cents/k/Wh) - Residential/non-Residential	3/2	6/5			5/5	10/8
Commercial perception of electricity services (1=worst 7=best)	5.8	4.3	5.1	2.6	4.3	4.2
Commercial perception of public agency electricity provider (1=worst 7 = best)	6.0	4.3	6.0	3.8	5.0	4.8
Electric power transmission and distribution losses (% of total output)	8.0	19.0	14.0	22.0	12.0	18.0
	Europe & Central Asia	Low Income	Middle Income	Upper Middle Income	High Income OECD	World
Access to Electricity Network (% of Pop)	99	31	85	87		6.0
Households Reporting Access to Electricity (% of Households)	99	32	79	74		45
Energy Use Per PPP GDP (kg of oil equivalent/1000 PPP dollars, constant 2000)	375	374	246	249	188	275
Electricity average End-user prices (US cents/k/Wh) - Residential/non-Residential	6/6	6/6	8/7	9/7	13/6	9/6
Commercial perception of electricity services (1=worst 7=best)	4.8	2.8	4.7	5.2	6.3	5.0
Commercial perception of public agency electricity provider (1=worst 7 = best)	4.8	4.0	5.2	5.3	5.3	4.8
Electric power transmission and distribution losses (% of total output)	18.0	22.0	15.0	14.0	6.0	14.0

Table 1: Benchmarking South Africa's Infrastructure Performance: Energy

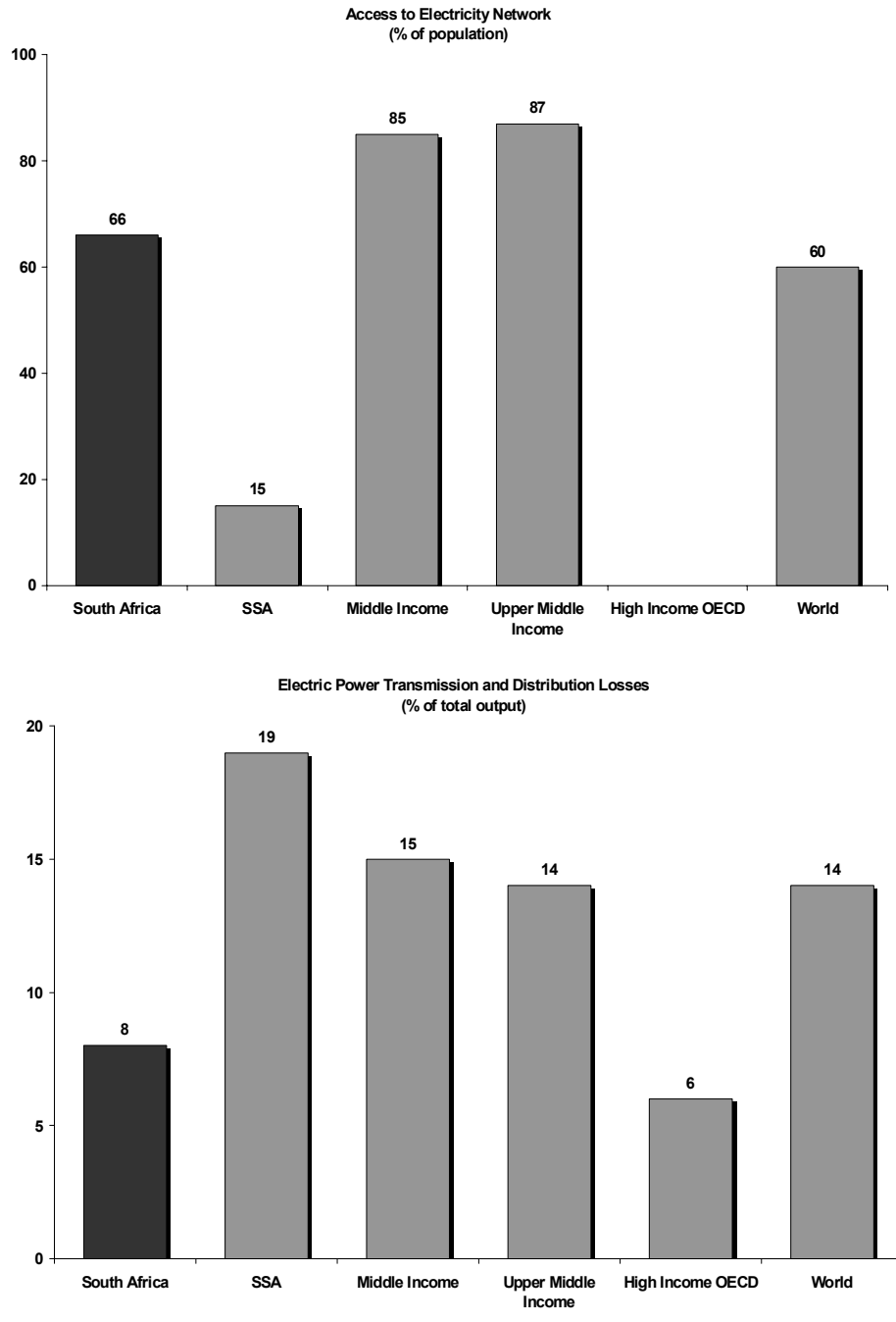


Figure 5: Benchmarking South African Electricity Provision Internationally.

	South Africa	SSA	Mid. East & S. Africa	South Asia	East Asia Pacific	Latin America & Carib.
Access to Improved Water Sources (% of population)	87	64	85	72	75	90
Access to improved Sanitation (% of Population)	67	37	77	48	60	77
Commercial Perception of Water Source (1=worst 7=best)	5.7	4.2	5.6	4.1	4.8	4.7
Households using piped or well water as main source of drinking water (% of household)	85	78	89	90	74	75
	Europe & Central Asia	Low Income	Middle Income	Upper Middle Income	High Income OECD	World
Access to Improved Water Sources (% of population)	87	65	89	93	99	80
Access to improved Sanitation (% of Population)	78	41	79	86	100	64
Commercial Perception of Water Source (1=worst 7=best)	4.6	4.0	4.9	5.0	5.2	4.7
Households using piped or well water as main source of drinking water (% of household)	83	78	81	80		79

Table 2: Benchmarking South Africa’s Infrastructure Performance: Water

rest of Sub-Saharan Africa (SSA) with 66% of the population having access,<sup>4</sup> compared to 15% for SSA. However, South Africa is lagging significantly behind—by about a third—its own income group of upper middle-income countries (87%). This suggests continued, large segments of the population in South Africa which remains unserved, despite major gains from expanding the network over the past decade. A related (and corroborating) statistic focusing on households indicates that about 65% of all households in South Africa report having access to electricity compared to 23% for the SSA region and 74% upper middle-income countries. Compared with other regions of the world, South Africa performs better than South Asia and East Asia Pacific.

- **Affordability—pricing.** South African average end-user prices (US cents/kwh) are one of the cheapest in the world at 3 cents for residential and 2 cents for non-residential customers. By comparison, these user prices in upper middle-income countries are, on average, about 9 and 7 cents, respectively, while SSA rates are 6 and 5 cents. The world average is 9 cents for residential customers and 6 cents for non-residential customers. In South Africa, the low user prices do not reflect overall underpricing, as is the case in many developing countries with the attendant quasi-fiscal losses. Instead, it is a consequence of the rather low cost structure of what is considered a very well run state electricity company (ESKOM) and the fact that part of the capital stock has already been depreciated; hence, the fixed cost component of the electricity cost/price in South Africa is very low. However, this static picture is going to change soon. Specifically, the South African rates are likely to increase over the coming years as the electricity company, ESKOM, implements its major investment upgrading program aimed at rehabilitating and expanding its existing capacity and the distribution network. Part of the financing of this investment program will need to come from increased rates to accommodate higher fixed costs arising from the new investments. When it comes to pricing, this will require careful thought to the rebalancing/design of tariffs to balance the objectives of access, efficiency, revenue and affordability.
- **Quality—technical efficiency.** Measured by the percentage of transmission and distribution losses, technical efficiency of the electricity sector is quite strong. Electric power transmission

<sup>4</sup>The database observation for South Africa is from 2002. More recent country data suggests an access rate of 70% (UNDP/World Bank, 2005), but the overall comparative conclusion here remains the same.

	South Africa	SSA	Mid. East & S. Africa	South Asia	East Asia Pacific	Latin America & Carib.
Teledensity (total telephone subscribers/1000 people)	408	99	292	72	172	433
Mainlines Teledensity (mainlines subscribers/1000 people)	107	31	129	35	76	192
Cellular Teledensity (cellular subscriber/1000 people)	364	73	167	37	96	249
Households with own telephone (% of household)	28	4	24	4	9	23
Cost of local call (US cents/3minutes)	15	10	6	4	5	7
Cost of phone call to the US (US cents/3minutes)	58	497	281	536	450	325
Cost of cellular local call (US cents/3 off-peak minutes)	25	42	52	17	42	57
Commercial perception of telephone/fax infrastructure quality (1=worst 7=best)	5.1	4.3	5.8	4.3	5.2	46
Commercial perception of availability of mobile or cellular telephone (1=worst 7=best)	6.3	5.7	5.9	5.9	5.7	5.5
Commercial perception of Internet access in schools (1=worst 7 = best)	3.6	2.8	3.5	2.7	3.4	2.8
Commercial perception of postal efficiency (1=worst 7 = best)	3.3	3.7	4.9	3.3	4.2	3.1
Phone faults (reported 100/mainlines)	48	57	23	97	39	24
Unmet demand (% of main telephone lines in operation)	1	50	26	24	13	17
	Europe & Central Asia	Low Income	Middle Income	Upper Middle Income	High Income OECD	World
Teledensity (total telephone subscribers/1000 people)	547	64	468	635	1393	501
Mainlines Teledensity (mainlines subscribers/1000 people)	224	29	193	261	572	213
Cellular Teledensity (cellular subscriber/1000 people)	325	37	280	381	827	296
Households with own telephone (% of household)	43	6	22	13		13
Cost of local call (US cents/3minutes)	7	8	7	9	15	9
Cost of phone call to the US (US cents/3minutes)	325	504	309	305	128	335
Cost of cellular local call (US cents/3 off-peak minutes)	40	40	49	54	57	49
Commercial perception of telephone/fax infrastructure quality (1=worst 7=best)	5.3	3.4	5.3	5.6	6.6	5.5
Commercial perception of availability of mobile or cellular telephone (1=worst 7=best)	6.0	5.0	5.9	6.0	6.7	6.1
Commercial perception of Internet access in schools (1=worst 7 = best)	3.7	2.1	3.4	3.8	5.4	4.0
Commercial perception of postal efficiency (1=worst 7 = best)	4.3	3.1	3.9	4.4	6.2	4.6
Phone faults (reported 100/mainlines)	34	64	25	18	11	37
Unmet demand (% of main telephone lines in operation)	8	47	12	4	0	21

Table 3: Benchmarking South Africa's Infrastructure Performance: ICT

	South Africa	SSA	Middle East & North Africa	South Asia	East Asia Pacific	Latin America & Caribbean
Road density in terms of population (road-km/1000 people)	6.1	3.3	4.8	2.4	4.2	5.7
Road density in terms of land (road-km/1000 sq km)	227.2	155.7	608.9	544.6	276.4	712.7
Rail density in terms of population (rail-km/1000 people)	0.44	0.18	0.1	0.05	0.14	0.33
Rail density in terms of land (rail-km/1000 sq km)	16.5	3.65	5.5	18.79	8.85	14.78
Travel time to work in main cities (minutes/one way work trip)	35	34	25	27	36	29
Commercial perception of services delivered by road department/public works (1=worst 7=best)	5.3	3.7	5.5	3.9	4.4	4.0
Commercial perception of port facilities (1=worst 7=best)	4.7	3.8	4.1	3.4	3.6	3.1
Commercial perception of rail road services (1=worst 7=best)	4.3	3.2	3.5	3.6	3.1	1.5
Commercial perception of air transport services (1=worst 7=best)	5.6	4.5	4.9	4.2	4.4	4.2
Paved roads (% of total roads)	21	25	56	38	32	3.6
	Europe & Central Asia	Low Income	Middle Income	Upper Middle Income	High Income	World
Road density in terms of population (road-km/1000 people)	8.6	3.0	7.0	9.2	17.3	6.7
Road density in terms of land (road-km/1000 sq km)	580.3	181	702	1076.4	1340.4	840.6
Rail density in terms of population (rail-km/1000 people)	0.47	0.13	0.4	0.51	0.53	0.33
Rail density in terms of land (rail-km/1000 sq km)	33.22	9.33	23.26	31.33	46.22	23.12
Travel time to work in main cities (minutes/one way work trip)	29	33	29	29	32	31
Commercial perception of services delivered by road department/public works (1=worst 7=best)	3.6	3.4	4.1	4.1	4.3	4.0
Commercial perception of port facilities (1=worst 7=best)	3.6	2.6	3.6	3.8	5.4	4.2
Commercial perception of rail road services (1=worst 7=best)	3.7	2.7	2.7	2.9	4.8	3.4
Commercial perception of air transport services (1=worst 7=best)	3.9	3.6	4.4	4.5	5.7	4.8
Paved roads (% of total roads)	76	30	52	57	82	50

Table 4: Benchmarking South Africa's Infrastructure Performance: Transport

and distribution losses are 8% of total output for South Africa, which outperforms both SSA (19%) and upper middle-income countries (14%). This performance is more comparable to the high-income group of OECD countries (6%).

- **Quality–perceptions.** In terms of commercial perception of electricity service, South Africa ranks amongst the best with 5.8 rating out of 7 (7=best 1=worst). This compares favorably with high-income OECD countries (6.3) and is higher than upper middle-income countries (5.2). South Africa also performs well on commercial perception of public agency electricity provider with a ranking of 6 out of 7. This ranking is only matched by Middle East and North Africa (MENA) and is higher than upper middle-income (5.3) and high-income OECD (5.3). As noted above, however, this may reflect a selection bias in that only customers with access to service would normally respond to this question. In that sense, the indicators of the lack of access (about 34% of the population) and the generally favorable perceptions of service cover essentially different segments of the population.

### 3.2 Water & Sanitation

Overall, South Africa’s performance in access to water lags behind its benchmark upper middle-income group, essentially because of the much lower access in rural areas, and even more so in sanitation. In terms of the overall average, the quality of the drinking water as measured by the percentage of households using piped or wellled water in the aggregate is better than in its benchmark group, but this is because of the very high performance on this indicator in urban areas. (The database does not have information on affordability/pricing.). By contrast, rural households score lower than the benchmark and also lower than almost all world regions, including Sub-Saharan Africa. Apparently, while access and quality do not appear to be major problems in urban areas, the performance in these dimensions in rural areas lags seriously behind most comparator groups. This favorable urban picture should also be qualified by the fact that in South Africa, some communities in urban areas, referred to as “peri-urban” areas (e.g., parts of Soweto, Diepsloot etc.) that may or may not belong formally or statistically to their larger urban agglomerations, often lack quantity and quality of basic service, such as water and sanitation. Figure 6 illustrates.

- **Access.** Overall access to *water* is below the benchmark upper middle-income countries, because of the significantly lower access in rural areas. Specifically, the percentage of the population with access to improved water is 87%, which is significantly higher than SSA (64%) but lags behind upper middle-income countries (93%). South Africa compares well to the broader group of middle-income countries (both lower and upper middle-income) (89%), but is noticeably below high-income OECD (99%). However, looking at the rural/urban differences, rural South Africa (73%) lags far behind the upper middle-income rural average (85%) for conciseness, not shown in Figure 6), while South African urban areas (98%) do better than other upper middle-income countries (96%). About 67% of the population has access to improved *sanitation*, which is almost twice the SSA level and slightly above the world average (64%). However it is still far behind upper middle-income countries (86%) and high-income OECD countries (100%).
- **Quality—technical.** The percentage of households using piped or wellled water as main source of drinking water is 85% for South Africa, which is higher than in upper middle-income group (82%), East Asia and Pacific (80%), and SSA (78%), but below both Middle East & North Africa (89%) and South Asia (89%). Once again, however, this figure masks a stark contrast between urban and rural areas. The share of rural households in South Africa using piped or wellled water as main source of drinking water is only 65% compared to 98% for urban areas. Significantly, the rural area percentage for South Africa is lower than the comparable rural household percentages in all the world region, including SSA (71%), except for East

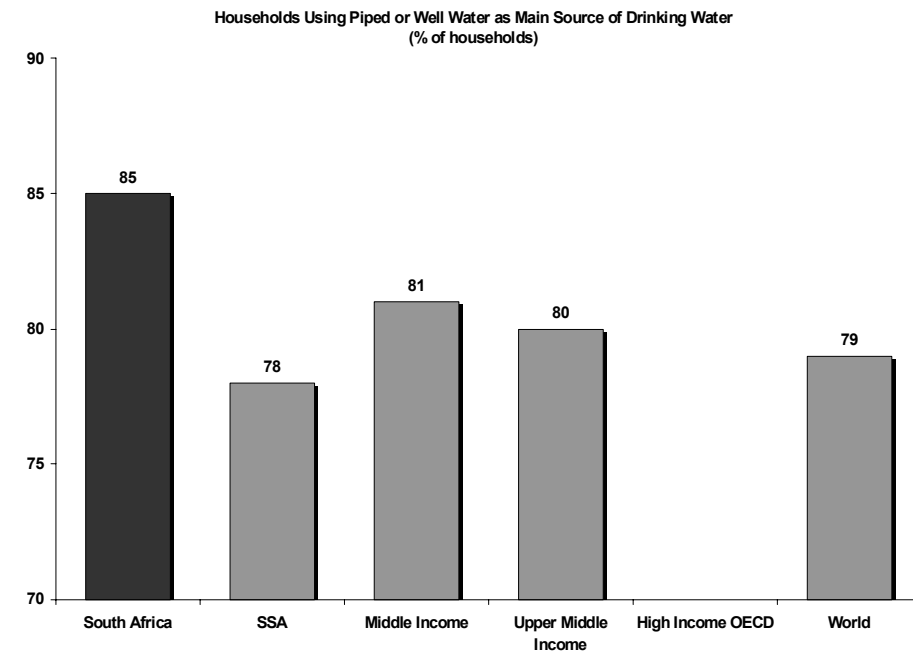
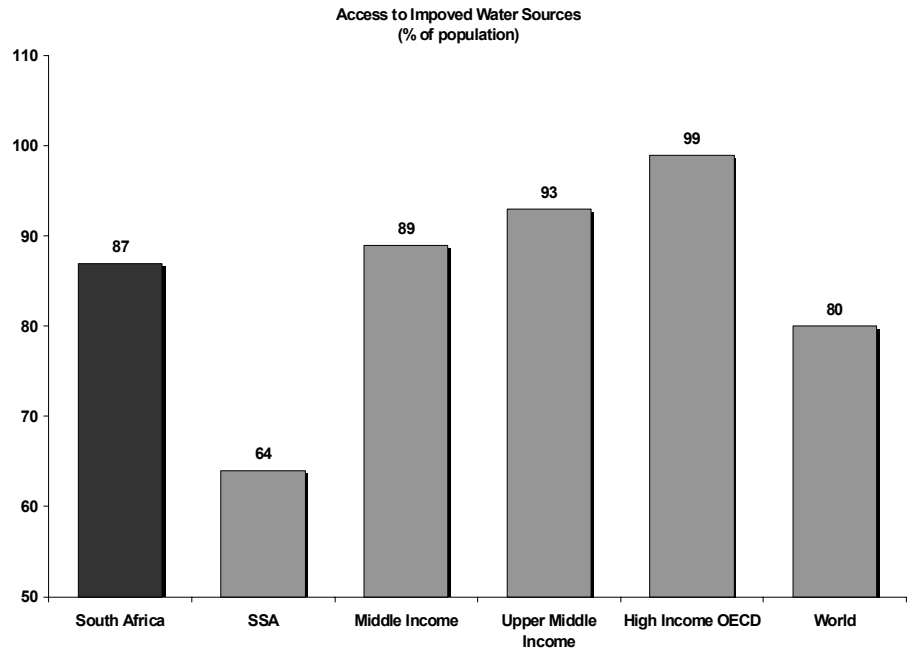


Figure 6: Benchmarking South African Water Provision Internationally.

Asia & Pacific and Latin America & the Caribbean which have very similar performance (64% each); the latter is the region that has been documented as having a significant backlog of infrastructure deficiencies that, *inter alia*, contributed to its low growth (Leipziger, 2001). By contrast, South Africa's performance on this indicator in urban areas (98%) is the highest (together with South Asia) among all world regions and low- and middle-income countries.

- **Quality—perception.** At 5.7 out of 7, South Africa gets one of the highest ratings in commercial perception of water service. The rating for high-income OECD countries is 5.2 and SSA (4.2). Again, this may represent the view of the satisfaction with service by the segments of the population already enjoying access. Also, it may reflect the “urban bias” of the perception indicator with vast differences between the quality of service in urban versus rural communities.

### 3.3 Information and Communications Technology (ICT)

In general, the ICT sector in South Africa displays performance akin to that of the energy and water with some interesting variations in the prices of various services. At first glance, the overall indicator of access appears good, but supplementary indicators suggest less than expected quality and major gaps in service delivery, quality, and even access in rural areas. For example, South African households pay some of the highest local rates in the world, and the low affordability is reflected in low telephone ownership in rural areas. By contrast, off-peak cellular service and international calls to the United States are provided at low, competitive prices, catering largely the wealthier segments of the population. Nevertheless, in the local debate on the cost issue, there are indications that high international prices prevail for calls to many other destinations. Moreover, quality, as measured by reported faults per year per 100 mainlines, appears surprisingly low for an upper middle-income country. Figure 7 illustrates.

- **Access.** In terms of mainline teledensity, the picture is similar to energy and water whereby South Africa has better penetration than SSA, Middle East & North Africa, South Asia, and East Asia Pacific countries but lags somewhat behind middle-income countries and Latin America & the Caribbean. However, cellular teledensity is reasonably comparable to upper middle-income countries though it still lags high-income OECD. In terms of household ownership of telephones, only 28% of South African households own a telephone, which is much higher than the upper middle-income benchmark of 13% and comparable figures for SSA and South Asia regions, both at 4%, and East Asia Pacific (9%). But it is still a long way from Europe and Central Asia (ECA) at 43%, suggesting considerable remaining room for growth. The ownership rates in rural areas, however, are seven times lower (6%) than in urban areas (43%) in South Africa, making the rural rate more comparable to those in the entire group of middle-income countries.
- **Affordability—pricing.** A 3-minute local call in U.S. cents is one of the most expensive in the world in South Africa at 15 cents, which is three times the cost in South Asia and East Asia Pacific and equal to the high-income OECD countries. This reflects monopolistic market structure in local services. Local debate in South Africa has also emphasized high cost structure, including on the international call market segment. Nevertheless, within the cellular and international segment, some calls are very competitive. For example, the database used for this benchmarking shows that in terms of the cost of three off-peak minute cellular local calls (25 cents), South Africa is one of the cheapest compared with upper middle-income (54 cents) and high-income OECD (59 cents) where costs are twice as high. In addition, an international, 3-minute call to the United States (58 cents) is much lower than in upper middle-income countries (305 cents) and high-income OECD countries (128 cents).

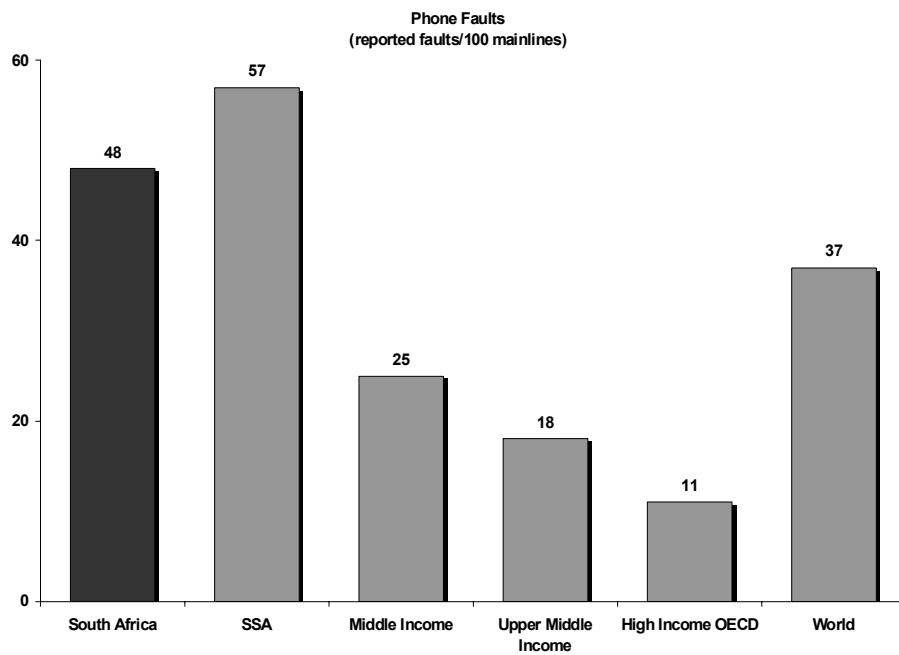
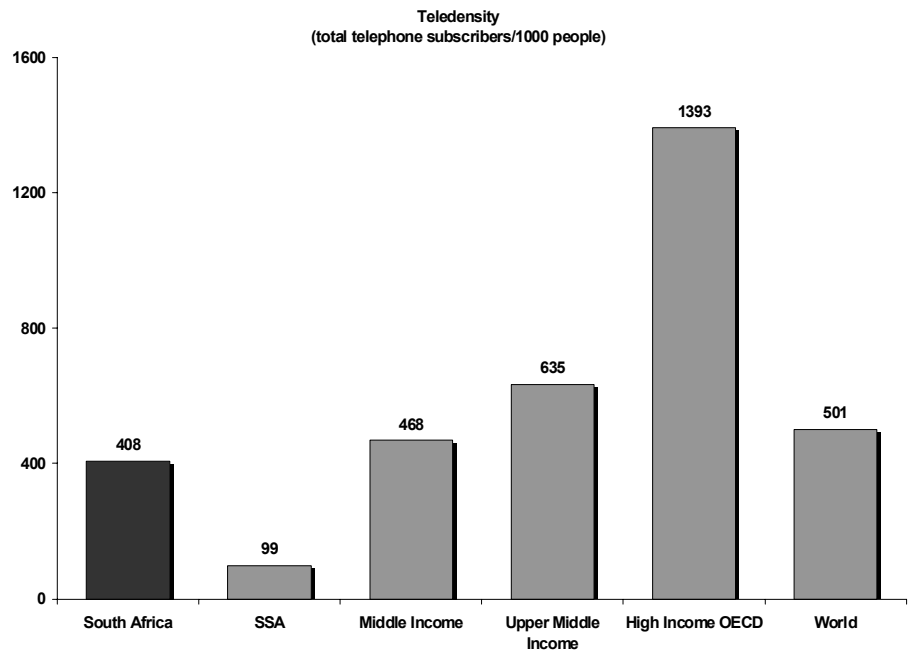


Figure 7: Benchmarking South African ICT Performance Internationally.

- **Quality—technical.** Perhaps surprisingly, reported faults per 100 telephone mainlines (per year) are very high (48) by upper middle-income (18) country standards and are closer to the SSA average (57). High income OECD country rates—towards which South Africa may aspire in this highly globalized sector—are more than four times lower (11%).
- **Quality—perception.** Interestingly, perceptions of ICT are more closely aligned to the other indicators of performance. Commercial perception of telephone infrastructures rating is 5.1 out of 7 compared to 6.6 for high-income OECD countries and 5.6 in upper middle-income countries. Commercial perception of availability of mobile telephones is much higher at 6.3 (vs. 6 for upper middle-income), which is only better in high-income OECD at 6.6. Commercial perception of internet access in schools is low by high-income OECD standards, 3.6 vs. 5.4 and slightly lower than upper middle-income countries (3.8). Commercial perception of postal efficiency is even worse at 3.3, which is only just above the average for low-income countries (3.1), and almost half the rating given to high-income OECD and 4.4 for upper middle-income countries.

### 3.4 Transport

Transport sector’s overall performance indicators show South Africa lagging behind its comparator country groups and several other regions. This finding must be taken with caution though, reflecting at least two factors at play. First, it may simply reflect the more idiosyncratic territorial distribution of population and economic activity in a large, coastal, resource-rich country such as South Africa than is the case for the average country group. However, it also reflects the legacy of the Apartheid era and wide inequalities in infrastructure stocks and service delivery between the privileged group and the majority of the population. Perceptions of the quality of service delivery are relatively favorable. Figure 8 illustrates.

- **Access.** Road density in terms of population (road-kilometers per 1,000 people) is twice the average for low-income countries and higher than Middle East & North Africa, and East Asia Pacific. However, at 6.1 road-km per 1000 people it is only a third of the density of high-income OECD countries and two-thirds of upper middle-income countries. Interestingly, Brazil has significantly higher road density in terms of population (10), while Indonesia and Malaysia score lower (1.7 and 2.8). Road density in terms of land (road-kilometers per 1,000 sq km) is very low (227) when compared with many other groups and is only higher than that of SSA (155) and low-income countries (181). It is also much lower than in benchmark upper middle-income countries (328). At the same time, it is important to recognize that these road density indicators for South Africa may be somewhat misleading in comparative perspective because of the specific territorial configuration of population density that is concentrated in comparatively small parts of an otherwise large national territory. To the extent that South Africa has lower than average population density and greater differences in the concentration of population and economic activity (parts of the country are very poorly inhabited with very little or no commercial activity) in different regions, the indicator may overstate the gap with comparator countries. For example, South Africa performance on density in terms of land appears similar to Brazil (203 road kilometers per 1,000 sq km), another resource-rich, coastal country with vast sparsely populated territory; Indonesia and Malaysia also have very similar road density in terms of land (203 and 200 road kilometers per 1,000 sq km, respectively).<sup>5</sup> *Rail* lines density in terms of population is very high when compared to SSA, Middle East & North Africa, South Asia, East Asia Pacific, and Latin America & the Caribbean. It is slightly higher than the average for all middle-income and just below the benchmark upper-income group. South Africa’ rail lines density in terms of land, however, is far behind those

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<sup>5</sup>Estache and Goicoechea (2005), Table A4-2, pp. 105-07.

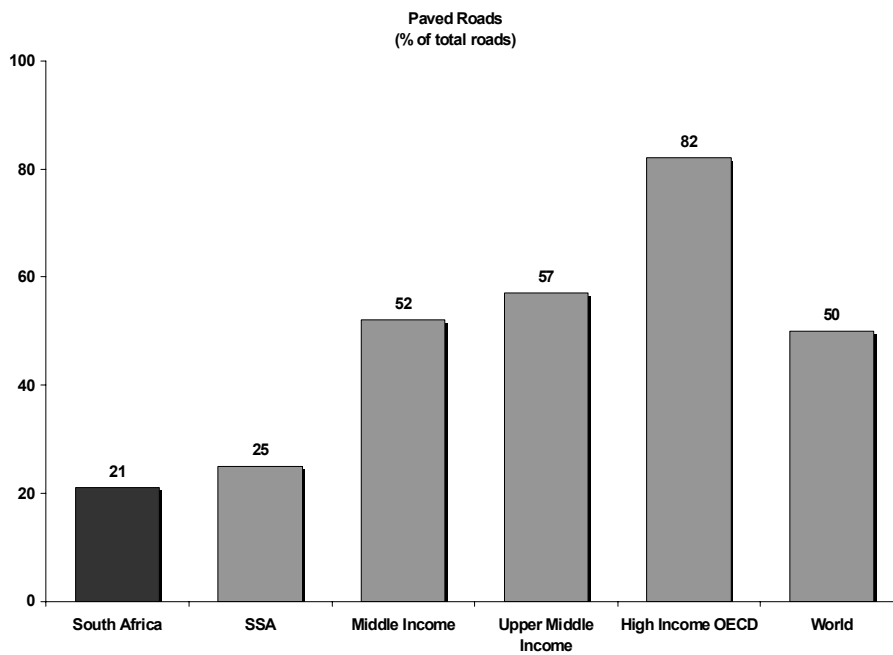
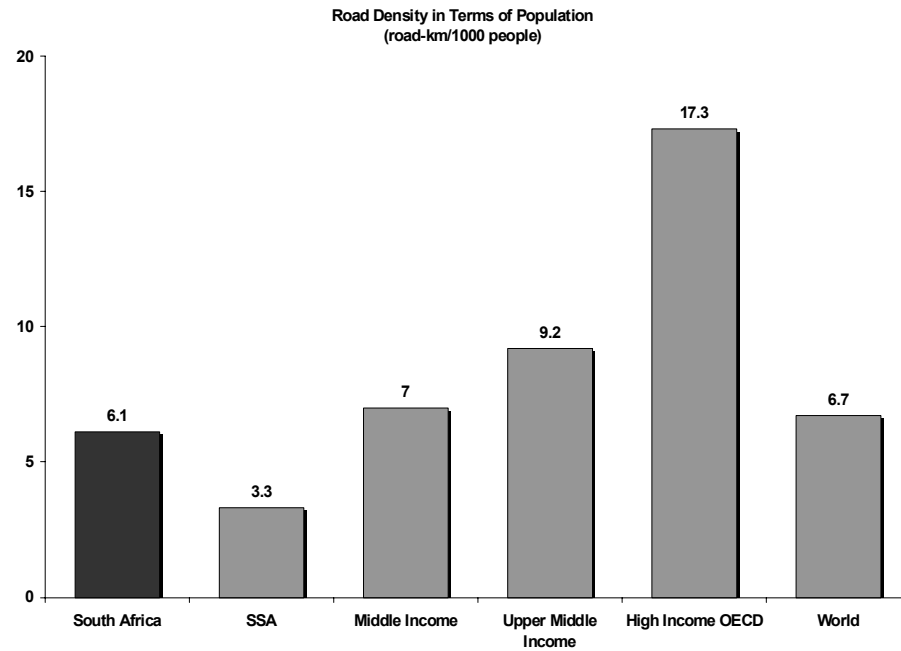


Figure 8: Benchmarking South African Roads Infrastructure Internationally.

in middle-income and high-income countries and is also behind South Asia but ahead of other groups.

- **Quality.** According to the database, South Africa has one of the lowest percentages of paved roads at 21%. This is lower than SSA (25%) and low-income countries (30%) and far behind upper middle-income (57%) and high-income countries (82%). This may reflect the legacy of the strong urban bias and the economic configuration of economic activity inherited from the Apartheid era. Two important caveats are in order here. First, local information on paved roads shows a higher percentage (31%) that was already achieved in 1994;<sup>6</sup> as of writing, we could not reconcile this with the number from the benchmarking database that on this indicator originates in the World Bank’s World Development Report 2004. If the 31% figure is taken at face value, it would imply better performance in South Africa than in SSA region, but still worse than in upper middle-income countries. Second, the quality of the paved roads variable itself probably hides considerable cross-country variation: paved roads in South Africa may be of higher quality than those in most SSA countries, but this variation would presumably be much less relevant for the upper middle-income group. As a result, irrespective of which figure is used (21% or 31%), it is safe to say that South Africa compares less favorably with its benchmark group of upper middle-income countries, and lags significantly behind high-income OECD countries.
- **Quality—perception.** South Africa has one of the longest travel times to work in main cities (35 minutes) when compared to upper middle-income (29 minutes), high-income OECD (32 minutes) and SSA (34 minutes) countries. The world average is 31 minutes. This also reflects the inherited road network from the pre-1994 era that now results in the majority of the population often facing long and costly commute; in some communities, commuting costs may reach prohibitive levels as a proportion of the prospective wage, thereby discouraging job search and earning opportunities for the poor.<sup>7</sup> Commercial perception of service delivered by road department is one of the highest in the world at 5.3, only better in MENA at 5.5. The average for high-income OECD countries is 4.3. Commercial perception of *port* facilities, and railroad services are lower than road but are still much higher than in low- and middle-income countries and are not too far behind the ratings of high-income OECD countries. Commercial perception of *air transport* services gets the highest ranking of all transport sectors at 5.6, which compares well with 5.7 for high-income OECD countries.

### 3.5 Large Differences from the Benchmark

As a conclusion to the detailed benchmarking of South Africa’s infrastructure performance discussed above, it might be useful to highlight some of the large differences—positive and negative—between South Africa and comparator groups of countries, especially the benchmark upper middle-income group (Table 2). With appropriate caveats, this selection of indicators showing particularly large deviations from the benchmark can be taken as indicative of the possible significant strengths and weaknesses in infrastructure performance. Together with the additional, country specific indicators and analysis of sectors, it is hoped that this could help focus the attention of policymakers on those areas where performance improvements are most needed.

In a nutshell, the *electricity* sector epitomizes the stark duality of the broader South African economy with a modern “first” economy, and the underserved “second”, largely rural economy. As a result, indicators of internal technical efficiency (e.g., losses in distribution/transmission) and low prices are quite favorable compared with the benchmark country group as well as other comparators.

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<sup>6</sup>See Perkins et al (2005).

<sup>7</sup>Department of Transport (1999) estimated that based on OHS data for 1995 the average public transport trip in South Africa was 20km, about twice the length experienced in Asian developing countries. South African commuters spent about 40% more time travelling than their Asian counterparts.

	South Africa	Benchmark Upper Middle Income	SSA	World	South Africa's performance vs. Benchmark
<b>Energy-Electricity</b>					
Energy: Access to Electricity Network (% of Population)	66	87	15	60	Lower
Energy: Households reporting access to electricity (% of households)	65	74	23	45	Lower
Electricity: Average End-User Prices (U.S. cents/k Wh) (Residential Non-Energy: Residential)	3/2	9/7	6/5	9/6	Higher
Energy: Electric Power Transmission & Distribution Losses (% of total output)	8.0	14.0	19.0	14.0	Higher
<b>Water</b>					
Water: Access to Improved Sanatation (% of population)	67	86	37	6.4	Lower
<b>ICT</b>					
ICT: Teledensity (total telephone subscribers 1000 people)	408	635	99	501	Lower
ICT: Mainlines Teledensity (mainlines subscribers 1000 people)	107	261	31	213	Lower
ICT: Cost of Local Phone call (U.S. cents/3 minutes)	15	9	10	9	Lower
ICT: Cost of Phone calls to the U.S. (US cents/3 minutes)	58	305	497	335	Higher
ICT: cost of cellular local call (U.S. cents/3 off-peak minutes)	25	54	42	49	Higher
ICT Phone Faults: (reported faults 100 mainlines)	48	18	57	37	Lower
<b>Transport</b>					
Transport: road density in terms of population (road-km 1000 people)	6.1	9.2	3.3	6.7	Lower
Transport: road density in terms of land (road-km 1000 sq km)	227.2	1076.4	155.7	840.6	Lower
Transport: travel time to work in main cities (minutes/one way work trip)	3.5	29	34	31	Lower
Transport: Paved roads (% of total roads)	21	57	25	50	Lower
Transport: Rail lines density in terms of land (rail-km 1000 sq km)	16.5	31.33	3.65	23.12	Lower

Table 5: SA's Infrastructure Performance

These are comparatively strong dimensions of South Africa’s performance in electricity. However, indicators of access to network and reported access to service by households fall significantly short of what would be expected of a well-run sector in an upper middle-income country. Clearly, while much was done in recent years to extend the service to the previously unserved population, much more remains to be done, especially in rural (and peri-urban) areas.

In *water and sanitation*, access is much lower than in benchmark upper middle-income countries, especially in rural areas. Quality indicators also indicate relative shortfalls. To the extent that the shortfalls reflect the internal imbalances between supply and demand for this vital service that is closely monitored internationally under the Millennium Development Goals (MDG) because of its multiple links with health and the general wellbeing, expanding access and quality in this sector may be particularly important.

Similar duality seems to be reflected in performance indicators of the *information and communications technology*. Pricing of services catering to the wealthier segments of the population and the large, internationally oriented enterprise sector—cellular calls and some international calls (to the U.S., for example)—reflect generally good and competitively provided services. We note, however, that in the current debate, broadband speed and access in particular remain a strong area of concern. Arguably, broadband services are of particular concern to economic activity (Reynolds 2005). Further, local service rates, which may be used relatively heavily by the middle class and the poorer segments of the population, are among the highest in the world. Moreover, access rates, especially in poor, rural areas are much lower compared with the benchmark. The implication is that more could be done to raise competitiveness in the local service segment and generally expand access to the rural areas.

Finally, in *transport*, both road and rail, indicators of performance show worse performance than the benchmark upper middle-income countries. However, with respect to roads these differences require more careful interpretation of the evidence, given South African climatic and geographical peculiarities. While in-depth comparison of a more detailed battery of road indicators of quality and quantity of service would be needed to draw firmer conclusions, the indicators presented may suggest the need for another look at the adequacy of the road and rail network to service the needs of a growing, upper middle-income countries, including large segments of the rural population.

### 3.6 Reflections on the Benchmarking Evidence

In sum, we have benchmarked South Africa’s infrastructure performance on all four major infrastructure sectors in terms of key indicators of access, affordability-pricing, and quality using the new World Bank database of infrastructure sector outcome indicators from 207 countries. The broad results of the benchmarking are probably not surprising for a reader acquainted with the dual structure of the South African economy and society. But they do provide a broad international comparative perspective on the performance of South African infrastructure.

Compared to the benchmark and other country groupings, South Africa’s utilities, overall, provide solid service at reasonable quality and, in some cases, very competitive prices. But there remain significant shortfalls relative to benchmarks in all infrastructure sectors, largely related to limited access and less than expected quality, especially in rural areas where large numbers of South Africa’s poor live with limited or no access to service.

To catch up with its income group in terms of these indicators, South Africa will need to improve access to and quality of electricity and water and sanitation in presently unserved areas. Indicators of transport performance, while less definitive, point in the same direction. Even in telecom, the most globalized and “modern” infrastructure sector, access to rural areas seems lacking and pricing of local services uncompetitive. Moreover, to put it simply, if South Africa is to strengthen its overall infrastructure performance, it will need to improve these dimensions’ performance in the sectors faster than the average country in the upper middle-income group while maintaining or improving its position in the already strong areas of performance. This will not be easy in competition within a

group of countries all aspiring to move to much higher levels of income and ambitious poverty reduction. But catching up with these relative shortfalls may also help South Africa reduce its economic inequities and poverty rates and, therefore, meet the infrastructure related Millennium Development Goals (MDGs). It could also help address some of the concerns about South Africa's external and industrial competitiveness and service delivery that in good part depends on the efficiency and capacity of network utilities to deliver basic services to population and businesses alike.

## 4 Theoretical Background

The core rationale for infrastructural investment that emerges from the theoretical literature is that it raises the marginal product of other capital used in production.

Consider a framework in the spirit of Barro (1990). Posit an endogenous growth model in which government owns no capital and does not produce services, but purchases private-sector output to provide productive services which serve as inputs in private-sector production or as consumption services to households. The services are purchased under a balanced budget constraint, financed by a flat-rate income tax without cost recovery.

By way of condensed illustration, under closed-economy conditions, Cobb-Douglas technology and homogeneity of degree one, our labor-intensive production function might be:

$$y = A \cdot g^\alpha \cdot k^{1-\alpha}, \quad 0 < \alpha < 1 \quad (1)$$

where  $y$  denotes output per worker,  $A > 0$  the level of technology,  $g$  productive government expenditure (or services) per worker with no congestion effects, and  $k$  an inclusive measure of private capital per worker. It follows that the marginal products of  $g$  and  $k$  are, respectively,  $\partial y / \partial g = A\alpha (k/g)^{1-\alpha} > 0$ , and  $\partial y / \partial k = A(1-\alpha) (g/k)^\alpha > 0$ . The positive effect of infrastructure on the marginal product of physical capital is clearly illustrated – analogous to the Arrow (1962) and Romer (1986) learning-by-doing growth models.

Suppose further that a representative, infinitely-lived household seeks to maximize overall utility:

$$U = \int_0^\infty u(c) e^{-\rho t} dt \quad (2)$$

with  $u(c) = (c^{1-\sigma} - 1) / (1 - \sigma)$ , where  $c$  is consumption per worker,  $-\sigma$  is the elasticity of marginal utility with respect to consumption ( $\sigma > 0$ ), and  $\rho > 0$  is the constant rate of time preference.

Since the balanced budget constraint imposes a tax rate of  $g/y$ , the steady state growth rate, denoted  $\gamma$ , can be shown to be:

$$\gamma = \frac{1}{\sigma} \left[ \left(1 - \frac{g}{y}\right) \cdot A \cdot \left(\frac{g}{k}\right)^\alpha \cdot (1 - \alpha) - \rho \right] \quad (3)$$

It follows that:

$$\frac{d\gamma}{d(g/y)} = \left(\frac{1}{\sigma}\right) \cdot A \cdot \left(\frac{g}{k}\right)^\alpha \cdot \left(\frac{\partial y}{\partial g} - 1\right) \quad (4)$$

consider a policy intervention under which  $d(g/y) > 0$  (given any level of  $k$ ). From equation (3) it follows that  $\gamma$  decreases due to the tax effect in  $g/y$ , and increases due to the increase in  $g/k$  that is the consequence of the positive effect on the marginal product of  $k$ . The net effect depends on which of the two impacts is dominant. Since  $g/k = (A \cdot g/y)^{1/(1-\alpha)}$ , and hence  $d(g/k)/d(g/y) > 0$ , it follows from equation (4) that the net effect of  $d(g/y) > 0$  is conditional on the positive but decreasing  $\partial y / \partial g$ , with  $d\gamma/d(g/y) > 0$  for  $\partial y / \partial g > 1$ ,  $d\gamma/d(g/y) < 0$  for  $\partial y / \partial g < 1$ , and  $\gamma_{\max}$  at  $\partial y / \partial g > 1$ . Thus the capital productivity effect dominates at low  $g/y$ , and the tax effect at high  $g/y$ .

A clear, theoretical link between output and government infrastructure investment follows. Infrastructure expenditure ( $g$ ) can prevent diminishing returns to scale in private-sector capital ( $k$ ), raise the marginal product of private-sector capital ( $\partial y/\partial k$ ), and raise the rate of growth of output ( $\gamma$ ). An equally important message is that government intervention of this nature can raise economic growth *only within limits*. Once the marginal product of government productive expenditure falls below unity, further increases in  $g/y$  are *harmful* to economic growth, since the tax effect comes to dominate the capital productivity effect.

In this section the paper examines two distinct questions. First, we explore whether, to what extent, and through what channels infrastructure in South Africa impacts on productivity. We do so by examining two mechanisms explained below. Second, we estimate and then forecast infrastructure demand in South Africa to provide an indication of required infrastructure investment over the next decade. The following subsections outline the relevant methodologies.

## 4.1 Infrastructure and Productivity

We employ two approaches in establishing the existence of an impact of infrastructure on productivity.

The first examines whether infrastructure has an impact on labour productivity. The specification for this exploration is derived from Bogetić and Sanogo (2005). Though the objective of the Bogetić and Sanogo (2005) is to isolate factors influencing regional location decisions by industries intranationally in Côte d’Ivoire, implicit within the model is that infrastructure has an impact on labour productivity, and hence will influence decisions on the regional location of industries. The corollary to this link, which finds confirmation for Côte d’Ivoire, is that infrastructure at the national level should certainly impact output per worker. The general specification estimated in Bogetić and Sanogo (2005) is:

$$\left(\frac{Y}{L}\right)_{i,t} = f\left(\frac{K}{L}, S, U, I\right)_{i,t} \quad (5)$$

where  $Y$  denotes real value added of industry  $i$  in period  $t$ ,  $L$  the size of the labour force,  $K$  the size of the physical capital stock,  $S$  a vector of variables measuring scale economies,  $U$  urbanization, and  $I$  denotes a vector of variables measuring infrastructural capital stock.

The specification provided by equation (5) is explicit in considering public capital stock to be a factor of production that enters directly into the aggregate production function. Not all models of the impact of infrastructural investment on output follow this route. In Barro (1990), for instance, the impact of public capital on output may indeed be direct, or may exercise its influence by raising the marginal product of the private sector capital stock. Under this specification, infrastructure would impact not on output per worker, but on total factor productivity.

Given endogenous growth theory, measurement of efficiency improvements must be suitably modified. A useful overview of the computation of TFP growth under endogenous growth is provided by Barro (1998). While there are undoubtedly a number of limitations of growth accounting as a means of isolating technological change, the approach remains in wide-spread use due to the simplicity and consistency of its internal structure.<sup>8</sup>

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<sup>8</sup>The literature on growth accounting, its strengths and weaknesses, has come to be vast since the contributions of Denison (1962, 1967, 1974). The first crucial limitation of simple decomposition approaches is that its factor inputs are not disaggregated by quality classes, with resultant upward bias in TFP measures. See, for instance, Jorgenson and Griliches (1967), and Jorgenson, Griliches and Fraumeni (1987). Our empirical results reflect further on this. A second limitation attaches to the assumption that factor social marginal products coincide with observable factor prices. One response to this difficulty is provided by recourse to a regression approach, in order to obtain direct evidence on factor elasticities. However, the regression approach is subject to its own, and severe limitations, since factor input growth rates are likely endogenous, and factor input growth rates are likely to be subject to considerable measurement error. Both Hulten (2001) and Bosworth and Collins (2003) confirm the continued usefulness of TFP computations.

Perhaps the most significant limitation of the simple decomposition approach for present purposes is the assumption of constant returns to scale. Since endogenous growth theory directs its most fundamental challenge against traditional growth theory on this very assumption, this constitutes a fundamental limitation. Fortunately the limitation can be addressed for estimation purposes. We outline three alternatives corresponding to three alternative conceptions of endogenous growth. Where we have *increasing returns due to spill-over effects*, it follows that:<sup>9</sup>

$$\begin{aligned} TFP &= \frac{\dot{Y}}{Y} - \alpha \frac{\dot{K}}{K} - (1 - \alpha) \frac{\dot{L}}{L} \\ &= \frac{\dot{A}}{A} + \beta \frac{\dot{K}}{K} \end{aligned} \tag{6}$$

where  $\frac{\dot{A}}{A}$  captures exogenous technological progress, and  $\beta \frac{\dot{K}}{K}$  captures the spill-over effect due to the factor of production with a weight greater than that implied by its income share (here given by  $\alpha$ ).

An early example of this approach is given by Grilliches (1979), who proxied for  $\frac{\dot{K}}{K}$  by means of R&D activity. Under the now more conventional approach of Romer (1986), the appropriate growth rate is in terms of physical capital stock, while the Lucas (1988) specification would require *additional augmentation with investment in human capital* through which the spill-over channel runs in the Lucas specification.

Under a Schumpeterian approach with an *increasing variety of intermediate (capital) goods* (denoted  $X$ ),<sup>10</sup> we have instead:

$$\begin{aligned} TFP &= \frac{\dot{Y}}{Y} - s_L \frac{\dot{L}}{L} - s_X \frac{\dot{X}}{X} \\ &= \frac{\dot{A}}{A} + b \frac{\dot{N}}{N} \end{aligned} \tag{7}$$

where terms are as defined above,  $s_i$  denotes the income share of factor  $i$ , and  $\frac{\dot{N}}{N}$  denotes the endogenous expansion of intermediate (capital) good varieties (i.e. technological progress). Under the alternative Schumpeterian quality ladders conception<sup>11</sup> a symmetrical derivation follows, with the  $\frac{\dot{N}}{N}$  term coming to denote the overall quality growth rate instead of the variety growth rate. The only remaining difference between the two Schumpeterian conceptions relates to the  $b$  coefficient. Under the varieties approach,  $b$  can be shown to equal  $(1 - \alpha)$  where  $\alpha$  has the usual elasticity interpretation with respect to intermediate inputs, while under the quality ladder interpretation  $0 < b < 1$ , with  $b \rightarrow 1$  associated with “high,” and  $b \rightarrow 0$  denoting “small” quality differentials.

The usual proxy for the  $\frac{\dot{N}}{N}$  term under both Schumpeterian approaches is given by the ratio of the flow of R&D to the market value of the stock of past R&D. While the flow measure is generally readily available, the stock measure is not. Fortunately, from the relationship given by equation (7) it can be readily demonstrated that  $TFP$  growth is linear in the ratio of the R&D flow measure to per capita output, easing the requirements of empirical specification.<sup>12</sup>

A remaining problem with the empirical specification is that a danger of simultaneity bias continues to lurk in the above specifications. Where R&D proves successful in stimulating TFP growth, firms have an incentive to respond by raising R&D expenditure further. There is thus no reason to suppose that R&D activity would not respond to changes in productivity growth. In order to

<sup>9</sup>For a fuller discussion of this and the following derivations see Barro (1998).

<sup>10</sup>In the Romer (1990) or Grossman and Helpman (1991: ch3) vein.

<sup>11</sup>See the discussion in Aghion and Howitt (1992) and Grossman and Helpman (1991: ch4).

<sup>12</sup>Thus we can replace  $\frac{R\&D\ Flow}{Market\ Value\ of\ Past\ R\&D}$  with  $\frac{R\&D\ Flow}{Y/L}$ .

obtain reliable estimation results it is thus important to instrument the R&D measure. The most generic instruments relate to government policies toward R&D, the registration of patents, and other variables relating to the general enabling environment for private sector R&D activity.

R&D has found empirical support as a determinant of productivity growth.<sup>13</sup> Of course, innovation is unlikely to be determined by a single dimension such as R&D activity, however that is conceived. The empirical and theoretical literature has identified a range of other relevant conditioning variables,<sup>14</sup> including industrial bargaining characteristics,<sup>15</sup> product market characteristics (essentially industry concentration),<sup>16</sup> labour quality and human capital,<sup>17</sup> trade, international competition or openness of the economy,<sup>18</sup> foreign direct investment,<sup>19</sup> financial liberalization, and exchange rate overvaluation.<sup>20</sup>

Here we consider the possibility that infrastructure may similarly affect growth in TFP.<sup>21</sup>

We proceed with an application to South African data.

## 4.2 Establishing Infrastructure Needs

Fay (2001) and Fay and Yepes (2003) develop a methodology designed to identify the physical needs in infrastructural stocks. Basis of the methodology is the interaction of a demand for infrastructure, based on utility maximizing consumers, such that:

$$I_j^C = f(Y_j, q_I) \quad (8)$$

where  $I_j^C$  denotes the consumption of infrastructure by individual  $j$ ,  $Y_j$  denotes  $j$ 's income, and  $q_I$  the price of infrastructure. Profit maximization on the production side of the economy provides the standard first order condition:

$$\frac{\partial Y_i}{\partial I_i^P} = \frac{q_I}{w_i} \quad (9)$$

where  $Y_i$  denotes the  $i$ th firm's output,  $w_i$  the  $i$ th firm's output price, and  $I_i^P$  the production use of infrastructure.

This framework leads Fay (2001) and Fay and Yepes (2003) to the formulation of a reduced form demand for infrastructure in per capita format:

$$\frac{I}{P} = F\left(\frac{Y}{P}, \frac{q_I}{w}, Y_{ag}, Y_{ind}, A\right) \quad (10)$$

where  $P$  denotes population,  $Y_{ag}$  and  $Y_{ind}$  the output of the agricultural and industrial sectors respectively,<sup>22</sup> and  $A$  denotes technology.

<sup>13</sup>See for instance Lichtenberg and Siegel (1991), and Hall and Mairesse (1995).

<sup>14</sup>In addition to the conditioning variables specified, the literature has also identified the regulatory environment as relevant. See for instance the discussion in Pakes and McGuire (1994), Hopenhayn and Rogerson (1993) and Olley and Pakes (1996). Since we have data only on financial liberalization for South Africa, we do not pursue this line of enquiry further in this paper.

<sup>15</sup>See for instance Nickell (1996), Freeman and Medoff (1981).

<sup>16</sup>See Nickell (1996), Haskel (1991) and Haskel and Slaughter (2001), Baily, Hulten and Campbell (1992), Lichtenberg (1992), McGuckin and Sang (1995), and Jovanovic (1982).

<sup>17</sup>See for example the findings in Doms, Dunne and Troske (1997), and Entorf and Kramarz (1998). In a somewhat different tradition, see Nelson and Wright (1992) and Fagerberg (1994).

<sup>18</sup>See Grossman and Helpman (1991), Rivera-Batiz and Romer (1991), Coe and Helpman (1995), Coe, Helpman and Hoffmaister (1997), Keller (1998), Benhabib and Spiegel (1994), Haskel and Slaughter (2001), Mayer (2001), Sala-i-Martin et al (2004), Bosworth and Collins (2003), Sachs and Warner (1995). See also the discussion in Tybout (2000) with respect to developing country manufacturing sectors, and Bernard and Jensen (1995), Clerides, Lach and Tybout (1998), Doms and Jensen (1998), and Bernard and Jensen (1999).

<sup>19</sup>See De Mello (1997) and Ramirez (2000), and Fedderke and Romm (2005) for an application to South Africa.

<sup>20</sup>See Rajan and Subramanian (2005).

<sup>21</sup>An earlier paper employs a symmetrical methodology to investigate a wide range of other impacts on TFP growth - see Fedderke (2005).

<sup>22</sup>These are, admittedly somewhat *ad hoc*, proxies that substitute for the aggregation issues that arise from developing industry demand from firm level demand functions.

Manufacturing Sectors of South Africa included in Panel.	
Food	Plastics
Beverages	Glass & Glass Products
Textiles & Knitting	Other Non-metallic Minerals
Wearing Apparel	Basic Iron & Steel
Leather & Tanning	Basic Non-ferrous Metals
Footwear	Fabricated Metals
Wood	Machinery & Apparatus
Paper	Electrical Machinery
Publishing & Printing	Motor Vehicles & Accessories
Basic Chemicals	Transport Equipment
Other Chemicals & Fibres	Furniture
Rubber	Other Manufacturing & Recycling

Table 6: Manufacturing Sectors.

In estimation, Fay (2001) and Fay and Yepes (2003) employ fixed effects estimation, in which fixed effects are to control for the unobservable aggregate infrastructure price,  $\frac{qI}{w}$ , and technology dimensions. Application is to Latin America, as well as a wider set of countries.

An alternative approach to establishing an appropriate level of infrastructural expenditure, is provided by Randolph, Bogetić and Hefley (1996). Conditional mean of infrastructural expenditure in their model is determined by a wide range of regressors, including the existing stock of infrastructure, population density, the urbanization rate, the urban-rural balance, the labour force participation rate, per capita GDP, the internal and external balances, size of the foreign sector, terms of trade shifts, debt obligations, the level of institutional development, level and mix of foreign funding, and the degree of anti-poverty commitment on the part of government.

## 5 The Data and the Econometric Methodology Employed

### 5.1 The Data

The empirical work of this paper employs aggregate data for South Africa, manufacturing sector data for South Africa, as well as data from a panel of countries on which infrastructure data is available. Choice of the manufacturing data is determined by data reliability.

In the empirical section employing the manufacturing sector data, we employ a panel data set for purposes of estimation, with observations from 1970 through 1997. The panel employs data for 22 three-digit SIC version 5 manufacturing sectors in the South African economy for which data is available. The list of sectors included in the panel is that specified in Table 6. This provides a  $22 \times 28$  panel with a total of 616 observations.<sup>23</sup>

Variables for the manufacturing sector include the output, capital stock, and labour force variables and their associated growth rates. For data on TFP growth in South African manufacturing, we rely on Fedderke (2002).

To control for the market conditions firms face, and other determinants of productivity, we also employ:<sup>24</sup>

<sup>23</sup>In general, South Africa reports data on 28 3-digit manufacturing sectors. Some of these had to be excluded from the analysis for reasons of data availability. Television, radio & communications equipment and Professional & scientific equipment did not have data on R&D expenditure, while Tobacco, Plastic products, Television, radio & communications equipment and Other transport equipment lacked data on labour force skills levels. Petroleum products lacked consistent information on industry concentration.

<sup>24</sup>A fuller discussion of these data and their quality see Fedderke (2005).

- The skills mix of the labour force in each manufacturing sector. The ratio is of high and medium skill levels to unskilled labour. We denote the variable as SKRAT. Since TFP decompositions in South Africa do not control for changing skills composition of the labour force, it is vital to control for the skills ratio in any determination of TFP, in order to correct for the resultant upward bias in the TFP measure.<sup>25</sup>
- The net export ratio of each manufacturing sector,<sup>26</sup> incorporated on the hypothesis encountered in the literature that export competitiveness may require strong innovative capacity. We denote the variable as NX.
- R&D expenditure by manufacturing sector is compiled from published survey data on R&D expenditure. Data is collected for private sector R&D expenditure, public sector R&D expenditure, and expenditure by tertiary educational institutions earmarked for each of the 28 manufacturing sectors.<sup>27</sup> All expenditure is real. Fuller detail is provided in the data appendix to the paper.
- Two measure of industry concentration, given by the Gini index and Rosenbluth index computed for each industry in each year over the sample period. Data is obtained from Fedderke and Szalontai (2005). We denote the variables GINI and ROSEN respectively.
- The total number of patents registered in South Africa, in order to serve as a proxy for the quality of intellectual property rights.<sup>28</sup> We denote the variable as PATENT.
- An index of property rights in South Africa, as a second proxy for the quality of the property rights environment. The hypothesis is that the general quality of property rights may impact on the quality of intellectual property rights.<sup>29</sup> We denote the variable as PROPERTY.
- The urbanization rate for South Africa. This data is obtained from the world development indicators. We denote the variable URB.

From Perkins, Fedderke and Luiz (2005) we obtain measures of infrastructure capital stock and investment defined as follows:

- Economic infrastructure:
  - Gross fixed capital formation in infrastructure, denoted GFCF (1995 prices).
  - Fixed capital stock of infrastructure, denoted FCS (1995 prices).
- Railways:
  - Open railway lines, denoted RAIL (route kilometers).
  - Locomotives, denoted LOCO (total number steam, diesel and electric).
  - Coaching stock, denoted COACH (number).
  - Goods stock, denoted GOODS (number).
  - Carrying capacity of goods stock, denoted CCAP (tonnes).
  - Passenger journeys, denoted RPASS (number).

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<sup>25</sup>See the more detailed discussion of this point in Fedderke (2002).

<sup>26</sup>Computed as  $\frac{X}{X+IM}$  where  $X$  denotes exports, and  $IM$  imports.

<sup>27</sup>The surveys are the *Resources for R&D* surveys undertaken by the Office of the Scientific Adviser to the Prime Minister/President and the Council for Scientific and Industrial Research (CSIR).

<sup>28</sup>For details on the construction of this variable see Fedderke, de Kadt and Luiz (2001).

<sup>29</sup>For details on the construction of this variable see Fedderke, de Kadt and Luiz (2001).

- Revenue-earning traffic, denoted RFRT.
- Roads:
  - Total distance, denoted TRDS (kilometers).
  - Paved distance, denoted PRDS (kilometers).
  - Passenger vehicles, denoted VEHP (number).
  - Commercial (goods) vehicles, denoted VEHG (number).
- Ports:
  - Cargo handled, denoted PORTS (harbour tonnes).
- Air Travel:
  - Passengers carried by South African Airways, denoted SAA (number).
  - International passengers passing through South African airports, denoted APASS (number).
- Telecommunications:
  - Fixed phone lines, denoted FTEL (number).
  - Total phone lines (fixed + mobile), denoted TEL (number).
- Power generation: electricity generated, denoted ELEC (gigawatt hours).

## 5.2 The Econometric Methodology: The Panel Analysis

For the panel data analysis, we employ the Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (1999).

Consider the unrestricted error correction ARDL( $p, q$ ) representation:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta'_i \mathbf{x}_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \quad (11)$$

where  $i = 1, 2, \dots, N$ ,  $t = 1, 2, \dots, T$ , denote the cross section units and time periods respectively. Here  $y_{it}$  is a scalar dependent variable,  $\mathbf{x}_{it}$  ( $k \times 1$ ) a vector of (weakly exogenous) regressors for group  $i$ , and  $\mu_i$  represents fixed effects. Allow the disturbances  $\varepsilon_{it}$ 's to be independently distributed across  $i$  and  $t$ , with zero means and variances  $\sigma_i^2 > 0$ , and assume that  $\phi_i < 0$  for all  $i$ . Then there exists a long-run relationship between  $y_{it}$  and  $\mathbf{x}_{it}$ :

$$y_{it} = \boldsymbol{\theta}'_i \mathbf{x}_{it} + \eta_{it}, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T, \quad (12)$$

where  $\boldsymbol{\theta}_i = -\beta'_i / \phi_i$  is the  $k \times 1$  vector of the long-run coefficients, and  $\eta_{it}$ 's are stationary with possibly non-zero means (including fixed effects). This allows (11) to be written as:

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \quad (13)$$

where  $\eta_{i,t-1}$  is the error correction term given by (12), and thus  $\phi_i$  is the error correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

This general framework allows the formulation of the PMG estimator, which allows the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogenous; i.e.  $\theta_i = \theta \forall i$ . Group-specific short-run coefficients and the common long-run coefficients are computed by the pooled maximum likelihood estimation. Denoting these estimators by  $\tilde{\phi}_i$ ,  $\tilde{\beta}_i$ ,  $\tilde{\lambda}_{ij}$ ,  $\tilde{\delta}_{ij}$  and  $\tilde{\theta}$ , we obtain the PMG estimators by  $\hat{\phi}_{PMG} = \frac{\sum_{i=1}^N \tilde{\phi}_i}{N}$ ,  $\hat{\beta}_{PMG} = \frac{\sum_{i=1}^N \tilde{\beta}_i}{N}$ ,  $\hat{\lambda}_{jPMG} = \frac{\sum_{i=1}^N \tilde{\lambda}_{ij}}{N}$ ,  $j = 1, \dots, p - 1$ , and  $\hat{\delta}_{jPMG} = \frac{\sum_{i=1}^N \tilde{\delta}_{ij}}{N}$ ,  $j = 0, \dots, q - 1$ ,  $\hat{\theta}_{PMG} = \tilde{\theta}$ .

PMG estimation provides an intermediate case between the dynamic fixed effects (DFE) estimator which imposes the homogeneity assumption for all parameters except for the fixed effects, and the mean group (MG) estimator proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters. It exploits the statistical power offered by the panel through long-run homogeneity, while still admitting short-run heterogeneity. As long as sector-homogeneity is assured, the PMG estimator offers efficiency gains over the MG estimator, while granting the possibility of dynamic heterogeneity across sectors unlike the DFE estimator. In the presence of long-run homogeneity, therefore, our preference is for the use of the PMG estimator.

The crucial question is whether the assumption of long-run homogeneity is justified, given the threat of inefficiency and inconsistency noted by Pesaran and Smith (1995). We employ a Hausman (1978) test (hereafter  $h$  test) on the difference between MG and PMG estimates of long-run coefficients to test for long-run heterogeneity.<sup>30</sup> Note that as long as the homogeneity Hausman test is passed in our estimations, we report only PMG estimation results.<sup>31</sup>

Finally, it is worth pointing out that a crucial advantage of the estimation approach of the present paper, is that the dynamics generally argued to be inherent in growth processes are explicitly modelled, while recognizing the presence of a long-run equilibrium relationship underlying the dynamics. This is particularly important given the recurrent debate in the context of growth studies concerning the appropriate length of the time window used in averaging data for cross country studies. Justification for averaging rests on the need to remove short-run fluctuations in growth studies. Choice of any window is in the final instance arbitrary.<sup>32</sup> Thus the justification for the use of the PMG estimator is that it is consistent both with the underlying theory of an homogenous long-run relationship, while allowing for the explicit modelling of short-run dynamics around the long-run relationship, and the possibly heterogeneous dynamic time series nature of the data in the dynamics of adjustment.

### 5.3 The Econometric Methodology: The Time Series Analysis

Estimation is of structural systems by standard time series techniques, with variables that are first-difference stationary. Johansen<sup>33</sup> techniques of estimation are now standard, so that discussion of estimation methodology here can be brief. We employ a vector error-correction mechanism (VECM) framework, for which, in the case of a set of  $k$  variables, we may have cointegrating relationships denoted  $r$ , such that  $0 \leq r \leq k - 1$ . This gives us a  $k$ -dimensional VAR:

$$z_t = A_1 z_{t-1} + \dots + A_m z_{t-m} + \mu + \delta_t \quad (14)$$

where  $m$  denotes lag length, a  $\mu$  set of deterministic components and  $\delta$  a Gaussian error term. Reparameterization provides the VECM specification:

$$\Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \quad (15)$$

<sup>30</sup>An alternative is offered by Log-Likelihood Ratio tests. However, the finite sample performance of such tests are generally unknown and thus unreliable. We therefore employ the  $h$ -test instead.

<sup>31</sup>The author thanks Yongcheol Shin for the provision of the appropriate GAUSS code for estimation purposes.

<sup>32</sup>Indeed, some panel studies do not average at all. Unfortunately the estimators used in turn are generally not dynamic, so that the results obtained may also be driven by short-term fluctuations.

<sup>33</sup>See Johansen (1991) and Johansen and Juselius (1990).

The existence of  $r$  cointegrating relationships amounts to the hypothesis that:

$$H_1(r) : \Pi = \alpha\beta' \tag{16}$$

where  $\Pi$  is  $p \times p$ , and  $\alpha, \beta$  are  $p \times r$  matrices of full rank.  $H_1(r)$  is thus the hypothesis of reduced rank of  $\Pi$ . Where  $r > 1$ , issues of identification arise.<sup>34</sup> Estimation is by VECM cointegration.

## 6 Empirical and Estimation Results

### 6.1 The Impact of Infrastructure on Productivity

As discussed in the theoretical background to the paper, we investigate two separate productivity impacts of infrastructure. The first follows Bogetić and Sonogo (2005) in estimating the impact of infrastructure on output per worker, in effect allowing infrastructure to enter the aggregate production function of the economy directly. The second allows for an indirect impact of infrastructure on productivity, through TFP growth, within an endogenous growth framework.

#### 6.1.1 The Impact of Infrastructure on Output per Employee

In this section we follow Bogetić and Sanogo (2005) in exploring the impact of infrastructure on output per worker.

An empirical model of the general specification given by equation (5) is provided by:<sup>35</sup>

$$\left(\frac{Y}{L}\right)_{i,t} = \alpha + \beta_k \left(\frac{K}{L}\right)_{i,t} + \beta_I I_{i,t} + \beta_X X_{i,t} + \varepsilon_{i,t} \tag{17}$$

where all variables are as defined as before,  $I_{i,t}$  is provided by a vector of infrastructure measures as defined in the data section of the paper, and  $X_{it}$  denotes a vector of additional relevant variables. Here we incorporate a range of additional variables that may be relevant to labour productivity, including the net export ratio of the industry as an indicator of the openness of the sector, denoted  $NX_{i,t}$ , industry concentration in lieu of scale effects, denoted  $GINI_{it}$ , the skills ratio of the labour force, denoted  $SKRAT_{i,t}$ , and the urbanization rate to account for the possibility of urbanization economies, denoted  $URB_t$ .

Estimation is by means of the PMG panel estimator for South African manufacturing sectors. Results are reported in Tables 7 through 12.

For all specifications estimation results confirm not only adjustment to equilibrium, but rapid adjustment (see the *ECM*-parameters, which correspond to the  $\phi$ -parameters of equation 11). Moreover, in general the Hausman tests (denoted *h*-tests) confirm the legitimacy of the PMG estimator by failing to reject the homogeneity restriction on the long-run coefficients for South African manufacturing sectors at conventional levels of significance - the only exceptions occur in columns 12 of Table 9, and 21 of Table 11 in the specifications controlling for revenue earning rail traffic and fixed telephone lines respectively. Given the unknown finite sample properties of the LR test statistic, we thus proceed on the assumption of long-run parameter homogeneity. Finally, we note also that lag structure is stable across specifications, while parameter stability, with a few exceptions on which we comment below, is notable also.

The capital labour ratio proves to have the positive and statistically significant impact on labour productivity expected from standard economic theory. The implied constant output elasticity centers on the 0.3 – 0.4 range, which again conforms to prior theoretical and empirical expectations. The

<sup>34</sup>See Wickens (1996), Johansen and Juselius (1990, 1992), Pesaran and Shin (1995a, 1995b), Pesaran, Shin and Smith (1996).

<sup>35</sup>Bogetić and Sanogo (2005) employ the ratio of cumulative investment to employment instead of the capital labour ratio. Given the availability of capital stock data for South Africa, we employ the direct measure of capital intensity.

Dependent Variable: $\ln(Y/L)$				
	1	2	3	4
ARDL:	3,3,2,1,3	3,3,2,1	3,3,2,1	3,3,1
$\ln\left(\frac{K}{L}\right)$	0.140* (0.066) [1.18]	0.173* (0.083) [0.30]	0.246* (0.066) [0.10]	0.297* (0.076) [0.18]
SKRAT	-0.082* (0.017) [0.34]		-0.071* (0.034) [0.69]	
NX	0.151* (0.022) [0.17]	0.119* (0.027) [0.12]	0.173* (0.034) [1.35]	0.127* (0.034) [1.02]
GINI	0.084 (0.252) [1.13]	0.050 (0.291) [1.43]		
lnGFCF	-0.136* (0.031) [0.50]	-0.106* (0.041) [0.00]	-0.054* (0.042) [2.27]	-0.045* (0.044) [1.68]
<i>ECM</i>	-0.46* (0.101)	-0.48* (0.08)	-0.40* (0.07)	-0.40* (0.06)
h-test	3.43 [0.63]	2.61 [0.62]	2.74 [0.60]	7.53 [0.06]
RLL	723.89	660.79	706.50	661.92
ULL	1037.61	848.25	879.91	757.13
LR: $\chi^2$	627.43*	374.92*	346.81*	190.41*

Table 7: Labour Productivity Results I, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: $\ln(Y/L)$				
	5	6	7	8
ARDL:	3,3,2,1	3,3,2,1	3,3,2,1	3,3,2,1
$\ln\left(\frac{K}{L}\right)$	0.375* (0.161) [1.90]	0.225* (0.115) [1.39]	0.426* (0.077) [0.70]	0.530* (0.080) [0.62]
SKRAT	-0.127* (0.041) [0.35]	-0.122* (0.038) [1.29]	-0.130* (0.041) [0.97]	-0.142* (0.041) [0.46]
NX	0.169* (0.030) [0.06]	0.174* (0.023) [1.76]	0.174* (0.030) [0.02]	0.209* (0.030) [3.28]
lnFCS	0.032 (0.143) [0.87]			
lnRAIL		1.159* (0.506) [1.62]		
lnLOCO			0.046 (0.073) [0.14]	
lnCOACH				0.140* (0.055) [1.41]
<i>ECM</i>	-0.39* (0.07)	-0.38* (0.07)	-0.39* (0.07)	-0.37* (0.07)
h-test	3.12 [0.54]	3.09 [0.54]	1.39 [0.85]	7.34 [0.12]
RLL	696.43	698.27	696.49	697.36
ULL	838.93	851.79	829.35	825.16
LR: $\chi^2$	285.00*	307.02*	265.71*	255.60*

Table 8: Labour Productivity Results II, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: $\ln(Y/L)$				
	9	10	11	12
ARDL:	3,3,2,1	3,3,2,1	3,3,2,1	3,3,2,1
$\ln\left(\frac{K}{L}\right)$	0.611* (0.087) [1.01]	0.335* (0.075) [1.49]	0.373* (0.080) [0.07]	0.280* (0.089) [0.21]
SKRAT	-0.154* (0.040) [2.35]	-0.134* (0.039) [0.73]	-0.121* (0.040) [1.24]	-0.133* (0.039) [1.98]
NX	0.239* (0.026) [0.11]	0.218* (0.022) [1.06]	0.155* (0.030) [0.37]	0.167* (0.021) [0.20]
lnGOODS	0.396* (0.083) [0.45]			
lnCCAP		0.576* (0.121) [1.42]		
lnRPASS			-0.032 (0.048) [3.74]	
lnRFRT				0.200* (0.063) [4.32]
<i>ECM</i>	-0.35* (0.07)	-0.34* (0.07)	-0.39* (0.07)	-0.38* (0.07)
h-test	4.88 [0.30]	4.54 [0.34]	6.89 [0.14]	10.24* [0.04]
RLL	699.48	699.17	696.52	699.47
ULL	833.28	846.43	833.70	837.50
LR: $\chi^2$	267.60*	294.54*	274.36*	276.05*

Table 9: Labour Productivity Results III, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: $\ln(Y/L)$				
	13	14	15	16
ARDL:	3,3,2,1	3,3,2,1	3,3,2,1	3,3,2,1
$\ln\left(\frac{K}{L}\right)$	0.418* (0.095) [0.09]	1.300* (0.540) [1.72]	1.160* (0.241) [0.17]	1.228* (0.344) [1.18]
SKRAT	-0.126* (0.041) [1.37]	-0.130* (0.041) [0.33]	-0.121* (0.040) [0.95]	-0.116* (0.038) [0.72]
NX	0.167* (0.026) [3.92]	0.183* (0.029) [0.78]	0.139* (0.025) [2.72]	0.158* (0.030) [0.00]
lnTRDS	-0.001 (0.006) [0.36]			
lnPRDS		-1.087* (0.650) [1.66]		
lnVEHP			-0.552* (0.169) [0.01]	
lnVEHG				-0.571* (0.225) [1.04]
<i>ECM</i>	-0.39* (0.07)	-0.38* (0.06)	-0.40* (0.06)	-0.40* (0.06)
h-test	6.18 [0.19]	2.45 [0.65]	13.28* [0.01]	2.76 [0.60]
RLL	696.43	697.45	700.64	698.29
ULL	814.48	823.79	843.87	848.31
LR: $\chi^2$	236.10*	252.67*	286.46*	300.03*

Table 10: Labour Productivity Results IV, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: $\ln(Y/L)$				
	17	18	19	20
ARDL:	3,3,2,1	3,3,2,1	3,3,2,1	3,3,2,1
$\ln\left(\frac{K}{L}\right)$	-0.037 (0.157) [3.49]	0.193** (0.113) [1.63]	0.285 (0.119) [2.20]	1.334* (0.286) [0.70]
SKRAT	-0.132* (0.039) [1.07]	-0.132* (0.040) [0.27]	-0.122* (0.041) [0.07]	-0.121* (0.040) [0.01]
NX	0.156* (0.022) [0.53]	0.184* (0.026) [1.50]	0.149* (0.030) [0.88]	0.145* (0.020) [0.06]
lnPORTS	0.180* (0.052) [4.54]			
lnSAA		0.286* (0.095) [1.55]		
lnAPASS			0.043 (0.038) [0.95]	
lnELEC				-0.432* (0.138) [0.73]
<i>ECM</i>	-0.39* (0.07)	-0.39* (0.06)	-0.41* (0.07)	-0.38* (0.06)
h-test	5.49 [0.24]	2.13 [0.71]	3.87 [0.42]	3.25 [0.52]
RLL	701.27	700.10	696.69	699.36
ULL	836.13	816.80	855.10	832.24
LR: $\chi^2$	269.71*	233.39*	316.82*	265.74*

Table 11: Labour Productivity Results V, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: $\ln(Y/L)$			
	21	22	23
ARDL:	3,3,2,1	3,3,2,1	3,3,2,1
$\ln\left(\frac{K}{L}\right)$	0.727* (0.215) [2.21]	0.556* (0.211) [0.40]	0.309* (0.112) [1.56]
SKRAT	-0.142* (0.043) [3.40]	-0.132* (0.041) [0.12]	-0.122* (0.041) [0.33]
NX	0.184* (0.028) [2.08]	0.174* (0.029) [0.88]	0.151* (0.030) [1.11]
lnFTEL	-0.121 (0.081) [1.55]		
lnTEL		-0.050 (0.071) [0.39]	
URB			0.007 (0.007) [0.86]
<i>ECM</i>	-0.38* (0.07)	-0.39* (0.07)	-0.40* (0.07)
h-test	17.25* [0.00]	6.17 [0.19]	2.40 [0.66]
RLL	696.92	696.49	696.63
ULL	846.53	823.84	851.24
LR: $\chi^2$	299.24*	254.70*	309.23*

Table 12: Labour Productivity Results VI, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

only exceptions occur in the specifications controlling for paved roads, either passenger or goods vehicles, and electrification, for which the output elasticity rises to above unity - a level that is not easy to credit. High output elasticities also appear in the specifications that control for railway rolling stock ( $\ln\text{COACH}$ ,  $\ln\text{GOODS}$ ) and telecommunications ( $\ln\text{FTEL}$ ,  $\ln\text{TEL}$ ).

Industry concentration is consistently found to be statistically insignificant in estimation. Columns (1) and (2) of Table 7 reports two alternative specifications which include the GINI measure of industry concentration, which both prove to be insignificant.<sup>36</sup>

A more surprising finding is that the skills ratio of manufacturing employment consistently proves statistically significant, but proves to have a negative impact on labour productivity. While a negative sign is expected in a TFP growth equation (to account for an incomplete accounting for improvements in labour productivity), the finding is more difficult to explain in the context of output per worker. One possible interpretation may be that the long history of South African underinvestment in human capital<sup>37</sup> may have come to create a supply side constraint on industries that rely on a strong complementarity between human and physical capital. The negative sign on the skills ratio may be a reflection of the fact that industries with a strong human capital requirement have not been able to hire the requisite form of labour, and have therefore maintained a lower investment rate. Thus the poorly conceived educational policies of past South African governments may have served to generate the additional negative consequence of lowering investment in knowledge intensive sectors of the economy. While we remain uncertain as to the precise interpretation of the negative coefficient, its consistent statistical significance suggested its inclusion in estimation throughout.

Net exports consistently have a *positive* impact on labour productivity in the manufacturing sectors in South Africa, and the variable is statistically significant throughout. Parameter stability across the estimated specifications holds in general, with estimated coefficients of approximately 0.15. The NX measure spans the range from  $-0.97$  to  $0.84$  in the study sample. Thus an increase of 0.1 in the NX measure constitutes an increase of approximately 5% in the net export ratio over the total sample range in South African manufacturing. For a parameter value of 0.15, the implication is that labour productivity would improve by 1.5% per annum due to the 0.1 (5% of sample range) improvement in the net export ratio, suggesting a fairly sensitive response to international exposure of the South African manufacturing sectors.<sup>38</sup> Learning opportunities from exposure to international markets thus appear to be significant for South African manufacturing.<sup>39</sup>

Finally, results confirm the presence of a consistent, and economically significant impact of infrastructure on labour productivity.

The two aggregate measures of economic infrastructure,  $\ln\text{GFCF}$  and  $\ln\text{FCS}$ , carry negative and positive signs respectively, suggesting that while infrastructure investment ( $\ln\text{GFCF}$ ) carries a crowd-out effect with respect to private sector labour productivity, this effect is not persistent, since the impact of the infrastructure capital stock is positive. Moreover, at an elasticity of  $-0.05$  the negative impact on labour productivity is economically small. On the other hand, only the infrastructure investment measure proves to be statistically significant.

The railway measures consistently report not only a positive elasticities with respect to labour productivity, but often prove to be strongly related to labour productivity. In only two instances are the measures of railway infrastructure statistically insignificant, for the number of locomotives ( $\ln\text{LOCO}$ ) and number of railway passenger journeys ( $\ln\text{RPASS}$ ). The extensiveness of the railway network (the kilometers of railway track -  $\ln\text{RAIL}$ ) returns a very strong labour productivity elasticity

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<sup>36</sup>The alternative Rosenbluth measure of industry concentration proved similarly insignificant. We also employed a number of alternative specifications including industry concentration measures, which consistently proved insignificant. We therefore report the more parsimonious specifications excluding industry concentration for the remainder of this section.

<sup>37</sup>See the more detailed exposition in Fedderke, De Kadt and Luiz (2000, 2003), and Fedderke and Luiz (2002).

<sup>38</sup>Note that the implication is of a variable elasticity over the sample range.

<sup>39</sup>This confirms the finding already established in Fedderke (2005), though in the latter paper the focus is on TFP growth.

of 1.16, and the carrying capacity of goods stock (lnCCAP) is also strong at approximately 0.6. Even the two statistically significant elasticities for the goods stock (lnGOODS) and revenue earning traffic (lnRFRT) are relatively strong at approximately 0.4 and 0.2 respectively.

By contrast to the rail infrastructural measures, the measures of road infrastructure employed by this study are either statistically insignificant (total roads - lnTRDS), or report a statistically significant but perverse impact on labour productivity. The impact of paved roads (lnPRDS) is particularly strong at a negative unitary elasticity, but both the number of passenger (lnVEHP) and goods vehicles (lnVEHG) have strong negative elasticities of approximately  $-0.50$  also. This result deserves further study. Our preliminary conjecture is that this may reflect the territorial distribution and expansion of roads in part driven by non-economic objectives of the Apartheid era.

The remaining transport infrastructure measures all report positive labour productivity elasticities. Both the cargo handled by ports (lnPORTS) and air passenger traffic (lnSAA) have statistically significant elasticities in the  $0.2 - 0.3$  range, and only aggregate air passenger traffic (lnAPASS) is statistically insignificant (the elasticity remains positive, though economically negligible at 0.04).

In contrast to the aggregate findings for South Africa,<sup>40</sup> electricity generation is negatively, statistically significantly, and economically strongly related to labour productivity in the manufacturing sector of South Africa, with an elasticity of  $-0.4$ .

Finally, all telecommunications measures (lnFTEL for fixed lines, and lnTEL for total telephone connections) and the urbanization rate (URB) in South Africa prove to be statistically insignificant.

In summary, therefore, the findings on the impact of infrastructure on South African manufacturing sector labour productivity suggest that both statistical and economic significance attaches to transport infrastructure in various dimensions. Strong positive impacts on manufacturing labour productivity appear to attach to railway and ports infrastructure, while roads infrastructure have the opposite effect, and telecommunications have little impact.

### 6.1.2 The Impact of Infrastructure on TFP Growth

In our empirical investigation of an impact of infrastructure on TFP growth we proceed with an estimation of the empirical specification provided by equation (7). As discussed above, this requires regression of growth in total factor productivity on the ratio of R&D expenditure to per capita output.<sup>41</sup> While the literature also suggests a range of additional factors relevant to the determination of productivity gains,<sup>42</sup> including labour market conditions, labour quality and human capital, industry concentration, exposure to international competition, foreign direct investment, financial liberalization, and exchange rate overvaluation, these are dealt with in a separate paper,<sup>43</sup> and here we deal strictly with the impact of infrastructure.

Therefore, we estimate a baseline specification given by:

$$TFP_{it} = \alpha + \beta_{RD} \left( \frac{R\&D}{Y/L} \right)_{it} + \beta_{SK} SKRAT_{it} + \beta_{NX} NX_{it} + \beta_G GINI_{it} + \beta_Z Z_t + \varepsilon_{it} \quad (18)$$

where  $Z_t$  denotes a vector of the various measures of infrastructure identified in the data section.<sup>44</sup>

A final estimation issue concerns the possibility of simultaneity bias attaching to the  $\frac{R\&D}{Y/L}$  variable identified in the theoretical discussion. To address this problem we instrument the  $\frac{R\&D}{Y/L}$  variable.<sup>45</sup>

<sup>40</sup>See Fedderke, Perkins and Luiz (2005).

<sup>41</sup>There is some debate about whether the appropriate productivity measure is provided by labour productivity or total factor productivity. The TFP measure is generally preferred since  $Y/L$  may increase due to a rising  $K/L$ , without technology changes. TFP growth provides more direct information on growth due to technological change, and is the measure employed here.

<sup>42</sup>Bartelsman and Doms (2000) provides a useful overview of the issues beyond the literature already cited above.

<sup>43</sup>See Fedderke (2005).

<sup>44</sup>Note that all of these dimensions are generic to the economy, rather than industry-specific.

<sup>45</sup>Adequate instruments should be correlated with the private sector R&D variable, but not the TFP term. Public and tertiary R&D is employed in the current study, since they are likely to show association with the R&D activity of the private sector, but would not be associated with the innovation in production of the private sector. Correlation of

While the regressor in equation (18) is constructed with private sector R&D expenditure, we employ SURE estimations<sup>46</sup> in order to instrument the private sector R&D expenditure ratio on public sector R&D activity and tertiary educational institutions' R&D activity within each manufacturing sector.<sup>47</sup> We report the results of the SURE estimations in Table 13. Reported  $\chi^2$  test statistics based on equation and system log likelihoods confirm the presence of non-diagonal error covariance matrices throughout, confirming the appropriateness of SURE estimation.

Estimation of equation (18) is reported in Tables 14 through 18. Results again confirm rapid adjustment to equilibrium (see the *ECM*-parameters, which correspond to the  $\phi$ -parameters of equation 11), and in general the Hausman tests (denoted *h*-tests) confirm the legitimacy of the PMG estimator by failing to reject the homogeneity restriction on the long-run coefficients for South African manufacturing sectors at conventional levels of significance. There are five exceptions to the homogeneity finding, in the specifications controlling for paved roads, passenger and goods motor vehicles, and telecommunications (columns 11, 12, 13, 17 and 18).

A number of the results are symmetrical to those reported in Fedderke (2005). First, results confirm the presence of a positive impact of R&D expenditure on growth in total factor productivity, as postulated by Schumpeterian theory. The coefficient on the instrumented R&D measure is consistently positive, and is statistically significant in all but one specification (that controlling for railway locomotives, column 4 of Table 14). In general the R&D coefficient proves robust to alternative specifications,<sup>48</sup> and in most specifications lies in the range from 0.03 to 0.06. Thus the findings confirm the presence of a positive, and consistent impact on output growth of innovative R&D activity undertaken by the private sector. Indeed, the only concern with this set of results is that the impact of the R&D activity is potentially too strong to be plausible, since the stable coefficient range implies a more than proportional impact of R&D on TFP growth. Given the uncertainties surrounding R&D success, this is surprising, and likely implausibly large.

Second, the variable controlling for the skills composition of the labour force, SKRAT, corrects the TFP measure for its upward bias that results from not correcting the underlying decomposition for improving skills levels. Accordingly, the impact of the SKRAT variable proves to be consistently negative, as well as statistically significant in all estimations. What is more, parameter-values are consistently in the  $-0.03$  to  $-0.05$  range.<sup>49</sup> The inference is that the TFP decomposition does serve to bias upward the measure of technological progress, with at least some of the efficiency gain in production proving attributable to increasing skills levels in the labour force.

Third, net exports consistently have a positive impact on the innovative activity of the manufacturing sectors in South Africa, though in four of the estimated specifications the measure of exposure to international competitive forces proves to be statistically insignificant.<sup>50</sup> Parameter stability across the estimated specifications is less dramatic than in Fedderke (2005), but the range of parameter values spans a narrow range from 0.03 to 0.10. The NX measure spans the range from  $-0.97$  to  $0.84$  in the study sample. Thus an increase of 0.1 in the NX measure constitutes an increase of approximately 5% in the net export ratio within sample. For a parameter value of

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government and tertiary R&D with private sector R&D is 0.44 and 0.31 respectively; correlation of the two instruments with TFP is 0.01 and 0.02 respectively, confirming our prior.

<sup>46</sup>SURE estimation is appropriate on the assumption that contemporaneous correlation of disturbances attaching to growth in total factor productivity across manufacturing sectors may be non-zero - a reasonable assumption confirmed by relevant diagnostics. Given that we have separate R&D expenditure figures for private, public and tertiary sectors across manufacturing sectors, SURE promises efficiency gains over single equation estimation.

<sup>47</sup>Note, some sectors did not have data on public or tertiary sector R&D expenditure data available. For these we instrumented on either PATENT (marked †) or PROPERTY (marked ‡).

<sup>48</sup>There are three exceptions, higher coefficient estimates in the specifications controlling for lnGOODS and lnAPASS (columns 6 of Table 15 and column 16 of Table 17), and a lower coefficient in the specification controlling for lnTRDS (column 16 of Table 17).

<sup>49</sup>There are two exceptions: for the specifications controlling for locomotives and total roads in columns 4 of Table 14 and 10 of Table 16.

<sup>50</sup>In the specifications controlling for gross infrastructural capital formation (column 1 of Table 14), railway passenger journeys (column 8 of Table 15), passenger vehicles (column 12 of Table 16), and ports (column 14 of Table 17).

Dependent Variable: Private Sector R&D			
Sector	Public R&D	Tertiary R&D	$\chi^2$ {d.f.}
Food	1.68 (0.12)	1.26 (0.50)	260.71* {15}
Beverages	1.20 (0.55)	0.38 (0.50)	260.71* {15}
Textiles	0.25 (0.03)	-12.02 (2.74)	260.71* {15}
Wearing Apparel	-	-0.11 (0.06)	260.71* {15}
Leather	-	-0.19 (0.05)	260.71* {15}
Footwear‡	3917.8 (1354.2)		1837.60* {20}
Wood	0.14 (0.13)	0.76 (0.57)	260.71* {15}
Paper‡	2658.1 (1156)		1837.60* {20}
Print & Publish†		6.96 (2.28)	1837.60* {20}
Basic Chemicals	1.92 (0.21)	11.26 (0.31)	279.81* {15}
Other Chemicals	0.36 (0.02)	4.93 (0.17)	279.81* {15}
Rubber	-1.43 (0.52)	-	279.81* {15}
Plastics	-0.02 (0.06)	10.95 (1.08)	279.81* {15}
Glass	5.58 (0.58)	1.41 (0.20)	279.81* {15}
Non-Metallic	0.43 (0.20)	1.94 (0.59)	131.40* {6}
Basic Iron & Steel	5.36 (0.90)	17.81 (3.49)	131.40* {6}
Basic Non-Ferrous	0.10 (0.03)	0.60 (0.40)	131.40* {6}
Metal Products	10.26 (1.49)	-7.89 (5.08)	131.40* {6}
Machinery	$0.61 \times 10^{-7}$ ( $0.86 \times 10^{-7}$ )	$0.38 \times 10^{-5}$ ( $0.49 \times 10^{-6}$ )	188.50* {20}
Electr. Machinery	$-0.55 \times 10^{-8}$ ( $0.26 \times 10^{-7}$ )	$0.41 \times 10^{-6}$ ( $0.38 \times 10^{-7}$ )	188.50* {20}
Motor Vehicles	-0.16 (0.38)	14.74 (1.94)	188.50* {20}
Furniture	$-0.14 \times 10^{-4}$ ( $0.38 \times 10^{-5}$ )	$0.14 \times 10^{-4}$ ( $0.38 \times 10^{-5}$ )	1837.60* {20}
Other Industry	$0.86 \times 10^{-6}$ ( $0.15 \times 10^{-6}$ )	$0.27 \times 10^{-5}$ ( $0.43 \times 10^{-6}$ )	188.50* {20}

Table 13: Results of SURE Instrumenting Estimation, Figures in round parentheses represent standard errors.

Dependent Variable: Growth in Total Factor Productivity				
	1	2	3	4
ARDL:	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3
$\ln\left(\frac{R\&D}{Y/L}\right)$	0.042* (0.011) [2.16]	0.040* (0.011) [2.97]	0.036* (0.011) [1.46]	0.001 (0.008) [0.84]
SKRAT	-0.054* (0.019) [1.21]	-0.032* (0.017) [0.08]	-0.032* (0.016) [1.53]	-0.092* (0.022) [3.50]
NX	-0.023 (0.024) [0.06]	0.098* (0.016) [0.54]	0.109* (0.015) [0.27]	0.123* (0.021) [0.09]
GINI	-0.513* (0.130) [2.39]	-0.149 (0.162) [0.59]	-0.140 (0.171) [2.58]	-0.332* (0.103) [2.00]
lnGFCF	-0.076* (0.017) [1.08]			
lnFCS		-0.117* (0.033) [0.00]		
lnRAIL			-0.605* (0.164) [0.00]	
lnLOCO				-0.125* (0.026) [0.83]
<i>ECM</i>	-1.12* (0.13)	-1.16* (0.12)	-1.15* (0.11)	-1.23* (0.15)
h-test	7.49 [0.19]	9.58 [0.09]	7.02 [0.22]	4.62 [0.46]
RLL	593.68	591.10	591.11	590.24
ULL	853.43	884.01	840.75	879.09
LR: $\chi^2$	519.49*	585.81*	499.29*	577.70*

Table 14: TFP Results I, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: Growth in Total Factor Productivity				
	5	6	7	8
ARDL:	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3
$\ln\left(\frac{R\&D}{Y/L}\right)$	0.058* (0.013) [4.14]	0.118* (0.016) [3.29]	0.031* (0.010) [1.29]	0.034* (0.011) [4.09]
SKRAT	-0.044* (0.016) [2.42]	-0.037* (0.014) [1.14]	-0.041* (0.017) [0.52]	-0.049* (0.018) [1.82]
NX	0.042* (0.019) [0.51]	0.065* (0.019) [3.32]	0.096* (0.018) [0.79]	0.027 (0.022) [0.11]
GINI	-0.332* (0.127) [0.40]	-0.372* (0.108) [1.48]	-0.234 (0.162) [0.72]	-0.354* (0.128) [0.03]
lnCOACH	0.016 (0.025) [0.00]			
lnGOODS		0.145* (0.045) [0.90]		
lnCCAP			-0.157* (0.056) [0.99]	
lnRPASS				-0.050* (0.021) [1.08]
<i>ECM</i>	-1.11* (0.13)	-1.03* (0.16)	-1.17* (0.13)	-1.14* (0.12)
h-test	7.12 [0.21]	9.57 [0.09]	8.39 [0.14]	8.44 [0.13]
RLL	588.81	590.83	588.67	589.21
ULL	868.86	849.45	872.98	879.48
LR: $\chi^2$	560.10*	517.25*	568.61*	580.54*

Table 15: TFP Results II, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: Growth in Total Factor Productivity				
	9	10	11	12
ARDL:	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3
$\ln\left(\frac{R\&D}{Y/L}\right)$	0.033* (0.011) [1.01]	0.013* (0.006) [0.81]	0.057* (0.012) [1.57]	0.054* (0.012) [2.81]
SKRAT	-0.045* (0.019) [1.69]	-0.078* (0.015) [0.04]	-0.021 (0.015) [3.07]	-0.025* (0.015) [2.94]
NX	0.092* (0.019) [1.20]	0.040* (0.017) [0.39]	0.104* (0.014) [0.02]	0.098 (0.015) [0.42]
GINI	-0.186 (0.164) [4.52]	-0.649* (0.116) [2.89]	0.002 (0.146) [1.11]	-0.129 (0.147) [0.09]
lnRFRT	-0.084 (0.039) [0.10]			
lnTRDS		0.017* (0.002) [1.09]		
lnPRDS			-0.252* (0.047) [0.01]	
lnVEHP				-0.098* (0.022) [1.64]
<i>ECM</i>	-1.12* (0.11)	-1.27* (0.21)	-1.16* (0.12)	-1.16* (0.12)
h-test	6.82 [0.23]	5.03 [0.41]	11.07* [0.05]	11.37* [0.04]
RLL	588.74	599.25	595.95	593.53
ULL	831.12	947.02	845.97	860.18
LR: $\chi^2$	484.75*	695.55*	500.04*	533.29*

Table 16: TFP Results III, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: Growth in Total Factor Productivity				
	13	14	15	16
ARDL:	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3
$\ln\left(\frac{R\&D}{Y/L}\right)$	0.053* (0.012) [4.52]	0.058* (0.013) [2.56]	0.048* (0.012) [1.00]	0.082* (0.015) [2.71]
SKRAT	-0.025** (0.015) [4.61]	-0.053* (0.017) [1.65]	-0.047* (0.018) [1.01]	-0.046* (0.014) [1.70]
NX	0.098* (0.015) [0.27]	0.015 (0.021) [1.23]	0.038* (0.019) [1.00]	0.050* (0.017) [0.85]
GINI	-0.111 (0.152) [0.81]	-0.532* (0.161) [2.95]	-0.365* (0.158) [1.01]	-0.243* (0.123) [0.10]
lnVEHG	-0.099* (0.022) [2.19]			
lnPORTS		0.032* (0.017) [1.08]		
lnSAA			0.012 (0.029) [1.01]	
lnAPASS				-0.065* (0.019) [0.47]
<i>ECM</i>	-1.16* (0.12)	-1.11* (0.14)	-1.13* (0.13)	-1.06* (0.14)
h-test	14.47* [0.01]	5.18 [0.39]	3.77 [0.58]	5.84 [0.32]
RLL	593.05	589.61	588.67	591.60
ULL	842.65	852.14	869.65	863.63
LR: $\chi^2$	499.21*	525.05*	561.95*	544.05*

Table 17: TFP Results IV, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

Dependent Variable: Growth in Total Factor Productivity			
	17	18	19
ARDL:	3,3,2,1,3	3,3,2,1,3	3,3,2,1,3
$\ln\left(\frac{R\&D}{Y/L}\right)$	0.061* (0.013) [2.57]	0.064* (0.013) [2.56]	0.056* (0.012) [2.16]
SKRAT	-0.027** (0.016) [4.61]	-0.026** (0.016) [2.86]	-0.023 (0.016) [3.31]
NX	0.102* (0.016) [0.06]	0.102* (0.016) [0.10]	0.098* (0.015) [0.37]
GINI	-0.143 (0.146) [1.36]	-0.137 (0.145) [1.39]	-0.078 (0.152) [0.00]
lnFTEL	-0.051* (0.012) [0.03]		
lnTEL		-0.050* (0.012) [0.12]	
lnELEC			-0.071* (0.016) [0.29]
<i>ECM</i>	-1.13* (0.12)	-1.13* (0.12)	-1.15* (0.12)
h-test	11.52* [0.04]	12.32* [0.03]	7.02 [0.22]
RLL	592.04	592.04	592.94
ULL	862.40	868.49	850.72
LR: $\chi^2$	540.71*	552.90*	515.56*

Table 18: TFP Results VI, Figures in round parentheses are standard errors, Square parentheses below coefficients Hausman tests, Other square parentheses are probability levels, \* denotes significance at the 5 percent level of significance.

0.05, the implication is that output growth would improve by 0.5% per annum through the TFP channel due to the 5% improvement in the net export ratio, suggesting a fairly sensitive response to international exposure of the South African manufacturing sectors. Learning opportunities from exposure to international markets thus appear to be significant for South African manufacturing.

Fourth, increased concentration proves to lower TFP growth, regardless of whether the concentration measure is the GINI or the ROSEN.<sup>51</sup> The impact of industry concentration is consistently negative, though for approximately half of the specifications it proves statistically insignificant. Where statistically significant, parameter values generally centre on approximately  $-0.3$ . The within sample range of the GINI variable is from 0.69 to 0.99, such that for the parameter value of  $-0.3$  the implication of a reduction of the concentration measure of 0.1 (1/3 of the in-sample range of the GINI measure), would generate 3% more output growth per annum through the TFP channel.

These results closely mirror those already reported in Fedderke (2005). What is new in the present paper, are the results to emerge from the infrastructure measures.

In general, the estimated results differ sharply from those reported for the labour productivity specifications of the previous subsection.

The striking feature of the infrastructure coefficients is that they are almost uniformly negative - suggesting a negative impact of virtually all forms of infrastructure on efficiency gains as measured by TFP. The only exceptions to this are three infrastructure measures that prove insignificant statistically, coaching stock (column 5 of Table 15), revenue earning freight (column 9 of Table 16), and SAA flight passengers (column 15 of Table 17), and three infrastructure measures which are the only measures which appear to have a positive impact on TFP growth. Goods rolling stock (column 6 of Table 15), total roads (column 10 of Table 16) and ports (column 14 of Table 17).

<sup>51</sup>We report only the GINI results. Rosen results are entirely symmetrical, and available from the authors on request.

None of the positive impacts is economically strong, with the highest elasticity reaching no more than 0.15. By contrast, the negative elasticities attaching to some of the alternative infrastructure measures, is considerably higher, notably the negative elasticity of  $-0.6$  attaching to the railway network.

The evidence thus suggests that infrastructure is not a strong source of efficiency gains in the South African manufacturing sector as measured by TFP growth. This evidence stands in strong contrast to the pervasive and often economically powerful positive impact that infrastructure in South Africa appears to have had on manufacturing sector labour productivity.

One possible inference to draw from this evidence, is that the impact of infrastructure in South African manufacturing is directly on output per worker as a distinct factor of production - rather than indirect in fostering the productivity of private sector capital.

## 6.2 Estimating the Infrastructure Needs in South Africa

We next turn to the question of particular interest for policy: estimating demand for infrastructure services and based on these estimates, exploring the possible infrastructure needs that will need to be financed over the period of 2003-2010.

With respect to estimating the demand for infrastructure, we employ international panel data on 52 countries for the period 1980-2002 in order to estimate the infrastructure demand equation provided by equation (10). The estimator employed is again the pooled mean group estimator outlined in section 5.2. We limit the analysis to electricity generation and telecom lines since suitable international panel data sufficiently long in the time dimension was not consistently available for other forms of infrastructure. Here, we provide a more detailed presentation of the estimation issues and the resultant data implications in the following discussion.

Having projected the physical measures of electricity and telephone infrastructure, we obtain U.S. dollar values of required investment flows in the two sectors by using appropriate, available measures of the cost of infrastructure.

### 6.2.1 Forecasting Required Stocks of Infrastructure and Associated Investment Flows

We base our prediction of the required stocks and flows of infrastructure on an estimated long-run demand using a 52-country panel. The list of countries in the panel is listed in Appendix B. Justification for the use of international data is in the spirit of providing a benchmark against comparable country experiences. Advantage of the PMGE methodology is that the implicit assumption of homogeneity across the panel is explicitly tested for. The panel of countries was also limited to low- and middle-income countries, in order not to bias estimated infrastructure demand upward through the inclusion of high-income countries.

Estimation was of the empirical specification of equation (10) given by:

$$\ln \left( \frac{I}{P} \right)_{i,t} = \alpha + \beta_y \ln YPC_{i,t} + \sum_{k=1}^3 \beta_k YS_{i,t} + \delta Z_{i,t} + \varepsilon_{i,t} \quad (19)$$

where  $I$  denotes the relevant infrastructural measure (electricity, total telephone lines),<sup>52</sup>  $P$  population,  $YPC$  per capita real GDP,  $YS$  sectoral shares in GDP, where we consider agriculture ( $YAG$ ), manufacturing ( $YMAN$ ) and services ( $YSERV$ ), and  $Z$  denotes a vector of additional explanatory variables.

Table 19 reports estimation results for the two long-run relationships. Results confirm adjustment to equilibrium (see the *ECM*-parameters, which correspond to the  $\phi$ -parameters of equation 11), though unsurprisingly for infrastructure the adjustment to equilibrium is relatively slow, particularly in the case of telephones. The Hausman tests (denoted *h*-tests) confirm the legitimacy of the PMG

<sup>52</sup>Total telephone lines = fixed + mobile telephone lines.

Dependent Variable: I/P		
	1	2
	<i>Electricity</i> <i>Population</i>	<i>Telephones</i> <i>Population</i>
ARDL:	PMGE AIC(2)	2,1,1,1,1
$\ln YPC$	1.428* (0.022) [1.27]	1.198* (0.310) [1.34]
$YAG$	-0.007* (0.001) [0.46]	-0.035* (0.015) [0.72]
$YMAN$	0.011* (0.002) [1.15]	-0.055* (0.010) [0.43]
$YSERV$	-	0.079* (0.010) [0.43]
$D96$	-	1.059* (0.080)
$ECM$	-0.28* (0.05)	-0.04* (0.01)
h-test	3.10 [0.38]	8.89 [0.11]
RLL	1979.22	1422.89
ULL	2401.12	1821.27
LR: $\chi^2$	843.79*	796.77*

Table 19: Estimates of Long-Run Demand for Electricity and Telephones

estimator by failing to reject the homogeneity restriction on the long-run coefficients across our panel of 50 countries. The log likelihood statistics suggest a relatively high level of fit.

Both estimations return an income elasticity that lies above unity. In the case of electricity demand, the elasticity of 1.4 is comparable to other international findings. For instance, the World Development Report (1994) reports electricity income elasticities varying between 1.6 and 1.7, while Fay (2001) reports a power elasticity for Latin America of approximately 1.1. The telephone elasticity of approximately 1.2 is again comparable to other international evidence, with the World Development Report (1994) again reporting a 1.6 to 1.7 elasticity range for telephones, while Fay's (2001) Latin American elasticity is approximately 1.0. Given that the WDR (1994) data sample did not extend beyond the late 1980's, our estimated elasticities are thus relatively close to the study using more recent data (Fay's data sample extends to 1995).

The share of agriculture reports a negative and statistically significant association with the two per capita infrastructure measures. While Fay (2001) reports positive coefficients on  $YAG$  for Latin America, the broader panel of Fay and Yepes (2003) reports results consistent with ours. Given that a declining share of agriculture in GDP is associated with industrialization and urbanization, with a rising share of economic activity and of households more intensive in electricity and telephone use, the negative coefficient is plausible.

The share of manufacturing in output is positively related to per capita electricity, but negatively related to per capita telephone use. Given the relative energy intensity of manufacturing, the electricity result is intuitively plausible. One possible reason for the negative coefficient for the telephone per capita estimation, may be the existence of a threshold effect in the association - with demand initially rising rapidly in manufacturing activity, but at a sharply decreasing rate.<sup>53</sup> The net effect may thus be a plateau of demand by manufacturing.

For the telephone specification, we added both the share of services in output, and controlled for a structural break in telephone provision in 1996. The first augmentation of the specification is justified on the grounds that service sectors are likely intensive in the use of telephones, while the

<sup>53</sup>The essential intuition here is straightforward: manufacturing activity may require a relatively fixed number of lines per establishment, making the association with the level of value added strongly non-linear.

<b>Unit Cost of Infrastructure: Electricity and Telecom</b>	
<b>Sector</b>	<b>Unit Cost</b>
<b>Power:</b>	
Lower Bound:	\$0.021 per kwh
Upper Bound:	\$0.037 per kwh
<b>Telecom</b>	\$1,000 per telephone mainline
Lower bound represents long run marginal cost of generation. Figure may be underestimate since it is based on projected demand growth that the present study suggests may be an underestimate.	
Upper bound represents long run marginal cost of generation adjusted for average cost of generation. Upper Bound = $1.8 \times$ Lower Bound.	

Table 20: Source for Telecom Cost: Fay (2001), Source for Electricity Cost: National Integrated Resource Plan (2002).

1996 structural break corresponds to the introduction of mobile phone technology, which is reflected in a marked change in the rate of increase in telephone lines in most of the countries included in our panel.<sup>54</sup> The service sector share in GDP has the predicted positive impact on per capita telephone use, while the structural change also proves significant implying a permanent acceleration in the growth rate in per capita telephony of 1% per annum.

The panel estimator forms the basis for our forecast of electricity and telephony demand for South Africa.<sup>55</sup> Having projected the physical measures of electricity and telephone infrastructure, we obtain U.S. dollar values of required investment flows in the two sectors. For electricity, we used the average projected long-run marginal cost of power generation (National Integrated Resource Plan 2002) for the period 2005-2010. Due to some uncertainty about the precise projected unit cost of electricity generation, we used lower bound estimate of the average long run marginal cost for the period 2005-2010 (US\$2.1 cents) and an upper bound estimate (US\$3.7) based on the LRMC at the end of the projection period. For telecom, we used the best practice international unit cost (See Table 20)

Our forecast of infrastructure stocks indicate that the stock of generating capacity would grow from 4815.47 kwh per capita in 2002 to 5418.23 kwh par capita in 2005, reaching 6453.19 kwh per capita in 2010. The average annual forecast growth rate for electricity stock based on the estimated long-run relation during 2003-2010 is 3.7%. See Figure 9.

For telecom, our model forecasts the growth in total telephone lines per 1000 of population from 410 in 2002 to 474 in 2005, and then 664 in 2010. The implied growth rate in the period 2003-2010 is 6.0%. For comparison, a similar exercise for Latin American upper middle-income countries resulted in telephone lines of 255 per 1000 of population (Fay 2001). See Figure 9.

The estimates represent projected expansion in infrastructure stocks, and do not say anything about possible need for rehabilitation or upgrading or operations and maintenance expenditures. Hence both the physical and derived dollar value of required investments are likely to be lower-bound estimates.

To translate forecast stocks of infrastructure into dollar values of required investment flows, we follow the simple approach earlier applied by Fay (2001) in estimating infrastructure financing needs in Latin America. We calculate the investment needs as the total change in projected physical stocks multiplied by the cost of infrastructure as explained above (Table 20). Unit costs in Table 20 were inflation-adjusted over the period of projection for an average annual inflation rate of 4%.

Using this method, we predict that total value of the electricity generating stock employing the

<sup>54</sup>Note that previous studies did not include time periods subject to the structural change.

<sup>55</sup>Note that the forecast employs South Africa specific dynamics in addition to the long-run coefficients reported above. The full specification is available from the authors on request.

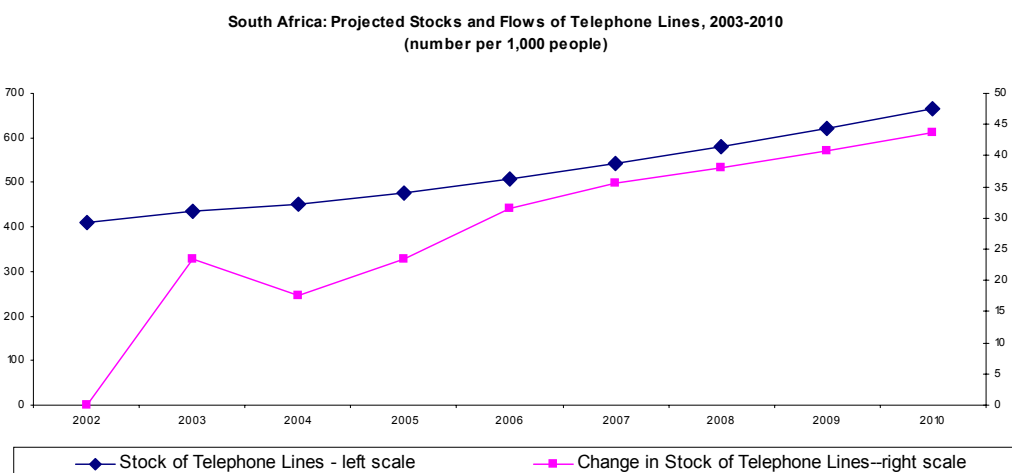
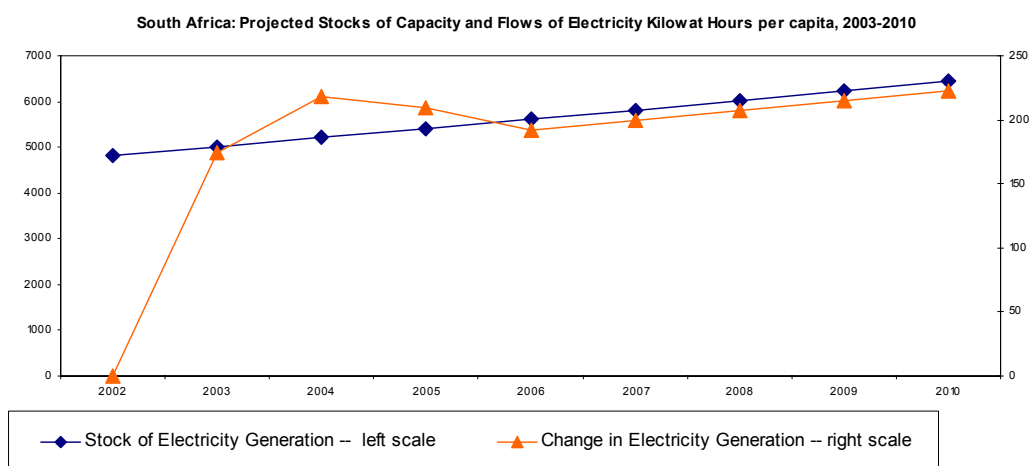


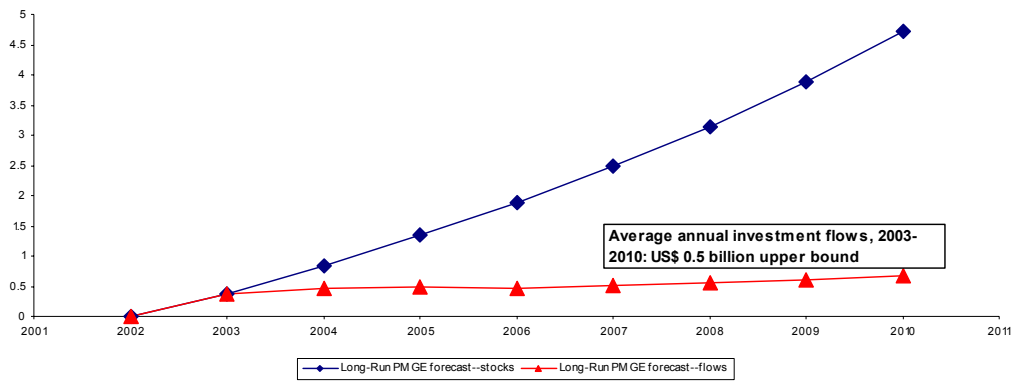
Figure 9: 2003 - 2010 Forecast of Infrastructure Demand: Electricity & Telephony

<b>South Africa- Estimated Required Investment in Infrastructure, 2003-2010</b>			
<b>Sector</b>	<b>Average Annual Investment Flows</b>		
	<b>(in billions of US\$)</b>	<b>(in billions of rand)</b>	<b>(in % of GDP)</b>
<b>Power:</b>			
Lower Bound:	0.29	1.87	0.11
Upper Bound:	0.52	3.37	0.20
<b>Telecom:</b>	1.98	12.90	0.75
<b>TOTAL (upper bound):</b>	<b>2.50</b>	<b>16.27</b>	<b>0.95</b>

Source: The authors' estimates.

Table 21: Investment Needs Forecast, 2003 - 2010

**South Africa: Projected Cost (including associated network costs) of Electricity Production Capacity and Flows (Investments) Based on Forecasted Demand, 2003-2010 (US\$ billions)**



**South Africa: Projected Cost of the Stock and Flow (Investments) of Fixed Line and Mobile Phone Infrastructure Based on Forecasted Demand, 2003-2010 (US\$ billions)**

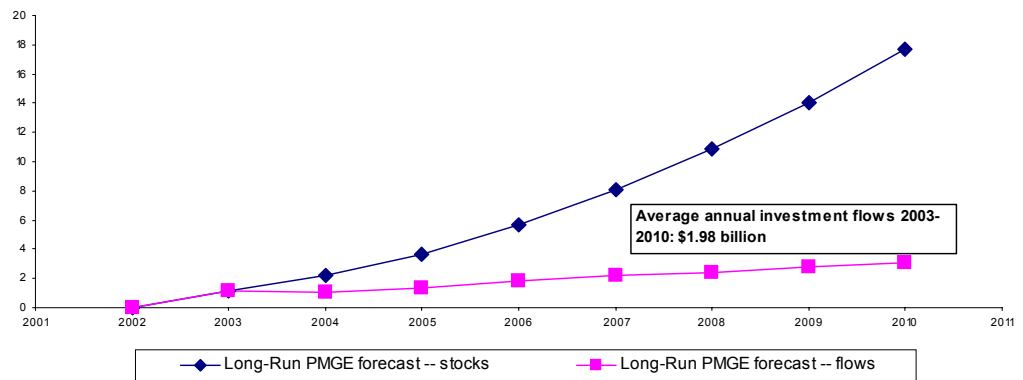


Figure 10: 2003 - 2010 Forecast of Cost of Infrastructure Demand: Electricity & Telephony

lower bound cost structure is going to increase from US\$ 4.03 billion (R 26.21 billion) in 2002 to US\$ 5.29 billion (R 34.38 billion at an exchange rate of R6.5/\$1) in 2005, and then to US\$ 8.13 billion (R 52.87 billion) in 2010. Therefore, required average annual investments — changes in stocks — in electricity over the period 2003-2010 are of the order of \$ 0.29 billion (R 1.87 billion) (See Table 21, and Figure 10).

Using the upper bound cost structure, we predict that total value of the electricity generating stock is going to increase from US\$ 7.26 billion (R 47.17 billion) in 2002 to US\$ 9.52 billion (R 61.88 billion at an exchange rate of R6.5/\$1) in 2005, and then to US\$ 14.64 billion (R 95.18 billion) in 2010. Therefore, required average annual investments — changes in stocks — in electricity over the period 2003-2010 are of the order of \$ 0.52 billion (R 3.37 billion) or about 0.2% of GDP (See Table 21 and Figure 10). Again, note that this covers only generation, excluding transmission and distribution and operations and maintenance expenditures.

Similarly, the value of the stock of total telephone lines is going to increase from US\$ 16.5 billion (R 107.2 billion) in 2002 to US\$ 22.3 billion (R 145 billion) in 2005, and then to US\$ 40.3 billion (R 262.2 billion) in 2010. Required average annual investments in telecom in the period 2003-2010 are therefore of the order of \$ 1.98 billion (R 12.9 billion) or about 0.75% of GDP (See Table 21 and Figure 10). Taken together, investment needs in electricity generation and telephone lines are of the order of US\$2.5 billion (about 1% of GDP).

## 7 Conclusion

The following five conclusions arise from this analysis.

First, new investments in infrastructure are required in South Africa to reverse the investment decline from the past several years and build the new capacity required to support accelerated growth, competitiveness, poverty reduction and more rapid economic and social integration of the society.

Second, international benchmarking of infrastructure performance suggests solid service at reasonable quality compared to relevant benchmarks and, in some cases, very competitive prices. But there remain significant shortfalls relative to benchmarks in all infrastructure sectors, largely related to limited access and less than expected quality, especially in rural areas where most of the poor reside.

Third, our econometric estimates suggest that infrastructure influences productivity in South Africa directly as a factor of production and less via the total factor productivity (TFP) channel.

Fourth, we estimated a long-run dynamic model of demand for electricity and telecom using panel data on 52 countries for the period 1980-2002; the model performs well in characterizing historical demand. And we use the model to project demand forward in the 2003-2010 period in order to derive preliminary preliminary estimates of the cost of required new investments in electricity generation and telephone lines.

Fifth, the estimates of required investments to meet demand in electricity generation and telephones are as follows:

Electricity (generation): US\$0.5 billion per year

Telephone lines: US\$1.98 billion per year

Finally, we hope that this analysis will contribute to the debate on infrastructure and constraints to growth in South Africa, as well as discussions about the likely investment requirements in these important infrastructure sectors.

## 8 Appendix A: Benchmarking Data Sources and Descriptions

Energy Performance Indicators		
<b>ACCESS</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
1. Access to Electricity Network (% of population)	World Bank Energy Help Desk. Data collected from different household surveys and weighted by population. Coverage consists on data for the year 2000 for 126 countries. Latest observations by country reported on table A1-1.	<i>Electricity access at the population level. It comprises commercially said electricity, both on-grid and off-grid. It also includes self-generated electricity, for those countries where access to electricity has been assessed through surveys by government or government agencies. The data do not capture unauthorized connections (World Energy Outlook 2002, Annex 13.1 pag.35)</i>
2. Households Reporting Access to Electricity (% of households)	Demographic and Health Surveys (DHS): 54 countries with data. One/three surveys per country between 1990 and 2001. Rural/ urban and Wealth Group breakdown is provided by DHS. Latest observation by country reported on table A1-2.	<i>Electricity access at the household level. Refers to the percentage of households who answered <input type="checkbox"/> yes <input type="checkbox"/> to the question: <input type="checkbox"/> does your household have electricity <input type="checkbox"/>? (DHS)</i>
3. Energy Use per PPP GDP (kg of oil equivalent/1000 PPP dollars, constant 2000)	World Development Indicators 2004: 121 countries, 1980-2002 Latest observation by country reported on table A1-3.	<i>Energy use refers to apparent consumption, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. (International Energy Agency, and world Bank PPP data). Measure of energy intensity. Differences in this ratio over time and across countries reflect in part structural changes in the economy, changes in the energy efficiency of particular sectors, and differences in fuel mixes. (World Health Organization, IEA, The World Bank, WDI 2002, Table 3.8).</i>
<b>AFFORDABILITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
4. Electricity Average End-User Prices (US \$ kWh)	International Energy Agency (IEA), Data Services: 29 OECD Countries, 1980-2003. Organizaci3n Latinoamericana de Energ3a (OLADE), Sistema de Informaci3n Econ3mica Energ3tica (SIEE): 25 LAC Countries, 1980-2003. Energy Regulators Regional Association (ERRA): 17 Central and Eastern Europe and Eurasia countries, 2000- 2004. South African Development through Electricity (SAD-ELEC): 13 Southern and East Africa, as of February 2002. Total: 84 countries. Breakdown by residential and non-residential customers is available. Latest observation by country reported on table A1-4.	<i>End –user prices include transport costs to the consumer; are prices actually paid, i.e. net of rebates; include taxes which have to be paid by the consumer as part of the transaction and which are not refundable. This excludes value added tax.</i>
<b>PERCEIVED QUALITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
5. Commercial Perception of Electricity Service (index)	World Economic Forum Firm Level Surveys – Global Competitiveness Report 2002-2003: 82 countries, 2001 and 2002. Latest observation by country reported on table a1-5.	<i>Weighted average of firm-perception ratings of quality services <input type="checkbox"/> based on a predetermined scale 1 = worst 7 = best (WB INFVP)&gt; Question in survey: Rank the quality of electricity supply in your country (in terms of lack of interruptions and lack of voltage fluctuations 1 = it is worse than most other countries, 7 = it is equal to the highest in the world.</i>
6. Commercial Perception of Public Agency Electricity Provider (index)	World Bank – Firm Level Surveys, World Business Environment Survey 2000: 79 countries, 2000. Latest observation by country reported on table A1-6.	<i>Weighted average of firm-perception ratings of quality services <input type="checkbox"/> based on a predetermined scale 1 = worst 7 = best (WB INFVP). Question in survey: How would you rate the quality and efficiency of power public services?</i>
<b>TECHNICAL QUALITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
7. Electric Power Transmission and Distribution Losses (% total output)	World Development Indicators 2004: 124 countries, 1980-2002. Latest observation by country reported on table A1-7.	<i>Technical and non-technical losses. Includes electricity losses due to operation of the system and the delivery of electricity as well as those caused by unmetered supply. This comprises all losses due to transport and distribution of electrical energy and heat (WB Energy Team). Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage (WDI).</i>

Source : Estache and Goicoechea (2005)

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## Water & Sanitation Indicators

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### ACCESS

Indicator	Sources and Coverage	Definition
1. Access to Improved Water Sources (% of population)	<p>Joint Monitoring Programme: 163-175 countries, 1990 and 2002.</p> <p>Rural/urban breakdown is provided.</p> <p>Latest observation by country reported on table A2-1.</p>	<p><i>'Improved' water supply technologies are: household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection. Availability of at least 20 litres per person per day, from a source within one kilometre of the user's dwelling. 'Not improved' are: unprotected well, unprotected spring, vendor-provided water, bottled water (based on concerns about the quality of supplied water, not concerns over the water quality), and tanker truck-provided water. (World Health Organization and United Nations Children's Fund, JMP report (2004), Geneva and New York (pp. 24-31)).</i></p>
2. Access to Improved Sanitation (% of population).	<p>Joint Monitoring Programme: 153-160 countries, 1990 and 2002.</p> <p>Rural/urban breakdown is provided.</p> <p>Latest observation by country reported on table A2-2.</p>	<p><i>'Improved' sanitation technologies are: connection to a public sewer, connection to septic system, pour-flush latrine, simple pit latrine, ventilated improved pit latrine. The excreta disposal system is considered adequate if it is private or shared (but not public) and if hygienically separates human excreta from human contact. 'Not improved' are: service or bucket latrines (where excreta are manually removed), public latrines, latrines with an open pit. (World Health Organization and United Nations Children's Fund. JMP report (2004). Geneva and New York (pp. 24-31)).</i></p>

### PERCEIVED QUALITY

3. Commercial Perception of Water Service (index)	<p>World Bank-Firm Level Surveys, World Business Environment Survey 2000: 80 countries, 2000.</p> <p>Latest observation by country reported on table A2-3.</p>	<p><i>Weighted average of firm-perception ratings of quality services □ based on a predetermined scale 1=worst 7=best (WB INFVP). Question in survey: How would you rate the quality and efficiency of water public services?</i></p>
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### TECHNICAL QUALITY

Indicator	Sources and Coverage	Definition
4. Households Using Piped or Well Water as Main Source of Drinking Water (% of households)	<p>Demographic and Health Surveys (DHS): 55 countries, one/three surveys per country between 1990 and 2002.</p> <p>Rural/urban breakdown is provided.</p> <p>Latest observation by country reported on tables A2-4.</p>	<p><i>Percentage distribution of households according to major source of drinking water. Question in questionnaire asks □ what's the main source of drinking water for members of your household? Piped, Well, Surface, Rain, Tanker Truck, Bottled, or other □ (DHS)&gt; The options Piped and Well were aggregated to calculate this indicator.</i></p>

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*Source : Estache and Goicoechea (2005)*

ICT Performance Indicators		
<b>ACCESS</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
1. Teledensity (total telephone subscribers/1000 people)	ITU-ICT Indicators: 203 countries, 1980-2003. Latest observation by country reported on table A3-1.	<i>Total telephone (fixed mainlines plus cellular) subscribers per 1000 inhabitants (ICT Team).</i>
2. Mainlines Teledensity (Mainlines subscribers/1000 people).	ITU-ICT Indicators: 203 countries, 1980-2003. Latest observation by country reported on table A3-2.	<i>The number of fixed mainlines per 1000 inhabitants (ICT Team). Telephone mainlines are telephone lines connecting a customer's equipment to the public switched telephone network (WDI).</i>
3. Cellular Teledensity (cellular subscribers/1000 people)	ITU-ICT Indicators: 204 countries, 1980-2003. Latest observation by country reported on table A3-3.	<i>Refers to users of portable telephones subscribing to an automatic public mobile telephone service which provides access to the Public Switched Telephone Network (PSTN) using cellular technology. This can include analogue and digital cellular systems but should not include non-cellular systems. Subscribers to fixed wireless (e.g. Wireless Local Loop (WLL)), public mobile data services, or radio paging services are not included. Calculated by dividing the number of cellular mobile subscribers by the population and multiplying by 100 (ITU).</i>
4. Households with Own Telephone (% of households)	Demographic and Health Surveys (DHS): 45 countries, one/three surveys per country between 1990 and 2002. Rural/urban breakdown is provided. Latest observation by country reported on table A3-5.	<i>Percentage of households possessing a telephone. Question in survey: Does your household have a telephone? Yes/no?</i>
<b>AFFORDABILITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
5. Cost of Local Phone Call (US cents/3 minutes)	ITU-ICT Indicators: 196 countries, 1981-2003. Latest observation by country reported on table A3-6.	<i>Local call refers to the cost of a peak rate 3-minute fixed line call within the same exchange area using the subscriber's own terminal (i.e. not from a public telephone). This indicator is expressed in US cents (ITU-World Telecommunication Development Report).</i>
6. Cost of Phone Call to the US (US cents/3 minutes)	World Development Indicators 2004: 175 countries, 1996-2003. Latest observation by country reported on table A3-7.	<i>Cost of international call to U.S. is the cost of a three-minute, peak rate, fixed line call from the country to the United States (ITU-World Telecommunication Development Report).</i>
7. Cost of Cellular Local Call (US cents/3 off-peak minutes)	ITU-ICT Indicators: 195 countries, 1980-2003. Latest observation by country reported on table A3-8.	<i>Cellular- cost of 3-minute local call (off-peak). Expressed in US cents (ITU).</i>
<b>PERCEIVED QUALITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
8. Commercial Perception of Telephone/Fax Infrastructure Quality (index).	World Economic Forum-Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2001-02. Latest observation by country reported on table A3-9.	<i>Weighted average of firm-perception ratings of quality of services based on a predetermined scale 1=worst 7=best. The relevant question in the GCR survey is: New telephone lines in your business are 1=scarce and difficult to obtain, 7=widely available and highly reliable.</i>
9. Commercial Perception of Availability of Mobile or Cellular Telephone (index)	World Economic Forum-Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2002-02. Latest observation by country reported on table A3-10.	<i>Weighted average of firm-perception ratings of quality of services based on a predetermined scale 1=worst 7=best. The relevant question in the GCR survey is: Mobile or cellular telephones for your business are 1=not available, 7=as accessible and affordable as in the world's most technologically advanced countries.</i>
10. Commercial Perception of Internet Access in Schools (index)	World Economic Forum – Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2001-02. Latest observation by country reported on table A3-11.	<i>Weighted average of firm-perception ratings of quality of services based on a predetermined scale 1=worst 7 = best. The relevant question in the GCR survey is: Internet access in schools is: 1=very limited, 7=pervasive- most children have frequent access.</i>
11. Commercial Perception of Postal Efficiency (index)	World Economic Forum – Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2001-2002.	<i>Weighted average of firm-perception ratings of quality of services based on a predetermined scale 1=worst 7=best. The relevant question in the GCR survey is: Do you trust your country's postal system sufficiently to have a friend mail a small package worth US\$100 to you? 1=not at all, 7 = yes, trust the system entirely.</i>
<b>TECHNICAL QUALITY</b>		
<b>Indicator</b>	<b>Sources and Coverage</b>	<b>Definition</b>
12. Phone Faults (reported faults/100 mainlines)	ITU-ICT Indicators: 182 countries, 1980-2002.	<i>This is calculated by dividing the total number of reported faults for the year by the total number of main</i>

Source : Estache and Goicoechea (2005)

Transport Performance Indicators		
ACCESS		
Indicator	Sources and Coverage	Definition
1. Road Density in Terms of Population (road-km/1000 people)	World Development Indicators 2004: 184 countries, 1990-2002.  Latest observations by country reported on table A4-1.	It is the total road network in km divided by total population and multiplied by 1000 (INFVPFO). Total road network includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country. (International Road Federation, World Road Statistics).
2. Road Density in Terms of Land (road-km/1000 sq km)	World Development Indicators 2004: 185 countries, 1990-2002.  Latest observations by country reported on table A4-2.	It is the total road network in km divided by total land area in sq km and multiplied by 1000 (INFVPFO). Total road network includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country. (Int. Road Federation, World Road Statistics).
3. Rail Lines Density in Terms of Population (rail-km/1000 people)	World Development Indicators 2004: 104 countries, 1995-2002. Only a few observations per year, except for 2000 and 2002.  Latest observations by country reported on table A4-3.	It is the total rail lines in km divided by total population and multiplied by 1000 (INFVPFO). Rail lines are the length of railway route available for train service, irrespective of the number of parallel tracks (World Bank, Transportation, Water, and Urban Development department, Transport Division).
4. Rail Lines Density in Terms of Land (rail-km/1000 sqkm)	World Development Indicators 2004: 104 countries, 1995-2002. Only a few observations per year, except for 2000 and 2002. Latest observation by country reported on table A4-4.	It is the total rail lines in km divided by total land area in sq km and multiplied by 1000 (INFVPFO). Rail lines are the length of railway route available for train service, irrespective of the number of parallel tracks (World Bank, Transportation, Water, and Urban Development Department, Transport Division).
PERCEIVED QUALITY		
Indicator	Sources and Coverage	Definition
5. Travel Time to Work in Main Cities (minutes/one-way work trip)	UN-Habitat: Available for 87 countries, 1998.  Latest observation by country reported on table A4-7.	Average time in minutes for a one-way work trip. This is an average over all modes of transport (UN-Habitat). In order to aggregate data at the country level simple averages of cities' travel time to work were taken even though the list of cities was not exhaustive. A more accurate approach, should more data become available, would be to use averages weighted by city population with a comprehensive list of cities per country (INFVPFO).
6. Commercial Perception of Services Delivered by Road Department/Public Works (index).	World Bank-Firm Level Surveys, World Business Environment Survey 2000: 80 countries, 2000.  Latest observation by country reported on table A4-8.	Weighted average of firm-perception ratings of services delivered by the Road Department/Public Works. 1=worst 7=best. The question in WBES 2000 is: <input type="checkbox"/> Please rate the overall quality and efficiency of services delivered by the Roads Department/Public Works. <input type="checkbox"/>
7. Commercial Perception of Port Facilities (index)	World Economic Forum – Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2001-02.  Latest observation by country reported on table A4-9.	Weighted average of firm perception ratings of quality services in port facilities based on a predetermined scale 1=worst 7=best. The question in the GCR survey is: <input type="checkbox"/> Rank from 1 to 7 port facilities and inland waterways in your country. 1=underdeveloped, 7=as developed as the world's best. <input type="checkbox"/>
8. Commercial Perception of Railroad Services (index).	World Economic Forum-Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2001-02.  Latest observation by country reported on table A4-10.	Weighted average of firm-perception ratings of quality of railroad services based on a predetermined scale 1=worst 7 = best. The relevant question is the GCR survey is: Rank from 1 to 7 the railroads in your country. 1=underdeveloped. 7=as extensive and efficient as the world's best.
9. Commercial Perception of Air Transport Services (index).	World Economic Forum-Firm Level Surveys, Global Competitiveness Report 2002-2003: 82 countries, 2002-02.  Latest observation by country reported on table A4-11.	Weighted average of firm-perception ratings of quality of air transport services based on a predetermined scale 1 = worst 7 = best. The relevant question in the GCR survey is: Rank from 1 to 7 air transport in your country. 1 = infrequent and inefficient, 7 = as extensive and efficient as the world's best.
TECHNICAL QUALITY		
Indicator	Sources and Coverage	Definition
10. Paved Roads (% of total roads)	World Development Indicators 2004: 178 countries, 1990-2002. Latest observation by country reported on table A4-12.	Paved roads are those surfaced with crushed stone (macadam) and hydrocarbon binder or bitumized agents, with concrete, or with cobblestones, as a percentage of all the country's roads, measured in length (WDI).

Source : Estache and Goicoechea (2005)

## 9 Appendix B: List of Countries in Panel for Infrastructure Forecast

1	Algeria
2	Argentina
3	Bangladesh
4	Benin
5	Bolivia
6	Brazil
7	Cameroon
8	Chile
9	China
10	Colombia
11	Congo, Dem. Rep.
12	Congo, Rep.
13	Costa Rica
14	Denmark
15	Dominican Republic
16	Ecuador
17	Egypt, Arab Rep.
18	El Salvador
19	France
20	Gabon
21	Ghana
22	Guatemala
23	Honduras
24	India
25	Indonesia
26	Iran, Islamic Rep.
27	Jamaica
28	Japan
29	Jordan
30	Kenya
31	Malaysia
32	Mexico
33	Morocco
34	Nepal
35	Nicaragua
36	Nigeria
37	Pakistan
38	Panama
39	Paraguay
40	Peru
41	Philippines
42	Senegal
43	South Africa
44	Sri Lanka
45	Thailand
46	Trinidad and Tobago
47	Tunisia
48	Turkey
49	Uruguay
50	Venezuela, RB
51	Zambia
52	Zimbabwe

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