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AN ANALYSIS OF ECONOMIC INFRASTRUCTURE INVESTMENT IN SOUTH AFRICA

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An Analysis of Economic Infrastructure Investment in South Africa[1]

Abstract

This paper analyses long-term trends in the development of South Africa's economic infrastructure and how this relates to the country's long-term economic growth. A database covering railways, roads, ports, air travel, phone lines and electricity was established for this purpose, and may facilitate further quantitative research. PSS (Pesaran, Shin and Smith, 1996, 2001) F-tests are used to identify directions of association between economic infrastructure and economic growth. These indicate long-run forcing relationships from public sector economic infrastructure investment and fixed capital stock to gross domestic product (GDP), from roads to GDP, and from GDP to a range of other types of infrastructure. There is also evidence of potential simultaneity between specific types of infrastructure and GDP. The evidence suggests three main findings. Firstly, the relationship between economic infrastructure and economic growth appears to run in both directions. Inadequate investment in infrastructure could create bottlenecks, and opportunities for promoting economic growth could be missed. Secondly, South Africa's stock of economic infrastructure has developed in phases. Policymakers should focus on choosing or encouraging the right type of infrastructure at the right time. Thirdly, the need for investment in economic infrastructure never goes away. The maintenance and expansion of infrastructure are important dimensions of supporting economic activity in a growing economy, provided that individual projects are chosen on the basis of appropriate cost-benefit analyses.

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[1] The infrastructure database used in this analysis was compiled by Peter Perkins for his dissertation "An analysis of economic infrastructure investment in South Africa", approved by the University of the Witwatersrand for the degree of Master of Commerce (partial fulfilment). Other aspects of this dissertation also contributed to the current study.

1. Introduction

Identifying determinants of long-run economic growth remains central to the South African policy debate. Numerous contributions have investigated both the changing structure of economic growth in South Africa,[2] and addressed the impact of a number of its determinants.[3] While a number of studies have examined the contribution of aggregate investment expenditure to economic growth, few have addressed the distinction between public and private investment expenditure, and the impact of infrastructure investment on long-run development in particular.[4] Similarly, to date little attention has been paid to the determinants of infrastructural investment in South Africa.[5]

Yet within the public policy debate, infrastructure investment has been re-emerging as a topic of significance. Investment by the public sector in South Africa's economic infrastructure grew by 15 per cent in real terms in 2003, and government has indicated that further growth is in the pipeline. For instance, according to a five-year plan (2005–2009) for transport and electricity outlined by government in October 2004, an amount of R165bn is to be invested in state-owned enterprises Transnet and Eskom. The South African government's renewed interest in infrastructure investment follows a long period of decline and stagnation (1976–2002), which gave rise to numerous concerns in the corporate sector regarding unreliable and/or expensive infrastructure services.

One reason for the disjuncture between the prevalence of debate surrounding infrastructure and its role as a driver of growth between academic and policy debates, lies in the relative difficulty of obtaining consistent time series on infrastructure in South Africa. This paper seeks to initiate more work on infrastructure and its role in development, by collating a wide range of indicators on the development of infrastructure in South Africa, over the 1870-2001 period. It also provides initial evidence on the nature of its interaction with output.

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[2] See for instance Fedderke (2002) and Lewis (2002).

[3] Examples are the impact of public policy in Mariotti (2002), of financial deepening in Kularatne (2002) and of the determinants of TFP growth in Fedderke (2001).

[4] Kularatne (2002) and Mariotti (2002) both place aggregate investment into a multiple equation framework of South African growth. DBSA (1998) represents the one prior attempt that we are aware of that endeavours to isolate the impact of infrastructural investment on growth in South Africa.

[5] We are not aware of any studies that address this question. By contrast, attempts to isolate the determinants of long-run private sector investment expenditure are relatively plentiful – see for instance Fielding (1997, 2000) and Fedderke (2004).

Section 2 of the paper provides brief background information on the existing literature concerning economic infrastructure and economic growth. Sections 3 to 7 analyse the long-term trends in individual measures of economic infrastructure in South Africa, namely national accounts data, railways, roads, ports, air travel, telephones and electricity. This includes preliminary tests on the relationship between economic infrastructure and South Africa's long-term economic growth. The analysis is based on an updated database of infrastructure variables for South Africa. Statistics South Africa and its predecessors used to publish a wide range of data relating to infrastructure goods and services in South Africa, but the publication of most of these series was discontinued in the late 1980s and 1990s. This paper provides an update and makes early data more easily accessible, and notes on individual series are provided in Appendix 2 of this paper. Section 8 discusses phases of infrastructure development, and section 9 provides a summary and conclusions.

2. Economic Infrastructure and Economic Growth

The relationship between an economy and its economic infrastructure is analogous to that between a building and its foundation. Economic infrastructure typically exists not for its own sake but rather to support various kinds of economic activity (Jimenez, 1995: 2774). Barro's model of endogenous growth (Barro, 1990) demonstrates that an important attribute of infrastructure expenditure by the public sector is that it raises the marginal product of other capital used in the production process, although only up to a point. Government spending is subject to diminishing marginal product, and once this falls below unity (in a Cobb-Douglas specification of the model), the financing of additional infrastructure services through higher tax revenue becomes counterproductive.

Empirical estimates of the impact of infrastructure on economic growth vary widely. Aschauer (1989) found an elasticity of output with respect to non-military public capital stock of 0.39 in the United States, implying an implausibly high marginal product for public investment.[6] Other studies that have indicated an important role for infrastructure in raising productivity include Munnell (1990a and 1990b), Easterly and Rebelo (1993), Lee *et al*. (1999), Pereira (2000), and Mitra *et al*. (2002). Different methodologies and econometric techniques were

[6] Commenting on Aschauer's results, Gramlich (1994) shows that Aschauer's elasticity of 0.39 implies marginal products of approximately 0.75 in 1970 and 1 in 1991.

used in these studies, and these are a source of much controversy in the literature. Both Holtz-Eakin (1994) and Garcia-Milà *et al*. (1996) estimated the elasticity of output with respect to government capital to be close to zero in the United States, and concluded that many previous findings were spurious.

The Development Bank of Southern Africa (DBSA) (1998) reports several estimates of the elasticity of output with respect to infrastructure in South Africa. These are relatively high, ranging from 0.15 to 0.33. Some of these results are spurious, however, having been obtained using OLS and time series data. A more comprehensive review of these and other studies is provided in Perkins (2003).

3. National Accounts – Economic Infrastructure Investment and Fixed Capital Stock

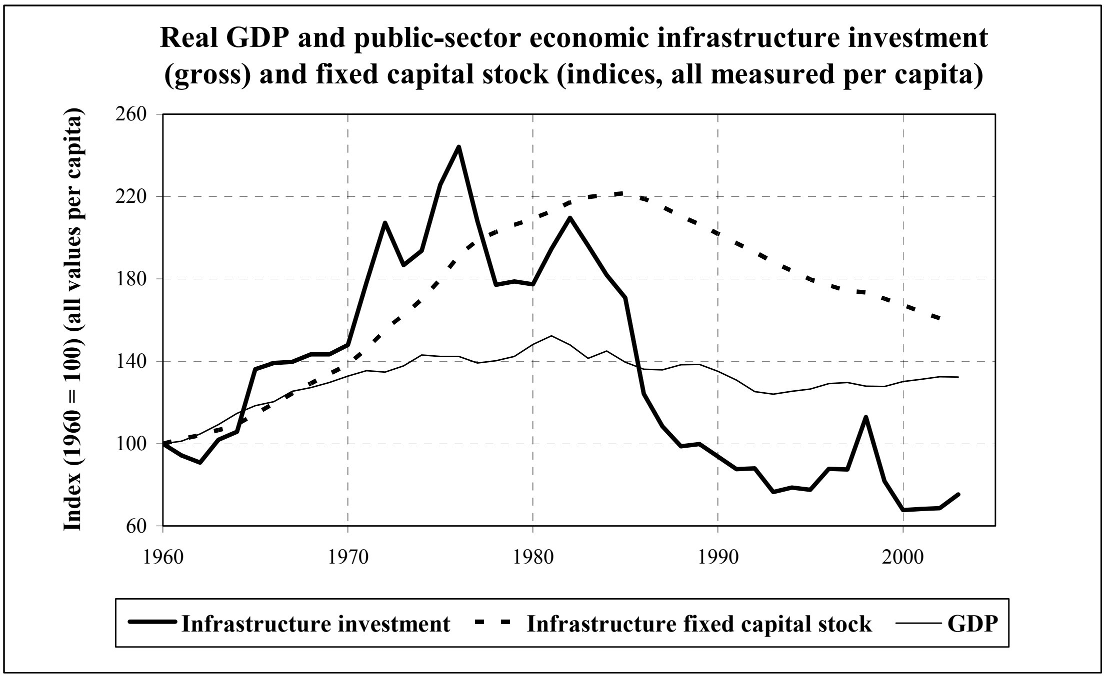
The South African Reserve Bank (SARB) publishes the public sector economic infrastructure components of South Africa's gross fixed capital formation and fixed capital stock (both general government and public corporations). Figure 1 shows indices of these measured per capita, and both demonstrate a long-term deterioration: from the mid-1970s in the case of investment, and from the mid-1980s in the case of fixed capital stock. Investment per capita fell from R1 268 in 1976 to R356 in 2002 (1995 prices), a collapse of 72 per cent over the same period. Investment fell from 8.1 per cent of GDP to 2.4 per cent of GDP, which lies below the international benchmark of approximately three to six per cent identified by Kessides (1993: ix). In 2002, 72 per cent of public-sector infrastructure investment consisted of transport, communication, power and water. The recovery of infrastructure investment in the 1990s and the subsequent slump were mainly the result of expansion programmes by Telkom and Eskom to extend telephone lines and electricity to areas which were under-serviced, and the purchase of new aircraft by South African Airways (South African Reserve Bank annual economic reports, 1996–2000).

The decline in infrastructure investment between the mid-1970s and 2002 was part of an overall decline in gross fixed capital formation (GFCF) over the same period. As a percentage of GDP, South Africa's gross savings also fell during the 1980s and 1990s.[7] Falling infrastructure investment may also have been a response

[7] After 1980 government consumption expenditure increased at the expense of government investment (Merrifield, 2000: 98). Before 1980 both types of spending rose at a similar pace, but

to overcapacity in certain areas (Merrifield, 2000: 92). The World Bank (1994: 23) points out that "infrastructure investments are often 'lumpy'… Costly episodes of over- or undercapacity often result."

Figure 1



The long-run relationship between economic infrastructure and real GDP was tested employing the methodology of Pesaran, Shin and Smith (1996, 2001). Each pair of PSS F-tests establishes whether there exists a long-run equilibrium relationship between the two variables, as well as the direction of association. The PSS F-statistics based on per capita measures are provided in Table 1. Those marked with an asterisk indicate a forcing relationship, with the direction of the relationship indicated in the column heading. A fuller description of the methodology is provided in Appendix 1. The PSS F-statistics in Table 1 indicate forcing relationships from infrastructure investment to GDP and from infrastructure fixed capital stock to GDP.

thereafter there was a sharp shift in policy, possibly reflecting the government's attempts to prop up a political system that was economically unsustainable. Growing consumption expenditure was made possible not only through investment cutbacks but by a growing fiscal deficit as well. As a proportion of GDP, the national budget deficit rose from an average of 2.9 per cent in 1980–1986 to an average of 4.9 per cent in 1987–1994 (fiscal years to March). In the post-apartheid period, both consumption and investment were constrained by the government's commitment to reducing the deficit as a proportion of GDP. It averaged 4.5 per cent in 1995–1998 and 1.8 per cent in 1999–2003. An analysis of government consumption expenditure and economic growth in South Africa is provided by Mariotti (2002).

Table 1 – PSS F-tests for the relationship between real GDP and infrastructure investment and infrastructure fixed capital stock ("INFR") (national accounts, real values)

Type of infrastructure or infrastructure "service"	*Relationship between GDP per capita and INFR per capita*	
	*GDP on left; * indicates GDP affected by INFR*	*INFR on left; * indicates INFR affected by GDP*
Infrastructure investment	6.39 *	0.88
Infrastructure fixed capital stock	7.69 *	2.78

4. Railways

The discovery of diamonds in 1867, which gave rise to the town of Kimberley, played an important role in the early development of South Africa's railway infrastructure. According to De Kock (1936), Kimberley's population and wealth grew rapidly in the 1870s and 1880s, but were nevertheless constrained by poor transport and communication services. Collaboration between private enterprise and the colonial governments of the Cape and Natal had resulted in the construction of approximately 110km of railway lines in and around Cape Town and Durban between 1860 and 1867. Extending the line from Wellington to Kimberley (900km) was a massive undertaking, but tax revenues flowing from the diamond mines allowed it to proceed. The railway line reached Kimberley in 1885. Between 1875 and 1885, the average annual growth rate in South Africa's railway lines was 29 per cent.

Similarly, the discovery of gold on the Witwatersrand in 1886 had a marked effect on the railways, as it generated both demand for transport services and the revenues with which to finance them. Despite episodes of stiff resistance from the Transvaal Republic, by 1892, Johannesburg was connected by rail to Cape Town, Port Elizabeth and East London, and by 1896 to Durban. The Johannesburg – Lourenço Marques (now Maputo) line, which President Kruger and his predecessors had been promoting for years as a means of attaining economic independence from Britain, was completed in 1894. The annual growth rate of railway lines averaged 5.7 per cent between 1885 and 1910 and 2.5 per cent between 1910 and 1930. Growth after 1930 was slow, with the level of railway lines resembling a plateau at the top of a rather steep mountain (Figure 2).[8] But until the

[8] By 1930, South Africa's railway lines measured 18 445 route kilometres, and the country's network of railway lines was substantially in place. In 2003 the distance stood at 20 796 route

1980s, the network supported relatively brisk growth rates in rolling stock and even brisker growth rates in railway traffic (both passengers and freight) and economic growth. These growth rates are compared in Table 2. After 1980 rolling stock fell sharply (Figure 2) as South Africa's overall investment rate fell and as roads came to play an increasingly important role in the country's transport system.

Figure 2

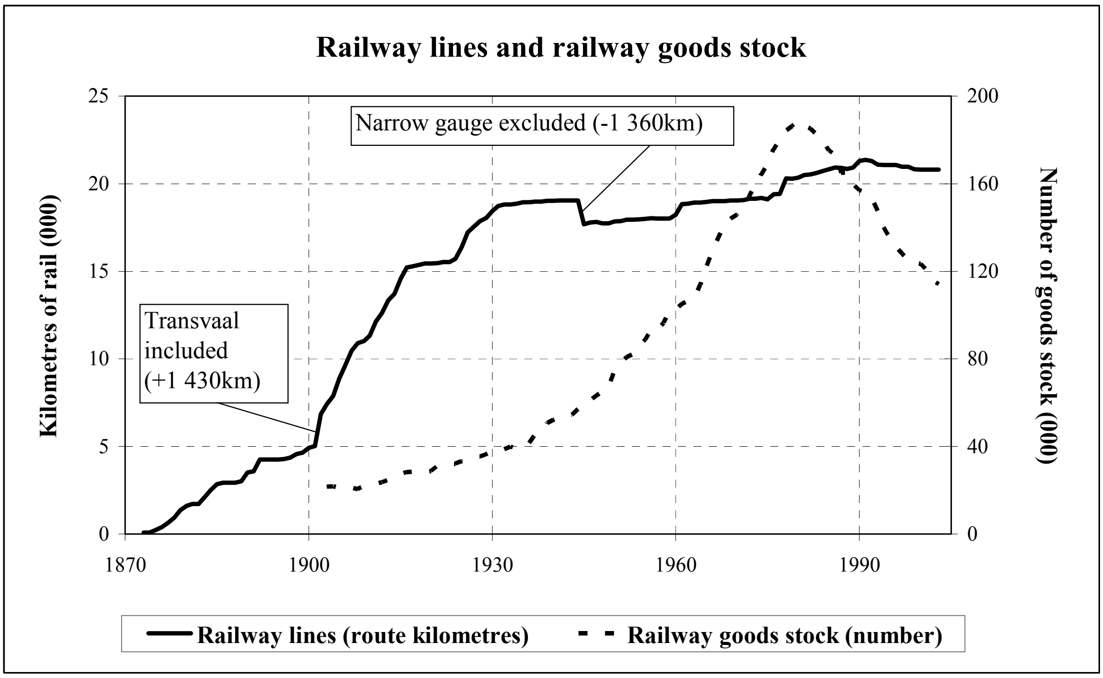


Table 2 – Average annual growth rates in railway infrastructure and traffic and real GDP

	1911-1930	*1930-1980*	*1980-2002*
Railway lines	2.2	0.2	0.1
Locomotives	2.4	1.6	–1.8
Coaching stock	2.7	2.2	–2.2
Goods stock	2.6	3.3	–2.2
Carrying capacity (goods)	4.0	4.3	–0.5
Passenger journeys	4.2	4.4	–1.7
Goods freight	3.8	4.4	0.2
Real GDP	2.0	4.6	1.7

kilometres. Of the 20 930 route kilometres in 1989, 17 240km were single track, 3 460km were double track, and the remainder were greater than double track, implying a single track equivalent distance of approximately 25 000km.

Table 3 shows PSS F-statistics for South Africa's real GDP and a range of railway infrastructure goods and services. They indicate long-run forcing relationships from GDP to railway lines, from GDP to coaching stock, and from GDP to passenger journeys, as well as potential simultaneity between GDP and locomotives and between GDP and goods stock.

Table 3 – PSS F-tests for the relationship between real GDP and railway goods and services ("RAIL")

Type of infrastructure or infrastructure "service"	*Relationship between GDP and RAIL*	
	*GDP on left; * indicates GDP affected by RAIL*	*RAIL on left; * indicates RAIL affected by GDP*
Railway lines	0.52	5.79 *
Locomotives	8.96 *	12.00 *
Coaching stock	4.49	9.98 *
Goods stock	6.61 *	6.17 *
Carrying capacity	5.72	4.35
Passenger journeys	2.60	8.33 *
Freight	5.30	2.40

5. Roads

South Africa's early roads began as footpaths and wagon tracks, which were subsequently developed into earth roads and then gravelled roads (Houghton, 1976: 201 and Floor, 1985: 14). Time series are available for national and provincial roads; urban roads and minor rural roads are excluded from the analysis. Growth rates for roads and road traffic are shown in Table 4.[9]

Apart from a structural break between 1956 and 1957, total roads essentially display a plateau effect after 1940. In 1938, the National Road Board decided that all national roads should be paved, rather than 25 per cent as previously planned. Prior to 1940, the development of South Africa's national and provincial road

[9] The choice of periods in Table 4 was determined by a substantial structural break in the series for total roads between 1956 and 1957 (approximately 25 000km of tertiary roads in the Orange Free State were reclassified and therefore included in the data for the first time), and difficulty in extending the time series for total roads after 1993 (responsibility for the funding of provincial roads was passed to the provinces in 1994, and since then consistent data for this time series do not appear to be available). Canning (1998: 534) notes that consistent data on roads tend to be problematic internationally.

network is best measured by total roads (most of which were unpaved), whereas after 1940, road development is best measured by paved roads. Between 1940 and 2001, South Africa's national and provincial paved roads increased from around 2 000km to around 63 000km. The declining growth rates for paved roads may indicate that a plateau effect is developing, but one caveat in this regard is that improvements such as the addition of road lanes are not reflected in the measured distance.[10]

Table 4 – Average annual growth rates in roads, road traffic and real GDP

	1920-1940	*1940-1956*	*1957-1993*	*1993-2001*
Total national and provincial roads (paved and unpaved)	2.1	0.5	0.04	–
Paved national and provincial roads	–	11.6	3.9	1.3
Passenger vehicles	11.4	4.3	4.8	1.0
Goods vehicles	22.1	8.3	5.6	1.7
Real GDP	5.6	4.1	3.2	2.8

Note: "–" indicates that the data are not available or not applicable; Appendix 2 provides notes on individual time series.

Figure 3 compares the growth in paved roads with real GDP and the growth in traffic which they have supported. The strong rise in vehicles transporting goods has been accompanied by the illegal overloading of vehicles, which causes serious damage to the country's road infrastructure.[11]

[10] Of the 57 034km of paved roads recorded for 1993, dual-carriage roads measured 2 405km (4.2 per cent) and single-carriage roads measured 54 629km (95.8 per cent).

[11] The South African National Roads Agency (SANRA) has estimated that overloading causes R600 million of damage to South Africa's paved roads annually (see page 19 of SANRA's document *Horizon 2010*, which sets out the agency's strategic vision for South Africa's roads). The financing of road maintenance and development is a key concern for SANRA, whose 2002 annual report (Chairman's report: 3) stated that limited financial resources were a major challenge and could adversely affect the condition of the road network. The Department of Transport (1998: 51) estimated that investment in roads in the late 1990s met approximately 75 per cent of long-term capital requirements, but that only 35 per cent of long-distance roads were adequately funded (1998: 79). It found that 30 to 40 per cent of South Africa's trucks were overloaded, causing 60 per cent of the damage to the road network (1998: 82). In recent years, national and provincial spending rose strongly from R3.7bn in 2000/01 to an estimated R6.4bn in 2003/04, an average annual growth rate of 20 per cent (excluding SANRA's toll revenue and municipal spending) (*Medium Term Budget Policy Statement*, 2003: 71).

Figure 3

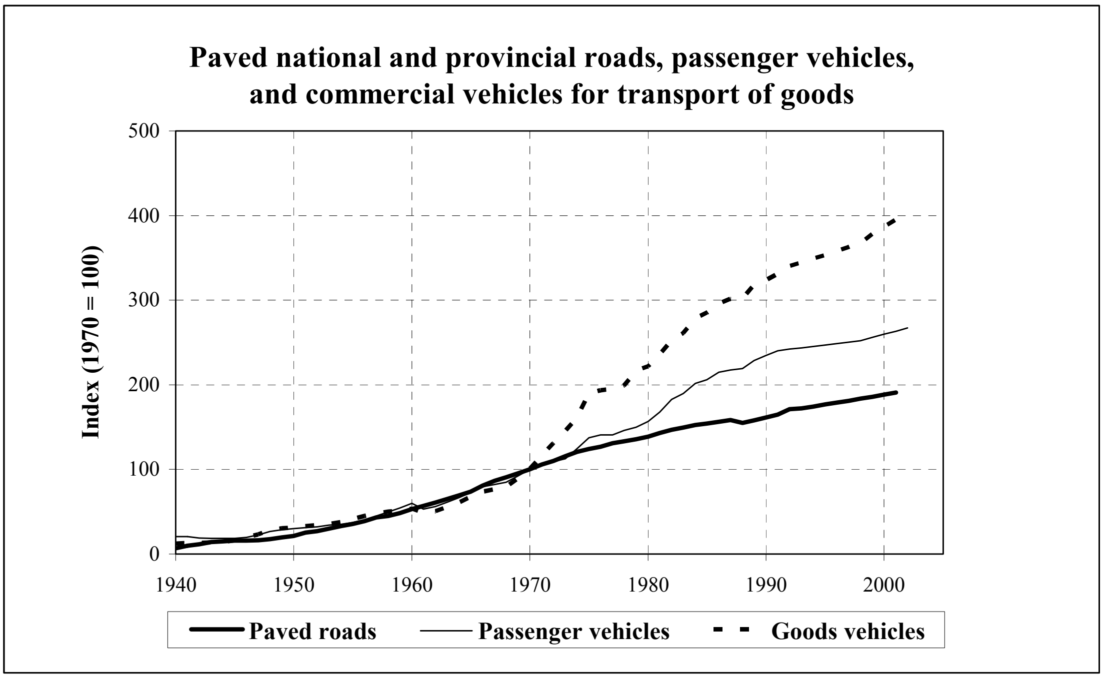


Table 5 – PSS F-tests for the relationship between real GDP and roads and vehicles ("ROAD")

Type of infrastructure or infrastructure "service"	*Relationship between GDP and ROAD*	
	*GDP on left; * indicates GDP affected by ROAD*	*ROAD on left; * indicates ROAD affected by GDP*
Unpaved and paved roads	6.38 *	3.78
Paved roads	5.90 *	1.39
Passenger vehicles	11.05 *	5.72
Goods vehicles	8.96 *	7.23 *

Table 5 indicates long-run forcing relationships from roads and passenger vehicles to GDP, and potential simultaneity between goods vehicles and GDP. Jones and Müller (1992: 77) argue that transport systems allow producers to supply larger quantities than can be consumed at their place of production, which results not only in higher output but also specialisation and lower unit production costs.[12]

[12] An early account of the relationship between roads and economic development in South Africa is provided by De Kock in his discussion of the period 1836–1856 (1936: 37-38): "The lack of adequate transportation facilities had always been a serious deterrent to the development of agriculture and wool-growing. In order to offset the disadvantages resulting from the absence of navigable waterways and railways, it was essential to have a good system of roads…

6. Ports and Air Travel

Whereas railways and roads are typically competitors in the supply of transport services, railways and roads on the one hand, and ports on the other, are typically complementary, especially in a country such as South Africa which does not have the benefit of major inland navigable waterways. Frankel (1938: 33) argues that railways were of great importance in the colonisation of Africa, but that without ports they were useless.

The National Ports Authority (NPA) of South Africa controls and manages the ports at Cape Town, Durban, Port Elizabeth, East London, Richards Bay, Saldanha, and Mossel Bay. The growth in the annual volume of cargo handled at these seven ports is shown in Table 6.

Although cargo is not a direct measure of infrastructure, it nevertheless demonstrates the ports' capacity to handle rising volumes, e.g. between 1976 and 1979 the volume doubled from 38 million harbour tons to 76 million harbour tons, the result of opening Richards Bay and Saldanha harbours. Further substantial increases in the 1980s and 1990s relate to South African exports and imports, whose combined volume rose by 158 per cent between 1979 and 2001 (cargo handled at the ports rose by 114 per cent and real GDP rose by 51 per cent). However, high growth in cargo handled has contributed to congestion problems at some ports. In Young (2003: 18), the Durban Container Terminal was reported to be working at 26 per cent above its intended capacity. The Department of Transport (1998: 42) stated that interviews with freight customers revealed high levels of dissatisfaction with service levels at some of the ports, and estimated (1998: 51) that investment in the ports in the late 1990s was running at around 35 per cent of their long-term capital requirements. Various initiatives are under way or under consideration to raise capacity at South Africa's ports, and a new deepwater port, Ngqura, is under construction next to the Coega industrial development zone in the Eastern Cape. According to the NPA, Ngqura is needed to provide additional container capacity.[13]

Accordingly, in 1844, the construction of a series of public highways, bridges and mountain passes was set on foot. This improvement of the system of internal transportation contributed in no small degree to the subsequent development."

[13] A study by Hosking and Bond (2000) questions the feasibility of Coega. The nearby harbour at Port Elizabeth handles only a fraction of the volumes at Richards Bay and Durban, and there is a lack of connecting transport infrastructure. Pollution could impose substantial costs on the fishing and citrus industries as well as human health, and ecotourism could be adversely

Table 6 – Average annual growth rates in cargo at ports, air passengers and real GDP

	1911-1950	*1950-1975*	*1975-1994*	*1994-2001*
Cargo handled at ports	2.1	5.0	7.0	3.5
SAA passengers (domestic and international)	na	12.3	2.1	4.8
Passenger on international flights at SA airports	na	17.4[(1)]	3.6	8.5
Real GDP	3.3	4.8	1.7	2.7

Note: (1) 1962–1975.

In the absence of a direct measure of South Africa's air transport infrastructure over time, Table 6 shows the growth of passengers on South African Airways (SAA) and passengers on international flights leaving or arriving at South African airports. In general there was brisk growth before 1975, much slower growth during the politically-fraught 1975–1994 period (when economic growth was also low), and a substantial recovery in growth in the post-apartheid period.[14]

Table 7 – PSS F-tests for the relationship between real GDP and cargo handled at ports ("PORT") and air passengers ("PASS")

Type of infrastructure or infrastructure "service"	*Relationship between GDP and PORT or PASS*	
	*GDP on left; * indicates GDP affected by PORT or PASS*	*PORT or PASS on left; * indicates PORT or PASS affected by GDP*
Ports (cargo)	3.87	19.73 *
SAA passengers	4.71	6.41 *
International air passengers	4.00	0.75

affected. They conclude that Coega's projected costs appear too great for it to proceed successfully given the limited projected employment and other benefits.

14 In financial 2003, SAA operated a fleet of 64 aircraft, of which it owned 15 and leased 49. The fleet is being upgraded through the introduction of 39 airbus aircraft between 2003 and 2005. Compared with the aircraft they are replacing, the new aircraft are more fuel-efficient, have lower maintenance costs and provide more comfort for passengers (SAA audited group results for the year ended 31 March 2003). The Department of Transport (1998: 50) reported that within South Africa's transport system, only airports (and *foreign* airlines using those airports) were making sufficient investments to replace and upgrade their assets.

Table 7 indicates long-run forcing relationships from GDP to the volume of cargo handled at the ports, and from GDP to the number of passengers transported by SAA. There is no evidence from the PSS-F tests of a relationship between GDP and international air passengers.

7. Telephones and Electricity

In 1876 telegraphic communication was established between Cape Town and Kimberly, once again indicating a link between mining (diamonds in this case) and infrastructure. South Africa's first telephone exchanges were opened in Port Elizabeth in 1882 and Cape Town in 1884 (*Official Year Book of the Union,* 1917: 675). Today the country's landline telephone infrastructure is provided by Telkom SA Limited, which also has a 50 per cent holding in Vodacom, South Africa's largest mobile telephone service provider.[15] In addition to supplying traditional telephone services, Telkom's infrastructure also provides a range of other communication services which have become essential for South African businesses to become globally competitive, e.g. fax, email, internet, data transmission.

Table 8 shows relatively strong growth rates for fixed phone lines during most of the 20th century, even after the mid-1970s when investment growth in South Africa was generally weak. The annual average growth rate for 1970–1990 was 6.5 per cent, probably reflecting the global upward trend in information technology. The slower growth in 1990–2002 must have been the result, at least in part, of strong competition from the mobile phone market, which grew from 7 000 in 1992 to 13.9 million in 2003.

A brief history of electricity in South Africa is provided by the Development Bank of Southern Africa (1998: 14). In 1906, the Victoria Falls and Transvaal Power Company (VFTPC) was established by the British South Africa Company, the German equipment supplier AEG, and German banks. Electricity demand from the gold mines resulted in rapid growth, and in 1923 the electricity sold by VFTPC

[15] In 1991, Telkom was incorporated and registered as a public limited liability company, wholly owned by the South African government. In May 1997 it was partially privatised, and in March 2003 it was listed on the JSE Securities Exchange and the New York Stock Exchange (with the South African government retaining a substantial share). In March 2003, Vodacom had an estimated 57 per cent share of South Africa's mobile phone market.

to the mines exceeded the combined electricity consumption of London, Sheffield and Birmingham. Eskom (previously the Electricity Supply Commission, or Escom) was established by government in 1922 as a means of supplying electricity at cost. The VFTPC was nationalised in 1948, Eskom expanded its capacity to meet growing electricity demand (e.g. from the development of the Free State goldmines in the 1950s), and municipalities discontinued electricity production as they found it cheaper to purchase electricity from Eskom, leaving Eskom as a virtual monopoly. In 2002, Eskom was converted from a statutory body to a public company (Eskom Holdings Limited) with the South African government as the sole shareholder.

Table 8 – Average annual growth rates in phone lines, electricity generated, and real GDP

	1920-1950	*1950-1970*	*1970-1990*	*1990-2002*
Fixed phone lines	7.7	5.9	6.5	4.0
Mobile phone lines	–	–	–	108.3[(1)]
Electricity generated	7.5	7.9	6.1	2.3
Real GDP	4.9	5.1	2.4	1.9

Note: [(1)] 1992–2002.

Annual growth in electricity generation was strong until the late 1980s. In the 1990s Eskom embarked on an electrification programme to expand its services to areas which had been neglected during apartheid, but the growth rate in electricity generation nevertheless slowed to 2.3 per cent from 6.1 per cent in the 1980s. In contrast to the amount of electricity actually generated, Eskom's total power station net maximum capacity was relatively stable in the period 1993–2002 (ranging from around 36 000 megawatts to around 40 000MW). Peak demand, however, grew from 23 169MW in 1993 (62 per cent of capacity) to 31 928MW in 2003 (approximately 80 per cent of capacity), an average growth rate of 3.3 per cent per annum. With this rate of growth and the need for a reserve margin, current capacity may be inadequate to handle peak demand as early as 2007. Eskom is considering various options to expand its capacity, one of which is to resurrect three mothballed power stations. New power stations will also be required, but it is unclear who will construct these. Government has expressed interest in mobilising private-sector involvement in electricity generation, but whether or not there are private-sector operators who are able and willing to enter this market on any significant scale remains to be seen.

Table 9 – PSS F-tests for the relationship between real GDP and fixed telephone lines ("TELE") and electricity generated ("ELEC")

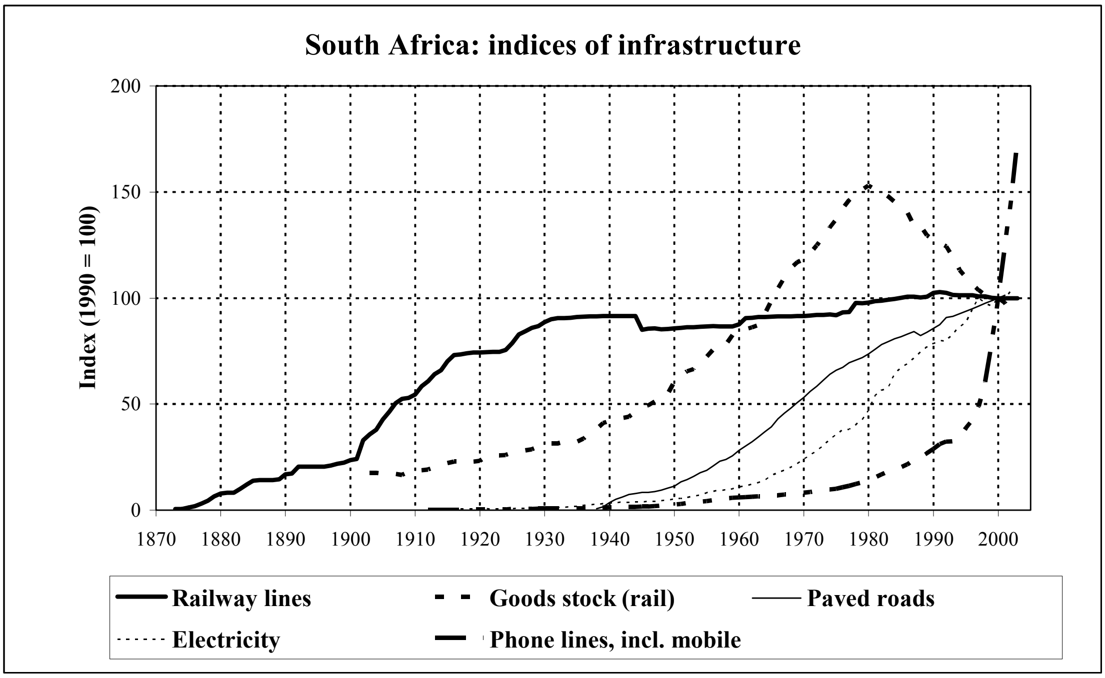
Type of infrastructure or infrastructure "service"	*Relationship between GDP and TELE or ELEC*	
	*GDP on left; * indicates GDP affected by TELE or ELEC*	*TELE or ELEC on left; * indicates TELE or ELEC affected by GDP*
Fixed phone lines	3.06	15.72 *
Electricity generated	11.87 *	14.33 *

Table 9 indicates a long-run forcing from GDP to the number of fixed phone lines, and potential simultaneity between GDP and electricity.

8. Phases of Infrastructure Development

Figure 4 shows selected indices of infrastructure development in South Africa, and Table 10 shows long-term growth rates for these and other measures.

Figure 4



They suggest that infrastructure development tends to take place in phases of development. As growth in one area declines, growth in another area rises. Given the links between infrastructure growth and economic growth indicated by the PSS F-tests, it is quite plausible that phases of infrastructure development took place in response to changes in the structure of the economy and also exerted some influence on changes in the structure of the economy. Since the economy's infrastructure requirements tend to change over time, and since infrastructure projects tend to take place on a large scale and are therefore expensive, this pattern of infrastructure phasing is unsurprising and is likely to continue.

Table 10 – Average annual growth rates for infrastructure goods and services

		1875-1899	*1900-1919*	*1920-1939*	*1940-1959*	*1960-1979*	*1980-2001*
RAIL	Railway lines	17.0	6.2	1.0	-0.3	0.6	0.1
	Locomotives		0.3 (1)	2.1	1.4	2.1	-1.7
	Coaching stock		2.4 (1)	2.7	1.4	2.9	-2.1
	Goods stock		1.7 (1)	3.0	3.6	3.1	-2.0
	Goods stock carrying capacity		3.8 (2)	4.0	4.8	3.9	-0.2
	Passenger journeys		3.8 (1)	4.0	4.5	4.2	-1.0
	Revenue-earning freight		5.4 (1)	3.8	4.2	4.8	0.8
ROADS (national & provincial)	Total (nat. & pr.)			2.0	1.3(3)	0.1	-0.1 (4)
	Paved (nat. & pr.)				15.0	5.3	1.6
	Passenger vehicles			12.1 (5)	5.0	5.2	2.6
	Goods vehicles			23.5 (5)	7.2	7.5	2.8
AIR TRAVEL	SAA passengers				9.1(6)	12.9	2.3
	Passengers on international flights at SA airports					13.0(7)	5.8
ELEC-TRICITY	Electricity generated			8.8	6.0	7.5	3.9
TELE-PHONES	Fixed lines			7.8	7.9	4.2	5.9
	Mobile lines						120 (8)
	Total lines (fixed plus mobile)			7.8	7.9	4.2	10.8

Notes: (1) 1905–1919 (2) 1910–1919
(3) 0.5 if the 1957 inclusion of previously unclassified roads is disregarded
(4) 1980–1993 (5) 1921–1939 (6) 1950–1959 (7) 1963–1979 (8) 1993–2001

9. Summary and Conclusion

Public sector investment in South Africa's economic infrastructure rose as a percentage of GDP between 1960 and 1976, but this was followed by a long-term decline. The period of strongest growth in South Africa's railway lines was 1875–1930, after which there was little change in the route-kilometre distance. We have characterised this as a "plateau effect". Railway rolling stock continued to grow after 1930 but fell sharply after 1980, partly reflecting the general decline in investment spending by government. Similarly to railways, national and provincial roads reached a plateau around 1940, but the paving of national and provincial roads then began in earnest. This supported rapid growth in road traffic. One of the country's oldest forms of infrastructure is its ports, the capacity of which was expanded substantially in the 1970s (Richards Bay and Saldanha). A new port (Ngqura) is under construction at Coega. During the second half of the 20th century air travel became widely available. In contrast to other measures of infrastructure goods and services, fixed telephone lines grew rapidly in the 1980s and 1990s (a response to the worldwide revolution in information technology), and there was explosive growth in mobile phones in the 1990s and early 21st century. Existing electricity generation capacity may be inadequate to handle peak electricity demand as early as 2007, which has created an urgent need for new capacity.

The results of the PSS F-tests reported in this study may be summarised as follows. In South Africa, growth in GDP tends to drive growth in individual measures of infrastructure-related goods and services, rather than vice versa. Roads are an exception, since there is evidence that roads have a strong effect on GDP growth: the correlation coefficient between paved roads and real GDP is 0.996 for the period 1938–2001, and the PSS F-tests indicate a long-run forcing relationship from roads to GDP. At the national accounts level, infrastructure investment seems to drive GDP growth. These patterns suggest two forms of constraint that infrastructure may exercise on economic growth. Firstly, if policymakers fail to provide additional infrastructure in response to the greater demand for infrastructure generated by GDP growth, further GDP growth could be hampered by bottlenecks, e.g. congestion at some of South Africa's ports. Secondly, underinvestment in certain types of infrastructure, e.g. roads, may leave potential areas of economic growth unexploited.

The preceding analysis suggests three main findings with regard to economic infrastructure and economic growth in South Africa. These are as follows.

Firstly, the relationship between economic infrastructure and economic growth appears to run in both directions. Economic growth provides both the need for, and the resources to fund, various types of infrastructure. Provided that infrastructure projects take place in response to appropriate cost-benefit analyses, they are more likely to promote GDP growth than hinder it. Alternatively, the failure to provide appropriate infrastructure services may hamper GDP growth.

Secondly, South Africa's stock of economic infrastructure has developed in phases. The growth rates of individual measures of infrastructure fluctuated substantially over time, in some cases even turning negative, and the historical pattern of infrastructure development differed substantially between sectors. Providing the right type of infrastructure at the right time will be an important dimension of South Africa's continued economic development.

Thirdly, the need for investment in economic infrastructure never goes away. Until such time as existing infrastructure becomes obsolete it needs to be maintained, and as certain infrastructure programmes reach maturity new ones should be implemented, always in response to the economy's changing needs and cost-benefit analyses. The continued need for appropriate infrastructure investment should be recognised in public-sector budgets from the national level to the municipal level, and public-sector agents need to be accountable for spending their capital allocations effectively. While some degree of fluctuation in the level of infrastructure investment may be harmless or even appropriate, a long-term decline in infrastructure investment, such as that experienced by South Africa between the mid-1970s and 2002, would probably be undesirable.

Appendix 1: Testing for the Direction of Association between Variables

In order to explore the directions of association between the variables included in this study, we employ the test statistic proposed by Pesaran, Shin and Smith (1996, 2001) (PSS F-statistic).[16] Suppose that the question is whether there exists a long-run relationship between the set of variables y_t, $x_{1,t}, \ldots x_{n,t}$. Univariate time series characteristics of the data are not known for certain. The PSS approach to testing for the presence of a long-run relationship proceeds by estimating the error correction specification given by:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=1}^{n} \sum_{i=1}^{p} \gamma_{j,i} \Delta x_{j,t-i} + \left(\delta_1 y_{t-1} + \sum_{k=2}^{n+1} \delta_k x_{k,t-1} \right) + \varepsilon_t \, .$$

The order of augmentation, *p*, is determined by the need to render the error term white noise, and is chosen from the set of all feasible lag structure combinations by means of an information criterion.[17] The test proceeds by computing the standard F-statistic for the joint significance of $\delta_1 = \delta_2 = \ldots = \delta_{n+1} = 0$. While the distribution of the test statistic is non-standard, and influenced by whether the $x_{i,t}$ are I(0) or I(1), the critical values are tabulated by Pesaran, Shin and Smith (1996, 2001), with $x_{i,t}$-I(0) $\forall$i providing a lower bound value, and $x_{i,t}$-I(1) $\forall$i providing an upper bound value, to the test statistic. The test statistic is computed with each of the y_t, $x_{1,t}, \ldots x_{n,t}$ as the dependent variable. Where the estimated test statistic exceeds the upper bound value, we reject $\delta_1 = \delta_2 = \ldots = \delta_{n+1} = 0$, and infer the presence of a long-run equilibrium relationship. Where the estimated test statistic lies below the lower bound value, we accept $\delta_1 = \delta_2 = \ldots = \delta_{n+1} = 0$, and infer the absence of a long-run equilibrium relationship. The test is indeterminate either where the computed test statistic lies between the upper and lower bound values (in which case it is not clear whether a long-run relationship between the variables is present), or where more than one variable is confirmed as the outcome variable of a long-run equilibrium relationship (in which case the long-run relationships between the variables would not be unique).[18]

[16] See also the discussion in Pesaran (1997) and Pesaran and Shin (1995a, 1995b).

[17] For instance Akaike.

[18] The test is analogous to a Granger causality test, but in the presence of non-stationary data. Of course, there exists an array of tests designed to establish the univariate time series characteristics of the data. The tests are not always conclusive, however. This renders the PSS F-test suitable in the current context.

In the current application, where there is an intercept but no trend, and the relationship being tested for is between GDP and individual measures of infrastructure, the lower bound critical value of the test statistic is 4.934 and the upper bound critical value of the test statistic is 5.764, at the five per cent level of significance.

Appendix 2: Data Sources and Technical Notes

Where necessary, statistics from different sources have been standardised, e.g. miles have been converted into kilometres, sterling into rands, short tons into metric tons. Abbreviations used in the notes below are as follows:

CGH:	Cape of Good Hope (Report of the general manager of railways)
CN:	Colony of Natal (Report of the general manager of railways)
CSAR:	Central South African Railways (Report of the general manager of railways)
NATIS:	National Traffic Information System
NGR:	Natal Government Railways (Report of the general manager of railways)
NPA:	National Ports Authority
OYBU:	Official Year Book of the Union
SAA:	South African Airways
SANRA:	South African National Roads Agency
SARB:	South African Reserve Bank (database)
SARH:	South African Railways and Harbours (Report of the general manager of railways and harbours / Annual reports)
SATS:	South African Transport Services (Annual reports)
SSA:	Statistics South Africa or its predecessors (South African Statistics and database)
US:	Union Statistics for Fifty Years

Real gross domestic product (GDP)
Sources: SSA, SARB
Figures for nominal and real GDP 1946–2002 are from the SARB database. Nominal GDP was extrapolated back to 1911 using percentage changes from nominal value added, published in SSA 1980. Nominal GDP for 1911–1945 was then inflated to 1995 prices using an estimate of the GDP deflator. The latter was extrapolated back to 1911 using percentage changes from an average of wholesale and retail price indices (US).

Population
Sources: Census figures for 1904 and 1911, US, SSA
Mid-year estimates were used. The figures for 1991–2002 are those published by SSA. Some of the earlier figures published by SSA exclude the former TBVC areas. To overcome this exclusion and other revisions, the series was extrapolated back using growth rates calculated from SSA, US and census (1904 and 1911) population figures.

Economic infrastructure: gross fixed capital formation and fixed capital stock (1995 prices)
Source: SARB

Rail: open railway lines (route kilometres)
Sources: OYBU, US, SSA, Spoornet
1873–1916: end of year. 1917–2003: March of year.
Data from 1945: 1065mm gauge only; earlier data include 610mm gauge.
Many of the published figures include Namibia, but the Namibian figures were obtained separately and excluded in order to show South Africa only.

Rail: locomotives (steam, diesel and electric) (number).
Sources: CGH, NGR, CSAR, US, SSA, Spoornet
1903–1916: end of year. 1917–2003: March of year.
1905: interpolated (Transvaal and Orange Free State unavailable).

Rail: coaching stock (number)
Sources: CGH, NGR, CSAR, US, SSA, Spoornet
1903–1916: end of year. 1917–2003: March of year.
1905: interpolated (Transvaal and Orange Free State unavailable).

Rail: goods stock (number)
Sources: CGH, NGR, CSAR, US, SSA, Spoornet
1903–1916: end of year. 1917–2003: March of year.
1905: interpolated (Transvaal and Orange Free State unavailable).

Rail: carrying capacity of goods stock (tonnes)
Sources: US, SSA, Spoornet
1910–1916: end of year. 1917–2003: March of year.

Rail: passenger journeys (number)
Sources: CGH, CN, NGR, SARH, US, SSA, Spoornet
1873–1916: calendar year. 1917–2003: year to March.
1873–1880: Cape only. 1881–1902: Cape and Natal only.
1903–1908: estimated from graph (SARH 1910, p151). 1917: interpolation.

Rail: revenue-earning traffic
Sources: CGH, CN, NGR, SARH, US, SSA, Spoornet
1873–1916: calendar year. 1917–2003: year to March.
1873–1880: Cape only. 1881–1902: Cape and Natal only.
1903–1908: estimated from graph (SARH 1910, p152).

Roads: total distance (kilometres)
Sources: OYBU, US, SSA, CSIR
March of year. The quality of the data is questionable; data for unpaved roads appear to be unreliable in many countries (Canning, 1998). No provision is made for the number of lanes.

Roads: paved distance (kilometres)
Sources: OYBU, US, SSA, CSIR, SANRA
March of year. Owing to the series being discontinued by SSA, the period 1994–2000 was interpolated using a constant annual growth rate.

Roads: passenger and commercial (goods) vehicles (number)
Sources: SSA, NATIS
1920–1960: End of year. 1961–1992: June of year. 1998–2002: End of year.
1923–25, 1963–65, 1967, 1969, 1971, 1993–97: interpolated using a constant growth rate.
Passenger vehicles include cars, minibuses, buses and motorcycles. Commercial vehicles are vehicles for the transport of goods.
Before 1979, the data *include* motor dealers' stocks and *exclude* vehicles exempt from licensing. From 1979, the data *exclude* motor dealers' stocks and *include* vehicles exempt from licensing. In 1979, these changes had the following offsetting effects: -20 084 and +65 746 for goods vehicles, and -74 388 and +25 698 for passenger vehicles.

Ports: cargo handled (harbour tons)
Source: OYBU, SSA, NPA
Namibia included for the years 1955–1974.
Petroleum is excluded.

Air travel: passengers carried by South African Airways (SAA) (number)
Source: SSA, SATS, SAA
Note that the figures refer to SAA only.

Air travel: international passengers passing through South African airports (number)
Source: SSA
Note that the figures refer to all airlines, including SAA.

Fixed phone lines (number)
Sources: OYBU, Canning (1998), Telkom
1912–1919: end of year. 1920–2003: March of year.
1934–1960: interpolated using growth rates for telephones in use (source: SSA).

Mobile phone lines (number)
Sources: Vodacom, Telkom
March of year.

Electricity generated (gigawatt hours)
Sources: US, SSA
1931, 1932, 1966, 1968: interpolated.

Producer (wholesale) price index
Sources: US, SSA

Consumer (retail) price index
Sources: US, SSA

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