INNOVATION IN SOUTH AFRICAN CITY-REGIONS:
CAN WE EXPLAIN IT[i]?

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Abstract

Much innovation takes place in cities and their adjacent and linked hinterland, or city-regions. Given that city-regions can be hotbeds of innovation, it is important to understand the determinants of these processes. The bulk of analytical work and of rankings concentrates on advanced economies, especially the US and Europe. One reason for this focus is that there is rich data about (city-) regions in those areas. The same cannot be said for developing countries in general, and for Africa in particular. South Africa is no exception. This paper is an attempt to assemble data that may be relevant for innovative outcomes in South Africa's city-regions and to make a few conjectures about the determinants of performance. To the best of our knowledge, to date no one has tried systematically to link comprehensive city-region data to innovative performance. South Africa has four major city-regions, namely the inland Gauteng city-region around the capital Pretoria and the commercial hub of Johannesburg, and Cape Town, eThekwini (Durban), and Nelson Mandela Bay (Port Elizabeth) on the coast. Together they host 60 per cent of the country's population and generate 72 per cent of GDP. Data show that South Africa's two relatively and absolutely most innovative city-regions (Gauteng and Cape Town) distinguish themselves from the other two (eThekwini and Nelson Mandela) through higher growth (of both economy and population), a higher employment rate, a sectorally more diverse workforce, lower poverty rates, and more investment in R&D, but not through higher per capita income, higher labour productivity, a higher share of the working in the total population, a higher growth of formal employment, a relatively more skilled workforce, and a larger degree of economic openness. Because of data limitations we run simple bivarite correlations on both patents and scientific publications. Our findings point to the fact that, R&D is good for innovation, and that a population equipped with the facilities to tune into global knowledge flows, supplied with a minimum level of services, and with very highly skilled scientists and engineers in their midst, produces more scientific articles. Due to unavailable, inaccessible, incomplete or otherwise problematic data we conclude that South Africa is not really in a position to understand innovative activities where they are generated, namely at the local level. Hence, in the short term, all that policymakers and academics can do is learn from innovation strategies in city-regions or countries elsewhere in the world in order to inform local policymaking.

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1   Introduction

Much innovation takes place in cities and their adjacent and linked hinterland, or city-regions. This influences their economic performance and explains their important role in regional or national development (cf. Feldman 2000). It also explains why policymakers pay much attention to city-region innovation or, more broadly, competitiveness (e.g. ODPM 2004). Figuring out what drives innovation is the first step to developing public policy that actively supports – or at least does not hinder – dynamic economic activities in both successful and laggard city-regions. There is a veritable cottage industry of (city-)region rankings based on more or less sensibly chosen indicators that somehow try to capture what makes a particular location dynamic (for a discussion, see Lever 1999 or Greene et al. 2007). For example, the *World Knowledge Competitiveness Index* (Huggins et al. 2008) compares 145 regions across 19 knowledge economy benchmarks and concludes that the metropolitan area of San Jose in California, home of Silicon Valley, leads the pack in terms of investment in education and business R&D, and reaping the results in the form of high productivity and earnings.

Given that city-regions can be hotbeds of innovation, it is important to understand the determinants of these processes. The academic literature gives us a variety of stories about how the relationship of firms with their surroundings, with each other, and with other actors that produce knowledge or with institutions that support such production, matter. These stories do not necessarily contradict each other but they do emphasise different features when trying to explain why certain (city-)regions prosper while others do not. What for some is agglomeration benefits derived from, say, superior infrastructure is intense knowledge exchange among firms in vertical or horizontal value chains for others, to name just two differences. This is why it is important to verify these propositions empirically. Insofar empirical verifications are guided by theory, they also advance our understanding better than mere competitiveness rankings which undoubtedly often assemble a rich and interesting set of indicators that are however not necessarily causally linked to each other.

The bulk of analytical work and of rankings concentrates on advanced economies, especially the US and Europe. One reason for this focus is that there is rich data about (city-)regions in those areas. The same cannot be said for developing countries in general, and for Africa in particular. South Africa is no exception. Both policy frameworks and analytical work focus primarily on the national, sectoral and systemic dimension of innovation as opposed to a more micro-based perspective on firms and lower-level spatial categories such as city-regions (Lorentzen 2009a). This paper is an attempt to assemble data that may be relevant for innovative outcomes in South Africa's city-regions and to make a few conjectures about the determinants of performance. Others have recently looked at innovation at the provincial level (Lorentzen 2009b, OECD 2008) or focused on the process of city region formation and its implication on social and spatial divisions and on urban governance (Rogerson 2000, Turok 2001, Pillay 2004, McDonald and Smith 2004, Parnell 2007, Lemanski 2007, and Lipietz 2008). South Africa's largest cities also regularly publish information about their activities, including economic performance (SACN 2008). To the best of our knowledge, however, to date no one has tried systematically to link comprehensive city-region data to innovative performance.

Section 2 discusses the possible reasons for the innovative performance of city-regions and presents some empirical results. It also introduces a conceptual model originally developed for the analysis of the differential economic performance of regions in the EU. Section 3 describes both basic innovation indicators and relevant variables on the input side drawn on the basis of the aforementioned model across four city-regions in South Africa. Section 4 discusses a few analytical results. Section 5 concludes.

2   Why does innovation happen in city-regions?

Much of the discussion of why innovation happens in certain places hinges on whether or not geographic and other kinds of proximity matter for economic performance, and how and why (see Simmie 2005 for an overview). Answering this question correctly is obviously of great importance to municipal, regional, and national governments alike. Unfortunately (for policymakers who rely on relatively straightforward recommendations, not for academics whose daily bread and butter depends on being able to argue convincingly that "further research" is needed) this issue is far from settled even though people have been applying their mind to it for more than a hundred years (cf. Iammarino and McCann 2006).

The various stories the literature gives us go as follows. First, a dynamic entrepreneur eager to commercialise new knowledge is likely to look for relevant ideas that other firms, including competitors, or perhaps research institutions might have had. This is not only a rationale for co-location – and, hence, underlines the importance of spatial proximity – but also an indication why the entrepreneur would choose a specific urban environment for it is only there that those spill-overs are likely to occur. This is Schumpeter's (1939) original story for whom linkages were a crucial part of the explanation of why innovations materialized in the first place and, thus, an essential facet of economic dynamism.

Second, and this is a very different story, early neoclassical economists explained the evident concentration of economic activity in reference to internal economies of scale. In other words the agglomerations we observe have nothing to do with linkages per se but are simply the result of being able to operate more profitably when one is surrounded by sizeable markets instead of by palm trees on an exotic beach. Marshall (1890) qualified this by arguing that the availability of common factors of production would result in co-location. Thus two firms ending up in the same place because of its airport that allowed them to access global markets both exploited the same externalities without necessarily having anything to do with each other. In this sense proximity was incidental rather than a causal factor in explaining the success of certain locations or the failure of others.[1]

There are many variations on this theme (see Simmie 2005), taking into account new phenomena such as globalization and new schools of thought such as the idea in evolutionary economics that the relative capability of firms to learn and to adapt to changing circumstances over long periods of time explains why the spaces where they are located prosper or decline. Yet none of these have caused breakthroughs so as to commit the academic community to one particular point of view. But what matters most for the purposes of this discussion is that one can explain the concentration of innovative activity basically in two very different ways. The first story is centrally about linkages and networks and therefore relates closely to the literature on national innovation systems. From the perspective of the global knowledge economy in which science, technology, and their application and dissemination play a key role for competitiveness, it is the story that is probably intuitively closer to how most policymakers see the world which of course does not mean that it is the correct view. The second story is not really interested in analyzing the determinants of knowledge-intensive processes as such and primarily revolves around how the combination of diverse firms, especially in large numbers, located in an environment endowed with favourable common production factors can lead to new combinations of inputs that eventually hit the market as innovations. In the second story, the policymaker must create a

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[1] Though Marshall was by no means a purist. His famous reference to "industrial atmosphere in the air" underlined the importance of tacit knowledge in specific industrial pursuits for which inter-firm linkages were key.

business friendly environment, and *basta*. In the first story, the policymaker must be part of an endeavour to incentivise knowledge flows among diverse actors, especially when information or coordination or network failures impede them. Obviously this is much more complicated than just revamping an existing airport. In fact, the informational requirements of such policy intervention are enormous.

It is therefore clear that settling this issue is far from trivial. Numerous empirical papers have attempted just that, with results that *tutto sommato* can best be summarized as "it depends". Depending on where one looks and which precise question one asks, proximity either matters or does not. Table 1 illustrates this with recent examples of the literature.

Not all investigations fall neatly into one or the other category. Simmie (2004) surveyed innovative firms in five of Europe's most innovative cities (Amsterdam, London, Milan, Paris, Stuttgart). Their answers suggest that reality is messier than the theories we come up with it to explain it. Urbanisation economies matter, especially in larger cities. This means that some firms prefer straightforward assets such as professional experts, skilled labour, efficient local and international transport systems over the benefits linked clusters more typical of smaller regional capitals generate. Put the other way round, interdependencies in clusters matter in smaller cities simply because of the lower returns to urban assets. In this interpretation strong supplier networks are not a strength in themselves but an adaptation to a relatively disadvantageous situation. On the other hand, firms reported that universities were important for innovation, and that especially in the early phases of innovative processes, the face-to-face exchange of knowledge was essential. Similarly, in an analysis of all US metro areas, Porter (2003) concluded that the strength of clusters – which for him combine linkages and agglomeration benefits – and innovative activity matter for regional economic performance.

An attempt to reconcile the different stories into a unified tale by constructing a model that allows for either set of factors to matter simultaneously was made by Cambridge Econometrics and EcoRys (2003) in a study for the European Commission on the factors of regional competitiveness. Thus, in this perspective, the competitiveness of a region resides in the competitiveness of its constituent firms and their interactions and in the wider assets and social, economic, institutional and public attributes of the region itself (see Figure 1).

Table 1 Proximity matters (not). Illustrative recent examples of relevant literature

Source	Data	Finding
		Proximity does not matter
Wolfe and Gertler (2004)	26 clusters in Canada in transition to more knowledge-intensive production	Dynamic clusters evolve in absence of strong local customer base and competition.
Niosi and Zhegu (2005)	Aerospace clusters in Montreal, Seattle, Toronto, Toulouse	New knowledge is mostly intra-firm; global sourcing constrains depth of local supply chain and regional externalities.
Simmie (2004)	UK high-tech and innovative firms	Nat'l and int'l linkages matter, local don't. Firms are reluctant to share knowledge but do so relatively more in global networks than locally.
Caniëls and Romijn (2003b)	Software industry in Bangalore	Traditional externalities matter: high demand for innovation, international technology transfer, low wages, good institutions.
Simmie, Sennet, and Wood (2002)	Award-winning firms in London Metropolitan Region	Regional infrastructure (Heathrow) and international connections with suppliers and customers are much more important than local linkages and networks. High-skilled matters in particular. Evidence of the existence of clusters and their impact on innovation is unclear
		Proximity does matter
Greunz (2003)	153 EU regions from 1989-96	Knowledge flows intensify with falling distance; university-industry linkages matter only in within very confined spaces.
Audretsch and Lehmann (2005)	Regions in Germany	Technological start-ups capture knowledge spill-overs more easily from close-by universities.
Asheim and Coenen (2005)	Several regions in Scandinavia	Dynamics of innovative activities depend on linkage between regions' sectoral specialization and the character of its knowledge base. In engineering based forms of knowledge, localized learning is important.
Carillo (2004)	Automotive supplier network around Ciudad Juarez, Mexico	Local social and institutional conditions enabled technological upgrading in GM-controlled supply chain.
Rondé and Hussler (2005)	1997 survey of 5000 geographically identified French manufacturing firms	Regionally networked actors explain differential innovative performance.
Cooke (2004)	Regions in UK	Social capital and business networking play a key role in developing competitive knowledge-based economies.

Figure 1   Regional Competitiveness Hat
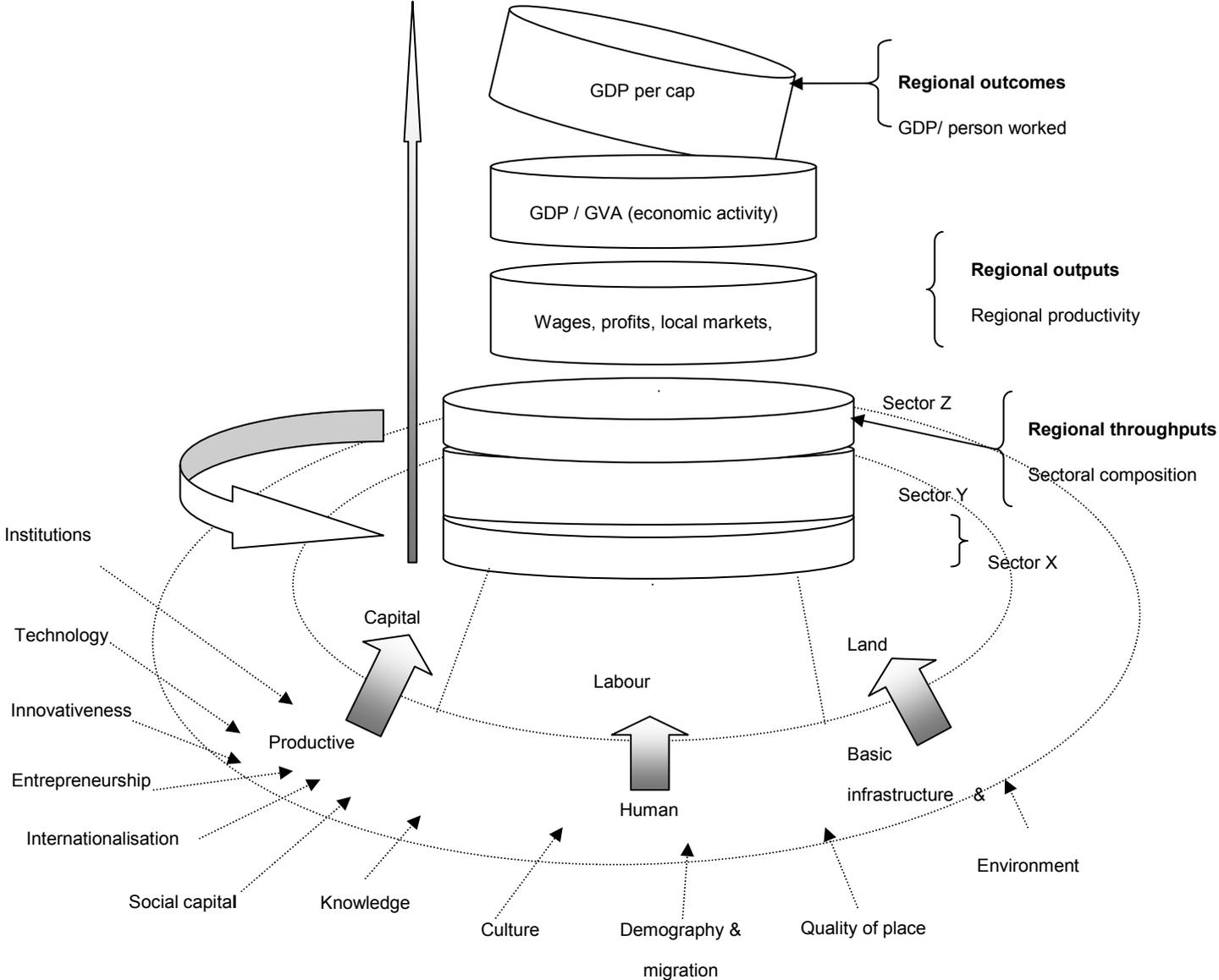
At its base, the model shows the factors of production (i.e. the region as a production site; innermost ring), primary factors that directly determine the regional investment climate (i.e. where regions are sites of scale economies; central ring), and secondary factors which indirectly influence the investment climate (i.e. regions as hubs of knowledge; outermost ring). Together they determine what firms do in which sector (regional throughputs), with what effect on productivity and market share (regional outputs), as well as with what consequences for average well being (regional outcomes). The model does not explicitly include innovation; if it did, it would lie somewhere between the activities of firms and productivity outcomes.

The merit of the model lies in depicting how linkages and agglomeration benefits may jointly determine outcomes as opposed to being completely different versions of what is essentially one story. But exactly therein lies its weakness: the proposition that *everything matters somehow* is a nightmare to subject to empirical testing. At the same time, however, it lends itself to organizing information about city-region innovative performance in contexts where data availability militates against rigorous testing anyway. The following section marshals data about city-region performance and its determinants in South Africa.

3   Innovation and its determinants in South African city-regions: a first look

Due to the administrative reorganization of the country after 1994, South African statistical information had to standardize data across newly demarcated sub-national boundaries. Although much progress has been made, there are still significant gaps in socio-economic data at a geographical level lower than the provincial boundaries. First, the only data that is collected on a full census is the population census, now on a 10-year frequency. This allows demographic analysis at the nodal or main-place level. For the most part, the remainder of socio-economic data (GDPR, employment, poverty), is collected on a sample basis, with a credible sample size at the provincial level. This means that sub-national trend analysis is usually beset by sample size confidence interval problems.

Second, there is a range of data that is critical to regional innovative performance analysis that is locked in various institutional databases and that even with extreme effort and tenacity can often not be extracted, let alone verified and analysed. Examples include air destination and passenger flows (ACSA 2009); road and rail network density (not unearthed); port capacity and usage (Transnet 2009); patent data (CIPRO); innovation and R&D data (HSRC), to name just a few. That this exacts a high cost in terms of *not* understanding the country's innovation system, is not widely appreciated.

Lastly, South African comparative socio-economic analysis has for the most part been undertaken at the national and provincial level. Only recently has attention shifted to cities and city-regions as key units of analysis. Furthermore, city-regions are not yet recognized as an official typology in the SA urban landscape. This means that city-region data analysis requires significant time and effort in collating from the lower level local municipality boundary to form a composite city-region boundary as the unit of analysis.

South Africa has four major city-regions, namely the inland Gauteng city-region around the capital Pretoria and the commercial hub of Johannesburg, and Cape Town, eThekwini (Durban), and Nelson Mandela Bay (Port Elizabeth) on the coast. They host almost 60 per cent of the country's population and generate 72 per cent of GDP (SACN 2008). Average standard of living is higher than in the country at large, due to higher average labour productivity, employment rate, and economically active population. In addition, Gauteng and Cape Town have higher

absorption rates and lower unemployment and poverty rates. In 2002-2007, Cape Town and Gauteng-city regions grew 5.6 and 5 per cent, respectively, compared to eThekwini at 4.7 per cent and Nelson Mandela at 4.1 per cent .

Gauteng and Cape Town city-regions are also more innovative than the rest of the country. They graduate more highly trained human capital, undertake more R&D, produce the major share of scientific excellence in the country, and register the highest number of both domestic and international patents.

Table 2: Outputs and outcomes

	Gauteng	Cape Town	eThekwini	Nelson Mandela	SA
Regional outcomes					
GDP per person (R)	36,423.81	34,186.01	28,524.09	34,063.95	23,203.38
GDP/ employment (labour productivity)	109,055	94,300	103,909	123,144	90,883
Employment/ working population (employment rate) (%)	47.93	53.02	40.59	39.96	41.72
Working population age population (%)	69.68	68.37	67.63	69.22	61.20
Unemployment, narrow (official) rate, 2007 (%)	20.63	16.63	28.87	26.19	22.66
Unemployment, expanded, rate, 2007 (%)	30.54	22.39	40.46	31.33	35.38
Employment absorption rate, 2007 (%)	49.64	53.69	38.80	45.92	41.31
Share of total employment, 2007 (%)	35.28	13.00	10.71	2.60	1000
Population share living below MLL (2004), % (of 2001 population totals)	30.00	23.37	41.46	44.40	
Population living below $1 a day (equivalent to R250 per person per month, 2007 prices), 2005 (Provincial level)	7.0	10.0	33.0	29.0	23
Outputs					
USPTO patents/ mil.pop., 2007	6.3	6.2	1.1	2.7	2.9
SET articles/ mil.pop., 2007 (ISI)	164.7	514.9	130.2	96.4	144.0

Source: SACN, 2008; Quantec Research, 2008; own calculations

In terms of outputs and outcomes, therefore, there is evidence that urban economic activity is generally more dynamic compared to the national average, and that there are important differences across the four regions analysed here. What stands out in particular is the lead role of the Gauteng and Cape Town city-regions. The question is whether this can be related to the inputs and the throughputs of the model introduced in the previous section.

Starting with the outermost ring (see Figure 1), we have information about two indicators. In terms of knowledge infrastructure, the four city-regions host 13 of the 23 universities and thus enroll most of the country's students.

In terms of internationalization, the Gauteng city-region accounts for more than two thirds of South Africa's export, followed by Cape Town (10%), eThekwini (8.3%), and Nelson Mandela Metropole (6.3%) (SACN 2008). At 48.8 and 42.6 per cent share of exports in city-region output, respectively, NMCR and GCR are more than twice as open as CTCR (20.1%) and eThekwini CR (18.6%).

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In the central ring, data about transport infrastructure shows that the Gauteng city-region where almost 20 million passengers transit through OR Tambo airport every year is more directly connected with the outside world than either Cape Town or Durban, with a quarter of traffic volume, and a much lower share of international commuters. In addition, OR Tambo lies at the core of the country's road network, connecting the Gauteng city-region to the main national corridors and the rest of Southern Africa. Freight movement from Gauteng is twice as high as that to Gauteng. Cape Town and eThekwini city-regions show the strongest coastal performance – 46 per cent of cargo is handled through the Cape Town and Saldana ports in the Cape Town city-region, while Durban and Cape Town ports process 68 and 20 per cent of containers (measured in tonnage equivalent units or TEUs), respectively (Transnet 2009).

Figure 2: City-region concentration of physical infrastructure, represented by total volume of freight movement on major corridors

Source: SACN, 2008

Cape Town city-region, by contrast, is the most wired. Alone among the four city-regions, it is twice as much turned on (share of households with computer) and tuned in (share of households with internet access) than the country at large.

Table 3: Technological infrastructure

	GCR	Cpt CR	eThekwini CR	NM CR	SA
Technological infrastructure					
ICT					
Share of households with mobile phone (%), 2007	79.66	75.84	74.74	64.33	72.72
Share of households with computer (%), 2007	21.93	32.10	17.88	19.90	15.60
Telecoms Share of households with fixed line telephone (%), 2007	21.77	44.21	29.53	28.84	18.55
Internet Share of households with internet access (%), 2007	10.27	17.26	8.50	8.00	7.20

Source:　　　SACN, 2008; Quantec Research, 2008.

Over 20 per cent of South Africa's working-age population lives in the Gauteng city-region where it accounts for almost 40 per cent of formal total employment; Cape Town city-region has 10 per cent working-age population and eThekwini 11 per cent, together making up a quarter of total employment in the country. Two-thirds of the country's (highly) skilled workers are in the four city-regions, with roughly two out of five in Gauteng city-region alone. Relatively speaking, however, Gauteng and Cape Town city-regions do *not* have a much more highly skilled workforce than the other cities. This is presumably because in-migration from the country's poor regions involves a large share of low-skilled economic activities.

Table 4　Inputs: Knowledge infrastructure, internationalization, human capital

	GCR	Cpt CR	eTheKwini	NM	SA
Knowledge Infrastructure					
Higher educational facilities	5	4	3	1	23
Internationalization					
Value of exports (R000s), 2007 (current prices)	319,146,432	46,853,766	38,339,416	29,667,708	434,007,322
Share of total exports, 2007 (%)	67.29	9.88	8.08	6.26	100.00
Share of total (national) GDP, 2007 (%)	18.05	2.65	2.17	1.68	24.54
Share of regional GDP, 2007 (%)	42.56	20.15	18.64	48.78	24.54
Value of imports (R000s), 2007 (current prices)	328,802,640	124,191,200	60,285,352	27,362,313	562,502,323
Share of total imports, 2007 (%)	58.45	22.08	10.72	4.86	96.11
Human Capital					
Working age population, 2007 (15-64 years)	9,113,940	3,037,077	3,266,981	806,038	29,682,969
Employment/ working population (employment rate) (%)	47.93	53.02	40.59	39.96	41.72
Secondary enrolment rate, 2006 (% of total population, 2007)	22.50	18.70	26.03	26.69	25.35
Tertiary enrollment rate , 2006 (% of total population, 2007)	4.03	1.82	0.77	1.00	1.55
Employment, highly skilled, 2007 (%)	13.6	12.9	13.2	13.3	12.75
Employment, skilled, 2007 (%)	44.0	44.2	45.1	44.7	43.3
Employment, unskilled, 2007 (%)	42.4	42.9	41.7	42.0	44.0

Source: SACN, 2008; Quantec Research, 2008 & National Department of Education, 2008.

In fact, the four city-region economies are relatively diversified. The tertiary sector makes up more than half of output. The share of manufacturing in city-region income peaks at 24 per cent

in the Nelson Mandela city-region. The Gauteng city-region is primarily specialized in mining, a wide range of manufacturing activities, electricity generation, and construction. The Cape Town city-region is specialized in clothing and textiles, finance and business services, tourism plus an agriculture value chain that extends into food processing and beverages. eThekwini city-region is specialized in manufacturing, water, and transport and communication. Economic activity in the NM city-region is concentrated in manufacturing, especially automotive and electrical machinery, and community services. Employment location quotients largely confirm these specializations. This underlines the importance of manufacturing to the four city-regions which are de facto the country's workshops. But it also shows that Gauteng and Cape Town city-regions are more diverse than eThekwini and NM city-regions.

Table 5 Inputs: Economic specialization

	GCR	Cpt CR	eThekwini CR	NM CR	SA
Agriculture, forestry & fishing	**0.57**	**3.06**	**2.93**	**1.43**	**2.43**
Mining	**7.21**	**0.13**	**0.36**	**0.05**	**6.07**
Manufacturing	**20.32**	**17.35**	**23.35**	**24.06**	**17.68**
Food, beverages & tobacco	*2.20*	*3.23*	*4.00*	*2.57*	*2.64*
Clothing, textiles & leather goods	*0.35*	*1.59*	*2.00*	*0.89*	*0.78*
Wood & paper, publishing & printing	*1.85*	*2.14*	*2.80*	*1.40*	*1.87*
Petroleum products, chemicals, rubber & plastic	*5.20*	*3.76*	*5.13*	*5.31*	*4.00*
Other non-metal mineral products	*0.72*	*0.56*	*0.52*	*0.74*	*0.59*
Metals, metal products, machinery & equipment	*5.36*	*2.91*	*3.27*	*2.25*	*3.71*
Electrical machinery, equipment & apparatus	*0.61*	*0.47*	*0.62*	*1.27*	*0.51*
Radio, TV, instruments, watches & clocks	*0.26*	*0.23*	*0.31*	*0.23*	*0.22*
Transport equipment	*1.83*	*0.92*	*2.20*	*7.36*	*1.66*
Furniture & other manufacturing	*1.94*	*1.55*	*2.51*	*2.03*	*1.71*
Electricity & water	**2.59**	**1.54**	**2.17**	**1.04**	**2.29**
Electricity	*2.35*	*1.43*	*1.71*	*0.99*	*2.02*
Water	*0.24*	*0.12*	*0.46*	*0.05*	*0.27*
Construction	**4.15**	**4.85**	**3.02**	**2.01**	**3.76**
Wholesale & retail trade; catering & accommodation	**14.94**	**16.75**	**16.52**	**15.26**	**15.43**
Wholesale & retail trade	*14.01*	*15.44*	*15.49*	*14.45*	*14.39*
Catering & accommodation	*0.93*	*1.31*	*1.03*	*0.81*	*1.04*
Transport & communication	**8.93**	**10.87**	**15.35**	**10.93**	**10.70**
Transport	*4.64*	*6.30*	*10.10*	*4.66*	*6.17*
Communication	*4.29*	*4.57*	*5.25*	*6.27*	*4.53*
Finance & business services	**23.14**	**31.82**	**20.09**	**24.08**	**22.20**
Finance & insurance	*12.35*	*17.50*	*10.46*	*13.68*	*11.88*
Business services	*10.79*	*14.32*	*9.63*	*10.40*	*10.31*
Community, social & other personal services	**18.15**	**13.62**	**16.20**	**21.16**	**19.43**
Community, social & other personal services - other	*4.29*	*4.71*	*5.74*	*8.92*	*5.77*
General government services	**13.86**	**8.91**	**10.46**	**12.24**	**13.66**
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: SACN, 2008; Quantec Research, 2008

In sum, the assembled data show that South Africa's two relatively and absolutely most innovative city-regions (Gauteng and Cape Town) distinguish themselves from the other two (eThekwini and Nelson Mandela) through higher growth (of both economy and population), a

higher employment rate, a sectorally more diverse workforce, lower poverty rates, and more investment in R&D, but *not* through higher per capita income, higher labour productivity, a higher share of the working in the total population, a higher growth of formal employment, a relatively more skilled workforce, and a larger degree of economic openness.

In addition, the two technologically most innovative city-regions differ from each other in two respects. First, Gauteng city-region is the country's transport hub, including air traffic and road and port shipping. It therefore offers agglomeration benefits.[2] Second, the Cape Town city-region has relatively the least people out of work, the highest increase in working population, the most dense communication infrastructure, and by far the largest and most productive scientific workforce.

In other words – if one accepts that growth is a consequence of innovation – having more people in jobs in a variety of activities (which is likely related to the lower incidence of poverty) and investing in R&D, is good for innovation. But being *on average* relatively better off and more productive, with a higher share of the population that is potentially economically active, better job growth in the formal sector, higher skills and more exposure to export markets, is not (necessarily). This is by no means an intuitive finding. In fact, a more sophisticated analysis of the data might reveal that a more highly trained and productive workforce is positively associated with innovation if one links *specific* technological activities with related patent classes. Then, innovative outcomes might not be related to the *aggregate* features of a specific spatial economy, but to activities that only manifest themselves at a micro level, such as inter- or even intra-sectoral differences in productivity and skill intensity.

Further, it might be that one city-region's path to technological innovation is based on superior infrastructure, whereas another one's is more based on a critical mass of scientifically trained people. Although both could be interpreted as agglomeration benefits, it is likely that scientifically trained people – especially to the extent that they work in universities or research institutes – generate technological outcomes only in the context of linkages with firms that stimulate their research agenda and adopt their findings.

The next section tries to treat these questions analytically.

4   Determinants of innovation: a second look

Although our database contains numerous variables (see Appendix 1 for a complete list), most are not available as time series. With only four city-regions analysed, this therefore very much limits its size. In addition, many variables are highly correlated which makes it impossible to test for multivariate relationships properly. Since there is no a priori reason to include or exclude certain variables, an ideal procedure would have been to reduce the number of variables by decomposing the dataset through principal component analysis (PCA), thus identifying the most relevant variables and grouping them on the basis of common traits. But although PCA might work in a cross-section, it would require a much larger number of observations than we have. The size of the dataset also limits feasible econometric estimations due to problems with degrees of freedom.

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[2] They could of course turn into diseconomies from congestion and so on.

Therefore, we run simple bivariate correlations on both patents and scientific publications. With patents as the dependent variable, most variables have the right sign yet only R&D per capita is statistically significant, and only at the 10% level. In addition, the coefficient is very low; in other words it takes lot of extra R&D to produce an additional patent. Regressing on scientific output shows that again most variables have the expected sign but only three are significant at the 5% level, namely ICT infrastructure and SET PhD graduates. The coefficient on secondary enrollment rate is also significant (at 10%) but has an unexpected sign. Almost all coefficients are very high which is rather difficult to interpret and might well rather be due to the nature of the dataset we are using. Finally, an increase in scientific output significantly improves GDP growth.

Table 6   Regression Results: Dependent Variable:

USPTO Patents/million population (Patents)

Category	Variable	Constant	Coefficient	t-statistic	P-value	R^2
Access to Infrastructure	hhmobile	-11.69	0.21	0.91	0.46	-0.06
	hhcomputers	-2.91	0.30	1.56	0.26	0.32
	hhtelephone	2.34	0.06	0.29	0.80	-0.44
	hhinternet	-0.58	0.42	1.38	0.30	0.23
Knowledge Economy	Litr_rate	18.59	-0.18	-1.02	0.42	0.01
	Litw_rate	18.49	-0.17	-1.02	0.42	0.01
	secenrolrate	18.15	-0.60	-2.28	0.15	0.58
	terenrolrate	1.33	1.0	1.62	0.25	0.35
	setphdmilpop	1.46	0.02	1.05	0.40	0.03
	Heduc_facilities	-2.60	1.48	0.99	0.43	-0.01
Economic Activity	gdppp	-17.50	0.0006	2.19	0.16	0.56
	expst	2.88	0.05	1.06	0.40	0.04
	impst	2.16	0.08	1.55	0.26	0.32
	Expsngdp07	2.88	0.20	1.06	0.40	0.03
	dependratio	38.13	-0.75	-0.96	0.44	-0.03
	poverty	12.23	-0.23	-2.73	0.11	0.68
	Labfnpr07	-26.03	0.49	2.11	0.17	0.53
	R&D per capita	1.08	0.007*	3.87	0.061	0.82

*, **, ***, significant at 10%, 5% and 1% level of significance respectively.

Table 7   Regression Results:

Dependent Variable: SET articles/mil.pop (Publications)

Category	Variable	Constant	Coefficient	t-statistic	P-value	R2
Access to Infrastructure	hhmobile	-555.13	10.61	0.54	0.64	-0.31
	hhcomputers	-460.82	29.95**	6.10	0.026	0.92
	hhtelephone	-333.66	18.02	2.55	0.13	0.65
	hhinternet	-270.57	45.15***	13.84	0.005	0.98
Knowledge Economy	Litr_rate	1177.97	-11.49	-0.84	0.49	-0.11
	Litw_rate	1141.09	-11.08	-0.81	0.51	-0.13
	secenrolrate	1371.68	-48.77*	-3.41	0.076	0.78
	terenrolrate	223.54	1.10	0.02	0.99	-0.50
	setphdmilpop	-99.93	1.99***	16.22	0.004	0.99
	Heduc_facilities	412.1	-41.23	-0.31	0.79	-0.43
Economic Activity	gdppp	-188.52	0.01	0.31	0.78	-0.43
	expst	251.77	-1.10	-0.24	0.83	-0.46
	impst	211.51	0.63	0.11	0.92	-0.49
	expsngdp07	251.77	-4.11	-0.24	0.83	-0.46
	dependratio	-786.39	22.24	0.32	0.78	-0.43
	poverty	813.08	-16.85	-2.31	0.15	0.59
	Labfnpr07	-1213.61	23.64	0.89	0.47	-0.07
	R&D per capita	94.80	0.30	0.94	0.45	-.04

*, **, ***, significant at 10%, 5% and 1% level of significance respectively.

5   Conclusion

These results are not exactly earthshattering. In fact, the answer to the question posed in the title – Can we explain innovation? – is no. At this point of the analysis all we can surmise is that R&D is good for innovation, and that a population equipped with the facilities to tune into global knowledge flows, supplied with a minimum level of services, and with very highly skilled scientists and engineers in their midst, produces more scientific articles. With the exception of the role of service delivery, this is pretty intuitive. More prosaically, the analytical harvest of the paper is not proportionate to the amount of blood, sweat and tears involved in assembling the data in the first place.

This is a serious indictment. Unavailable, inaccessible, incomplete or otherwise problematic data imply that South Africa is not really in a position to understand innovative activities where they are generated, namely at the local level. The data situation provides disincentives to researchers to engage with the situation at hand because papers without real results do understandably not carry much weight in the academic debate. The consequent lack of systematic insights means that provincial or city-level policymakers keen to develop innovation strategies cannot really rely pursue evidence-based policy. If they design policy anyway, there is a big chance that it is ineffectual. In fact, it might be a complete waste of money. In sum, the innovation system lacks the reflexivity that would allow it to evaluate its performance in terms of whether or not it is achieving its stated aims.

Improving the self-documentation of a system takes time, resources, and political will. In the long term, there is no reason that South Africa with its strong commitment to a national innovation system cannot see to it that missing data be collected, inaccessible data be put into the public domain, and incomplete datasets be improved country-wide. A good start would be to open up

the R&D and Innovation Surveys, both of which are publicly funded, to systematic scrutiny instead of merely drawing on what is somewhat euphemistically published as "high-level results". Understanding the dynamics of innovation requires panel data that will only be assembled if there is a long-term commitment on the part of public bodies, especially at national level, to fund the requisite data gathering. Establishing significance would then be much more meaningful than with our cross-section analysis.

In the medium-term, more advanced city-regions and provinces could pioneer systematic data collection that is informed by the need to understand what exactly determines their relative successes and failures in innovative performance. In contrast to the OECD-influenced R&D and Innovation Surveys, they could pay more attention to micro-level data that would allow to test for the existence of dualist urban (or provincial) economies where innovative sectors exist side by side with others that are untouched by new and better ways of doing things and that would greatly benefit from publicly supported endeavours of knowledge transfer.

In the short term, all that policymakers and academics can do is learn from innovation strategies in city-regions or countries elsewhere in the world in order to inform local policymaking. In sum, an assessment of network alignment in the way the U-Know project postulated, is some way off for South Africa.

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Appendix 1: DATA AVAILABLE AND USED FOR THE ANALYSIS

Available Variables	Acronym	Variables used in the analysis
Technological infrastructure		
Share of households with mobile phone (%), 2007	hhmobile	✓
Share of households with computer (%), 2007	hhcomputers	✓
Share of households with fixed line telephone (%), 2007	hhtelephone	✓
Share of households with internet access (%), 2007	hhinternet	✓
Knowledge infrastructure		
Higher educational facilities	Heduc_facilities	✓
Access to basic services		
Formal housing, households, 2007 (%)		
Informal housing, households, 2007 (%)		
Households using electricity as main energy source, 2007 (%)	hhelectricity	✓
Households with access to potable water in dwelling, 2007 (%)	hhpwater	✓
Households with access to potable water more than 200m away, 2007 (%)		
Households with access to flush/ chemical toilet, 2007 (%)	hhflush	✓
Households that have refuse removed by local authority at least once a week, 2007 (%)	hhrefuse	✓
Quality of Life		
Unemployment		
Unemployment, narrow (official) numbers, 2007		
Unemployment, narrow (official) rate, 2007 (%)		✓
Labour force (narrow) participation rate, 2007 (%)		
Unemployment, expanded definition, numbers, 2007		
Unemployment, expanded, rate, 2007 (%)		✓
Labour force (expanded) participation rate, 2007 (%)	Labfnpr07	✓
Employment absorption rate, 2007 (%)		✓
Poverty		
Population living below Minimum Living Level (MLL), 2004	poverty	✓
Population share living below MLL (2004), % (cf 2001 population totals)		✓
Population living below $1 a day (equivalent to R250 per person per month, 2007 prices), 2005 (Provincial level)		
Population living below $2 a day (equivalent to R467 per person per month, 2007 prices), 2005 (Provincial level)		
Employment Location Quotient 2006		
Agriculture		
Mining		
Manufacturing		
Electricity & water		
Construction		
Wholesale & retail trade; catering & accommodation		
Transport & communication		
Financial & business services		
Community social & other personal services (CSP)		

Employment by sector, 2006

Agriculture	empagric	✓
Mining	empmin	✓
Manufacturing	empmfg	✓
Electricity & water	empelec	✓
Construction	empconst	✓
Wholesale & retail trade; catering & accommodation	empwhol	✓
Transport & communication	emptrans	✓
Financial & business services	empfin	✓
Community social & other personal services (CSP)	empcom	✓

GDPR sector share (%), 2007

Agriculture, forestry & fishing

Mining

Manufacturing

Food, beverages & tobacco

Clothing, textiles & leather goods

Wood & paper, publishing & printing

Petroleum products, chemicals, rubber & plastic

Other non-metal mineral products

Metals, metal products, machinery & equipment

Electrical machinery, equipment & apparatus

Radio, TV, instruments, watches & clocks

Transport equipment

Furniture & other manufacturing

Electricity & water

Electricity

Water

Construction

Wholesale & retail trade; catering & accommodation

Wholesale & retail trade

Catering & accommodation

Transport & communication

Transport

Communication

Finance & business services

Finance & insurance

Business services

Community, social & other personal services

Community, social & other personal services - other

General government services

Available Variables	Acronym	Variables used in the analysis
GDPR Specialisation indices (2007)		
Agriculture, forestry & fishing	agric_sp	✓
Mining	min_sp	✓
Manufacturing	manuf_sp	✓
Food, beverages & tobacco		
Clothing, textiles & leather goods		
Wood & paper, publishing & printing		
Petroleum products, chemicals, rubber & plastic		
Other non-metal mineral products		
Metals, metal products, machinery & equipment		
Electrical machinery, equipment & apparatus	elecwater_sp	✓
Radio, TV, instruments, watches & clocks		
Transport equipment		
Furniture & other manufacturing		
Electricity & water		
Electricity		
Water		
Construction	cons_sp	✓
Wholesale & retail trade; catering & accommodation	whol_sp	✓
Wholesale & retail trade		
Catering & accommodation		
Transport & communication	transcom_sp	✓
Transport		
Communication		
Finance & business services	fin_sp	✓
Finance & insurance		
Business services		
Community, social & other personal services	comm_sp	✓
Community, social & other personal services - other		
General government services	gengov_sp	✓
Internationalisation		
Value of exports (R000s), 2007 (current prices)		
Share of total exports, 2007 (%)	expst	✓
Share of total (national) GDP, 2007 (%)	Expsngdp07	✓
Share of regional GDP, 2007 (%)		
Value of imports (R000s), 2007 (current prices)		
Share of total imports, 2007 (%)	impst	✓

Available Variables		Variables used in the analysis
Human resources		
Adult literacy (reading) numbers, 2007 (Provincial level)		✓
Adult literacy (reading) rate, age 15+ (%), 2007, (Provincial level)	Litr_rate	
Adult literacy (writing) numbers, 2007 (Provincial level)		
Adult literacy (writing) rate, age 15+ (%), 2007 (Provincial level)	Litw_rate	✓
Secondary enrolment rate, 2006 (% of total population, 2007)	secenrolrate	✓
Tertiary enrollment numbers, 2006 (Provincial level)		
Tertiary enrollment rate, 2006 (% of total population 15+, 2007)		
Tertiary enrollment rate , 2006 (% of total population, 2007)	terenrolrate	✓
Population, age 15+ , 2007 (Provincial level)		
Population, total, 2007 (Provincial level)		
Highly skilled workforce		
Employment, highly skilled, 2006 (%)		
Employment, skilled, 2006 (%)		
Employment, unskilled, 2006 (%)		
Employment, highly skilled, 2007 (%)	emphs07	✓
Employment, skilled, 2007 (%)	emps07	✓
Employment, unskilled, 2007 (%)	empus07	✓
Regional outcomes		
GDP, 2007 (R000s in constant 2000 prices)		✓
GDP, 2007 (R000s in current 2007 prices)		
GDP growth, 1995 - 2007 (%)		✓
GDP growth, 2002 - 2007 (%)		
Population, 2007		
Working age population, 2007 (15-64 years)		✓
Number employed, 2007 (formal + informal)		
Share of total employment, 2007 (%)		
GDP per person	gdppp	✓
GDP/ employment (labour productivity)		✓
Employment/ working population (employment rate) (%)	Emp/WPop	✓
Working population age /population (%)		
Innovation System		
R&D per capita, Rand, 2005 (Provincial)	R&D per capita	✓
SET PhDs/mil.pop., 2004	setphdmilpop	✓
SET articles/mil.pop., 2004 (local)		✓
USPTO patents/mil.pop., 2007		✓

Available Variables		Variables used in the analysis
Socioeconomic indicators		
Dependency ratio	dependratio	✓
EAP, annual average growth, 2001-2007, %		
Employment growth, 2001-2006		
City region population by age and race		
City region population by age and gender		