

Cloud Computing in the Global South: Drivers, Effects and Policy Measures

By: [Nir Kshetri](#)

Kshetri, Nir, (2011). "Cloud Computing in the Global South: Drivers, Effects and Policy Measures," *Third World Quarterly*, 32(6), 995-1012.

*** This is an Accepted Manuscript of an article published by Taylor & Francis in *Third World Quarterly* on June 27, 2011, available online:

<http://www.tandfonline.com/10.1080/01436597.2011.586225>

***© Taylor & Francis. Reprinted with permission. No further reproduction is authorized without written permission from Taylor & Francis. This version of the document is not the version of record. Figures and/or pictures may be missing from this format of the document. ***

***Note: Footnotes and endnotes indicated with parentheses

Abstract:

Cloud computing has started to transform economic activities in the global South. Many businesses are taking advantage of the pay-as-you-go model of the technology, and its scalability and flexibility features, and government agencies in the South have been investing in cloud-related mega-projects. Cloud-based mobile applications are becoming increasingly popular and the pervasiveness of cellphones means that the cloud may transform the way these devices are used. However, findings and conclusions drawn from surveys, studies and experiences of companies on the potential and impact of cloud computing in the developing world are inconsistent. This article reviews cloud diffusion in developing economies and examines some firms in the cloud's supply side in these economies to present a framework for evaluating the attractiveness of this technology in the context of evolving needs, capabilities and competitive positions. It examines how various determinants related to the development and structure of related industries, externality mechanisms and institutional legitimacy affect cloud-related performances and impacts.

Keywords: Global South | cloud computing | China | India | Vietnam | South Africa

Article:

Cloud computing (hereafter: the cloud), which is likened and equated to the Industrial Revolution in terms of technological innovations, structural change and the sources of economic growth, has started to transform economic activities in the Global South. Many interesting and creative techniques involving the cloud have been developed. For instance, mothers2mothers (M2M), a South African non-governmental organisation, combines the cloud with database technology and mobile services to fight HIV/AIDS transmission from mother to children.(1) M2M digitizes patient records and shares them with counsellors across its networks of over 700 sites in Africa. The records contain information on treatment plans, and advanced reporting tools,

which allow quick response. Women in African villages authenticate children's medication with text messages.(2)

The cloud may provide an opportunity to leapfrog and overcome barriers related to information and communications technology (ICT) infrastructures.(3) It is being combined with cellphones and mapping applications and other technologies to facilitate information flow. A novel and intriguing application has been improving water supply availability and reliability.(4) The cloud has empowered customers and forced water providers to be accountable, efficient and transparent. Tools are built to improve the performances of government agencies and water aid groups, and to provide information to users. Walton has documented various approaches used in improving water supply: 1) in cities with irregular supplies the start-up, Next Drop, utilises data gathered from cellphone users to predict water availability; and 2) The NGO Water for People uses data-tracking technology to assess real-time performances and functioning of water projects.(5)

Table 1. Some examples of cloud applications in the developing world

Cloud application	Examples
E-commerce	<ul style="list-style-type: none"> • China: Wang Fu Jing has deployed cloud services to share supply chain information and implement B2B e-commerce with suppliers. • South Korea: IBM's cloud computing centre provides architecture, skills and pilot projects for banking, telecommunications, and IT hosting services.
E-education	<ul style="list-style-type: none"> • South Africa: the University of Pretoria uses cloud for the next-generation medical research. • East Africa: the Higher Education Alliance for Leadership Through Health (HEALTH Alliance), a consortium of seven universities, which includes universities in Kenya, Jimma University, Ethiopia; University of Kinshasa, Democratic Republic of Congo; Muhimbili University of Health and Allied Sciences, Tanzania; and Makerere University, Uganda, is working with industry experts to extend education through virtual computing labs that students access remotely. • India: IIT Kanpur and other universities use the cloud. • Vietnam: VNU uses the cloud to build IT skills
E-governance	<ul style="list-style-type: none"> • Vietnam: Ministry of Education and Training, Ministry of Science and Technology, and Ministry of Information and Communications have jointly developed cloud-based academic programmes.
E-health	<ul style="list-style-type: none"> • China: Guang Dong Hospital of Traditional Chinese Medicine has implemented a suite of healthcare data-sharing and analytics technologies.
E-banking	<ul style="list-style-type: none"> • India: ICICI's insurance arm uses Zoho's applications to develop services such as personalised insurance for diabetes. • South Africa: Nedbank has automated business processes through cloud.
E-environment	<ul style="list-style-type: none"> • China: universities have access to a supercomputer power to analyse climate data. • West Africa: the UK's Hadley Centre for Climate Prediction and Research is negotiating with Amazon to sponsor a researcher for free access to cloud.

Unsurprisingly multinationals, local companies and policy makers have devoted considerable attention to the cloud (see Table 1).(6) IBM has cloud centres in China, India, Vietnam and Brazil. Microsoft, VMware, Salesforce and Parallels are active in the South. Similarly, developing world-based firms have jumped on the cloud bandwagon. Cloud related venture capital investments are flowing.(7)

Regarding the potential and impact of the cloud in the South, however, findings and conclusions drawn from surveys, studies and experiences are inconsistent. Some suggest that the cloud will make 'Health Care 2.0', 'Banking 2.0' and 'Education 2.0' realities in the South.(8) A study by International Data Corporation suggested that Brazil, Russia, India and China will drive the global shift towards the cloud.

In theory it is possible for the South to catch up with the North as the cloud allows access to the same infrastructure, data centres and applications. The cloud reduces infrastructure costs and levels the playing field for small and medium-sized enterprises (SMEs).(9) Second, unlike client-based computing, cloud-based software is easier to install, maintain and update.(10) Third, the cloud provides the flexibility of scaling up uses if demand increases.(11) Fourth, proponents argue that, as software becomes free via web-based applications, piracy may reduce.(12) A final observation is that the cloud allows third parties to provide cost-effective security.(13) However, these observations may have under-estimated the economic and institutional problems. There is little evidence to show how effectively these theories, ideas and speculations can translate into practice.

The as yet unanswered questions are: 1) What factors drive the development of the cloud in the South? 2) What are the potential impacts of this technology in the South? 3) What roles can businesses and policy makers play to facilitate the adoption and effective utilisation of the cloud? This paper outlines contexts, mechanisms and processes associated with the development of the cloud in the South. We present a framework for evaluating the attractiveness of the cloud with reference to the South's evolving needs, capabilities and competitive positions.

Before proceeding, we offer some definitions. Cloud computing involves hosting applications on servers and delivering software and services via the internet. In the cloud model companies can access computing power and resources on the 'cloud' and pay for services-based on usage. SaaS, a subset of the cloud, is a model of software deployment, in which a provider licenses an application to customers for use as a service on demand.

The remainder of the paper is structured as follows. The next section provides a survey of cloud computing in developing economies. The paper then reviews some developing country-based firms in the supply side of the cloud. Next, we propose a framework to understand the development of the cloud industry in the South. This is followed by a discussion of findings and implications. Concluding remarks end the paper.

A survey of cloud computing in the South

One estimate has suggested that the worldwide cloud market was US\$38 billion in 2010, which is expected to increase to \$121 billion by 2015.(14) According to Gartner, the global cloud

industry will reach \$149 billion by 2016.(15) Likewise Forrester Research's estimate suggests that this industry will be worth \$241 billion in 2020.(16) Industrialised countries account for most of the global demand. Nonetheless, while the cloud is a more recent phenomenon in the South, its growth rate and range of applications have been striking.

A fascinating aspect of the cloud is that the South can also participate in platforms by developing technologies, standards, innovations and services. The chairman of Trend Micro said that the cloud would allow the South to share the same resources and opportunities as players in the North.(17)

The cloud is especially attractive where there is resource scarcity and a high propensity to share ICT tools.(18) In Africa a person's cellphone is a community device.(19) Likewise, in the early 2000s, each phone in Bangladesh served 70 customers.(20) In this connection the one-laptop-per-child (OLPC) programme is among visible initiatives to improve ICT access. For an important reason, however, the OLPC falls short in supporting the South's digitisation: it does not encourage sharing. Despite the optimistic promises, the OLPC has been largely unsuccessful.(21) The cloud's direct benefit is its shared processors and data storage. It capitalises on computers' unused capabilities and a central processing unit (CPU) runs multiple terminals(22)

Cloud computing is also at the centre of debate on greenhouse gas emissions. This issue is critical to the South because of air pollution problems, among others. ICT companies account for three per cent of global greenhouse gas emissions.(23) According to a McKinsey Quarterly report, in 2009 the world's 44 million data servers accounted for 0.5 per cent of electricity consumption. The report noted: 'Without efforts to curb demand, current projections show worldwide carbon emissions from data centers will quadruple by 2020'. Some cloud-based applications can help address environmental issues. For instance, Google's 'Earth Engine' is planning to offer archives of satellite images and cloud power for free, which may prevent deforestation.(24)

Below we provide a brief survey of cloud computing in four major developing economies.

Cloud computing in China

China considers the cloud as an opportunity to provide cost-effective internet services to SMEs and consumers and has an ambitious virtualisation programme. According to CCID Consulting, China's cloud market was over \$1.5 billion in 2009 and will reach \$10 billion by 2012.(25) Analysts suggest that by 2015 China may produce cloud-based software service providers of the same calibre as those produced by Salesforce.com.(26)

The government allocated substantial funds to cloud in its \$586 billion stimulus package of 2008.(27) To develop into a 'smart city', Shanghai is planning to invest in 40 projects, including cloud, by 2015. Five cities have been chosen to develop the cloud as a national policy.(28) Global players such as Hewlett-Packard, IBM, Microsoft and Oracle have made significant investments.

In 2008 IBM opened a cloud centre in Beijing. Its Shanghai R&D facility has the cloud as a primary area.(29) In 2009 it opened a Healthcare Industry Solution Lab for hospitals and rural medical co-operatives. IBM has a partnership with China's Range Technolog to construct a 6.2 million square foot, state-of-the-art centre in Langfang city, which will be comparable to the Pentagon, with 646 000 square feet devoted to the data centre.(30) After its completion in 2016 the centre will be the largest of such facilities in Asia.(31) Analysts predict that, at the current growth rate, there will be enough demand to utilise the services offered by the country's cloud providers by 2016.(32)

China's domestic software development industry has viewed the cloud as an important means to increase market reach by reducing set-up and product development costs. The IBM cloud centre in Wuxi City serves to illustrate this point. The centre plans to support 'several hundred thousand developers across hundreds of companies'.(33) The tenants, mostly SMEs, have access to it infrastructures and enterprise-ready environments.(34) In 2009 IBM and the Wuxi National Software Park (iPark) launched PangooSky platform for SMEs.(35)

Thanks to the cloud Chinese universities have access to the power of a supercomputer to analyse data on disease spread patterns and climate change.(36) Similarly the Guang Dong Hospital of Traditional Chinese Medicine has implemented a suite of healthcare data-sharing and analytics technologies.(37) The system, also known as Clinical and Health Records Analytics and Sharing (CHAS) combines the strengths of Traditional Chinese Medicine (TCM) and modern Western medicine (MWM) and blends input from the two types of medicines. It is designed to enable the sharing of electronic medical records that incorporate TCM and MWM data across the hospital network.(38)

In 2008 a pilot project was started to provide access to business services based on a cloud platform: Project Yun (Chinese for 'cloud'). Project Yun dynamically allocates storage, server and network resources. Wang Fu Jing Department Store, one of China's largest retailers with more than 10 million customers, has benefitted from the project.(39) It uses the cloud to share information with retail stores and implement B2B e-commerce with suppliers. Baidu has also deployed cloud applications such as Baidu Wenku (Baidu Books).(40)

Because of the popularity of mobile clouds, we should also mention the Chinese mobile market. While the majority of China's population does not have a personal computer (PC), there were over 800 million cellphone users in 2010.(41) In mid-2009 155 million people in China went online using their cellphones.(42) Estimates suggest that by 2013 China will have 325 million handset users accessing the internet.

Cloud computing in India

According to India's National Association of Software and Services Companies (NASSCOM) and Mckinsey, remote infrastructure management will be a \$15 billion industry by 2013 in India. The Indian offshoring industry is the prime example of an industry that is likely to feel the impact of cloud computing. The demand for the cloud is high in technology hubs.

Local and global cloud providers are active (see Table 2). In 2008 IBM opened a cloud centre in Bangalore for mid-market vendors, universities, government bodies and microfinance and telecommunications companies.(43) The Indian Institute of Technology, Kanpur and other universities use the cloud.(44) In 2009 Microsoft launched cloud services such as email, collaboration, conferencing and productivity starting at \$2 per month.(45)

Table 2. Cloud-related entrepreneurship of developing world-based firms

Company	Country	Cloud-related entrepreneurship	Remarks
Alibaba Group	China	<ul style="list-style-type: none"> 2009: announced a plan to spend US\$146 million in software development, marketing and establishing cloud centres for customers, especially SMEs.^β 2009: established a 500-staff subsidiary focusing on the cloud. 	<ul style="list-style-type: none"> Expects to have 100 million online software users by 2011^β. 2009: captured more than 40 % of the Chinese SaaS market.^α
China Mobile	China	<ul style="list-style-type: none"> 2009: announced a plan to launch a cloud platform, BigCloud. 	<ul style="list-style-type: none"> Expected to enhance advanced mobile internet and 3G experiences and to diversify demand.
Stefanini IT Solutions	Brazil	<ul style="list-style-type: none"> 2009: announced an investment of US\$218 700 to boost cloud computing product offering. 	<ul style="list-style-type: none"> Has over 7300 employees and 36 offices in 16 countries across five continents.
Infosys	India	<ul style="list-style-type: none"> Partnered with its major clients in cloud research.^π 	<ul style="list-style-type: none"> Provides cloud-based services for the auto sector.^π
Computational Research Laboratories (CRL)	India	<ul style="list-style-type: none"> 2008: Yahoo signed a research pact with CRL to support cloud research.^τ 	<ul style="list-style-type: none"> A lab run by the Tata Group CLR would provide EKA supercomputer, which was the world's fourth fastest in March 2009.
AdventNet	India	<ul style="list-style-type: none"> Zoho division operates a popular suite of web-based applications.^ε Zoho had over 1.5 million users in March 2009—2 million in September 2009^θ (400 000 users, 20% of total, in India and China).^θ 	<ul style="list-style-type: none"> The ICICI bank's insurance arm uses Zoho's applications to develop innovative services such as a personalised insurance for diabetes. Premiums are adjusted depending on how well policy holders stick to a fitness plan.

Notes: ^αW Xing. 'Alibaba to pour 1b yuan into helping SMEs', *China Daily*, 31 March 2009, at http://www.chinadaily.com.cn/bizchina/2009-03/31/content_7634725.htm;

^βChinaknowledge.com, 'Alibaba to offer SMEs online management software for free', 2 April 2009, at http://www.chinaknowledge.com/Newsires/News_Detail.aspx?type=1&NewsID=22436;

^αAlibaba Group, 'Corporate overview', 2009, at <http://www.alibaba.com/aboutalibaba/aligroup/index.htm>, accessed 1 December 2009;

^πC Murphy. 'Can India's outsourcers step up?', *Information Week*, 30, 2008;

^τC McCarthy, 'Yahoo taps India supercomputer in cloud-computing push', 24 March 2008, at http://news.cnet.com/8301-10784_3-9901643-7.html?tag=head; and P Williams, 'ManageEngine flies into cloud computing—at \$5 a month per device', 9 March 2009, at <http://www.it-director.com/business/content.php?cid=11118>, accessed 1 December 2009;

^θD MacMillan, 'Google, Zoho challenge Microsoft abroad, too', 13 September 2009, at <http://www.businessweek.com/technology/content/sep2009/tc20090911=644394.htm>.

In October 2010 Intel announced an agreement with an alliance of 70 companies, including the Bombay Stock Exchange (BSE) and CtrlS to develop hardware and software for an open and interoperable cloud. The Open Data Centre Alliance (ODCA) works to address security, energy efficiency and interoperability.(46) The BSE expects that the new trading platforms supported by mobile telephony and clouds will broaden participation by allowing real-time and seamless access to data across phones, laptops and other devices. This approach would also deepen and widen asset classes traded.(47) The new platforms will increase the participation of younger Indians in pension funds, insurance and mutual funds, among others.(48) The popularity of mobile-based cloud applications is particularly promising. Only 80 million Indians were online in early 2011, but more than 670 million used cellphones.(49)

Many other global players are active in India. In 2009 VMware opened a cloud centre in Pune,(50) while *Parallels* announced a plan to establish cloud operations in the country.(51) Salesforce.com started operations in 2005 and is creating cloud awareness. Salesforce.com has many high-profile clients, including Bharti, eBay India, Sify, Polaris, Lodha, Servion, Maytas Properties, HCL, Sasken Communication, Ocimum and the National Research Development Corporation. In February 2011 India's Dr Reddy's Laboratories deployed Salesforce CRM to improve its deals pipeline, track sales cycles and analyse the sales funnel.(52) Dr Reddy's expects that the cloud-led streamlining will increase revenue by over 30 per cent.

Cloud computing in Vietnam

The cloud industry in Vietnam is driven by the government's initiatives to build a skilled workforce. The cloud is used to link government agencies, universities, private-sector research, start-ups and other organisations.(53) Vietnam started collaboration with IBM in 2007. Computer Sciences Corporation plans to develop a Vietnamese operation as a centre for cloud operational and support services.

Universities, government ministries and telecommunication vendors use the cloud to create new services. The Ministries of Education and Training, Science and Technology, and Information and Communications have developed cloud-based academic programmes which offer computing courses, free software tools and case studies. Vietnam National University (VNU) has established a cloud platform,(54) and IBM and VNU have signed a memorandum of understanding for the cloud.

Vietnam Technology and Telecommunication (VNTT) offers the server storage capacity and system capability for its clients, mainly SMEs. VNTT's clients can expand these services as their needs grow. VNTT also announced its plan to launch applications that are designed specifically for construction and for real-estate companies.(55)

Cloud computing in South Africa

IBM has built a data centre in Johannesburg. Starting in early 2009 several companies adopted VMware's 'Cloud OS' on a trial basis and the company started commercial sales of vSphere in the second quarter of 2009. Cloud-led telecommuting has led to lower capital investment and enhanced productivity. Call centres no longer own and maintain costly equipment. Call centre

agents and software developers have moved out of dedicated facilities. They work from home via the virtual private network (VPN). This cloud-led telecommuting can be attributed to high speed and low bandwidth costs. Call centres have reported a 20 per cent productivity gain.(56)

The Computational Intelligence Research Group at the University of Pretoria uses the cloud computing for medical research. Students at the university use the cloud to test the development of drugs to cure serious illnesses unique to Africa.

South-based firms in the supply side of the cloud

Despite stereotypically different expectations, the South's IT industries are playing crucial roles in the cloud. Some visible examples of South-based cloud firms are presented in Table 2 above. Platforms developed by global players provide South-based developers with opportunities to build applications.(57)

CRL and AdventNet are among high-profile Indian cloud providers (Table 2). TCS and Wipro have also entered the cloud market. TCS started cloud pilot projects in 2009 and had 130 clients by February 2011, a number that is expected to increase to 1000 by the end of that year.(58) TCS claims that its cloud can make savings of up to 30–40 per cent for SMEs.(59) Infosys has dedicated 175 engineers to identify potential areas attractive for the cloud,(60) while Hyderabad-based Pressmart provides SaaS based e-publishing and digitisation services to the print industry. The Pressmart solution can help firms deliver content across multiple platforms such as the web, mobiles, Really Simple Syndication (RSS), podcasts, blogs, social networking sites, articles directories and search engines.(61)

In China local players account for the bulk of cloud investments. China Mobile is planning to invest \$58 billion by 2013.(62) The cloud has also been a critical component at Huawei.(63)

Cloud Industry in the South: a proposed framework

Our proposed framework (see Figure 1) explains the contexts, mechanisms and processes associated with the cloud in the South in terms of interconnected flows. The impacts (right-hand side) reflect the 'value' created by the cloud, which is the ultimate objective. Cloud-related performances are actions of various economic actors that are instrumental in delivering the impacts of the cloud. Determinants are factors affecting performances.

Impacts

Operational efficiency: productivity and efficiency gains

Operational efficiency is related to the cost of accomplishing corporate functions. Anecdotal evidence from China, India and South Africa indicates that cloud adoption may lead to productivity and efficiency gains. We noted above that South African call centres have increased their productivity. India's Netmagic reported that its cloud helped its clients cut costs by 25–30 per cent.(64) Microsoft has claimed that its cloud will help reduce costs by 10 per cent to 50 per

cent.(65) Likewise, Chinese software start-ups' utilisation of virtualised resources has reduced product development costs.

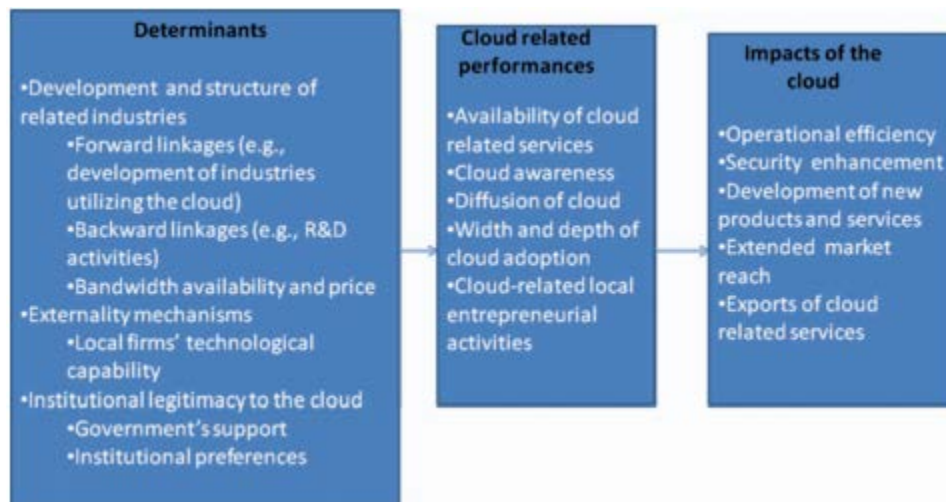


Figure 1. A Framework for Cloud Related Indicators in Developing Countries.

IT security enhancement

The concept of 'hollow diffusion' can be helpful in understanding the weak defence mechanisms of organisations in the South.(66) Many companies lack technological and human resources for security. 'Hollow diffusion' can take place in human terms (lack of skill/experience) as well as in technological terms (lack of anti-virus protection).

While the cloud is a double-edged sword from a security standpoint,(67) the nature of the South's risks suggests that it could be an attractive security option.(68) The cloud's economies of scale allow a business model in which third parties can integrate applications to provide cost-effective security.(69)

Development of new products and services

The cloud has also helped firms in the South launch products and services commercially. Zoho's applications are used by hospitals and banks in India to develop new products (Table 2). In another example students at the University of Pretoria use the cloud to develop drugs.

Extending market reach

The cloud can extend SMEs' market reach. Consider healthcare offshoring. Industrialised world-based healthcare providers offshore services related to medical transcription, billing and insurance claims, tele-imaging and telepathology. Most of these are dominated by big players. Cloud computing is likely to open the door for SMEs. Applications such as those offered by Zoho reduce the up-front investments.

Exports of cloud related services

There has been some achievement in the export of cloud-related applications and services. Unbelievable as it may sound, some developing world-based technology companies such as AdventNet have been exporting cloud-based applications.

Performance

Availability of cloud services

A primary reason for the slow diffusion of the cloud in the South is its 'hierarchical pattern'.(70) Economies in the South lack markets and infrastructures to control cloud availability and are unattractive for IBM, Google and other cloud players.

Cloud awareness

Awareness is the first step in the cloud adoption process. As noted above, there has been a lack of awareness of cloud computing, even among large enterprises in the developing world.

Cloud diffusion

Diffusion measures the extent to which the cloud has been dispersed or distributed among organisations. It can be measured by the cloud penetration level or the number of organisations adopting it. Specific cloud applications such as the number of users of Zoho's productivity tools or IBM's Pangoosky platform can also be used.

Width and depth of cloud adoption

A higher performance is achieved by wider and deeper adoption of the technology. Note that the width of cloud adoption can be defined as the number of different uses (see Table 1).(71) Similarly, the depth of adoption can be defined as the amount of cloud usage (eg software download frequency, amount of data stored, etc). At the level of the firm concepts related to width and depth can be further elaborated. For instance, a higher width of cloud usage is associated with a greater number of employees using the cloud to perform a function, while overall depth is related to total usage.(72)

Cloud-related entrepreneurship

There has been an abundance of cloud-related entrepreneurship, or enterprising actions undertaken to generate 'value, through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets'(73). China's Alibaba, India's CRL and Brazil's Stefanini have created market changes. The University of Pretoria's cloud deployment, Vietnam's cloud use in building IT skills and Wang Fu's deployment of supply chain solutions have all helped them integrate, reconfigure and gain resources to respond to evolving needs.

Determinants

A technology's ecosystem is influenced by numerous factors. First, domestic demand and inputs such as consumer preferences, income, infrastructures, government regulations and technological economies of scope are important.⁽⁷⁴⁾ Second, the importance of industry structure has been emphasised.⁽⁷⁵⁾ Of special interest is the development of related industries such as broadband and PCs. Competition level, size and distribution of suppliers, and the nature and structure of related industries are also important. Finally, transfer and export conditions such as trade policy, the export orientation of firms, strategic regulation, and market size also affect an industry's growth (see Figure 1 and Table 3).⁽⁷⁶⁾

Table 3. Determinants of the cloud industry in the developing world

Determinant	Mechanisms	Examples
Development and structure of related industries	Forward linkages	<ul style="list-style-type: none"> ● China: planning to spend US\$27 billion to create a fully electronic predictive health information network, which would create demands for cloud services.^σ ● China and India: economies of scale in B2B e-commerce, supply chain management and e-healthcare.
	Backward linkages	<ul style="list-style-type: none"> ● China: cloud related R&D has helped the development of the cloud industry: 490 of world's top 500 companies have invested in China and have established over 1160 R&D centres in the country. IBM computing centres in China draw upon experts from full-scale labs in the country, which are globally-oriented and work on advanced products.
	Horizontal or inter-sectoral linkages	<ul style="list-style-type: none"> ● South Africa: high speed and low cost of bandwidth have facilitated the development the cloud industry.
Externality mechanisms	Local firms' technological capability (MAR and Jacobs externalities)	<ul style="list-style-type: none"> ● China's Alibaba and India's Infosys illustrate how local firms' IT specialisation can contribute to the growth of the local cloud market through knowledge spillovers.
Institutional legitimacy	Government support	<ul style="list-style-type: none"> ● Vietnam: the cloud is driven by the government's belief that it will help build a skilled workforce.^Γ ● China: substantial funds in the economic incentive budget.
	Institutional concerns	<ul style="list-style-type: none"> ● Security issues are a big concern in authoritarian regimes. ● The cloud makes it easier to spy on citizens.

Notes: ^σcnn.com, 'MMR Information Systems, Inc to enter into definitive agreement with Unis-Tonghe Technology in China', 19 November 2009. ^ΓM Cleverley, 'Viewpoints: emerging markets—how ICT advances might help developing nations', *Communications of the ACM* 52(9), 2009, pp 30–32.

Development and structure of related industries

Development and diffusion of the cloud are tightly linked to the *forward* linkages (demand), *backward* linkages (supply) and *horizontal* or inter-sectoral linkages.(77)

The strength of forward linkages plays an essential role. A lack of demand from construction and real estate industries would limit the demand from the VNNTT's clouds in the above example. Availability of e-governance services and solutions for businesses and citizens, such as healthcare and education, permits, driving' licences, payment of bills, land records and registration, e-tendering, e-tax file return, and benefits determination and distribution, would strengthen forward linkages. In China and India strong demand has helped create forward linkages (Table 3).

The development of industries which supply various ingredients needed for the cloud offer strong backward linkages. In India and China R&D in the cloud and development of the supercomputer industry have provided backward linkages (Tables 2 and 3). Most cloud services rely on bandwidth, which is the most glaring shortcoming of most developing countries, especially in rural areas.(78) High bandwidth is important if the data to be transferred include large files such as high-quality multimedia content and videos.

Externality mechanisms

Firms' technology-related behaviours have self-reinforcing effects. IT firms may generate externalities by making cloud-related inputs and services available, forming a specialised 'labor market' and facilitating the exchanges and spillovers of information and technology.(79) These externalities originating from firms in the same industry are called MAR externalities,(80) which represent the role of specialisation in growth through knowledge spillovers.(81) There is also a possibility of 'inter industry knowledge spillovers', referred to as Jacobs externalities.(82)

Local firms' technological capability

The technological capabilities of some South-based firms have generated positive externalities for the economy. Technological capabilities combined with low cost and experiences in serving the home market may allow these firms to develop value-creating strategies and realise a significant share in the cloud market (Table 2).

Indian companies are among leading global it players. Their specialisation has generated Jacobs externalities. Some argue that India was an early cloud as the country's software companies had a huge data-processing centre for on-demand computing.(83) Such externalities can be considered MAR externalities.

Institutional support and legitimacy for the cloud

The development of an industry such as the cloud is a function of the level of government priority set for this sector and the focus of national policies on fostering it.(84) As reviewed above, government support has stimulated cloud adoption in China and Vietnam.

The cloud is described as the ultimate spying machine.(85) There are concerns about data privacy and security associated with unauthorised access and use of information.(86) An obvious danger in an authoritarian regime concerns the possibility that the government may intensify further controls on citizens.(87) In this respect, China is of special interest. Chinese leaders are suspicious of cyber-attacks from the US. Computer products imported from the West are subject to detailed inspection. Chinese technicians take control and either resist installation by Western experts or monitor it carefully.(88) The government may be uncomfortable with storing data on foreign multinationals' clouds.

Discussion and implications

While it took many years and large investments for the North to acquire infrastructure, data centres and customised applications, the cloud has made it possible for the South to access them easily. The cloud may increase the effectiveness and enrich the uses of technologies such as the cellphone. There are two interrelated reasons why this is likely to happen. First, less sophisticated cellphones are now 'cloud-ready' as a result of recent developments. A cellphone capable of running a browser can access mobile cloud applications. Low-cost phone users can thus tap into applications that are currently accessible only through smartphones. Second, consumers in the South are using increasingly sophisticated devices facilitating the diffusion of mobile-based cloud. It is expected that, by 2015, smartphones will account for 50% of cellphones in China.(89)

To understand drivers, effects and policy measures associated with the cloud in the developing world, let us revisit the three questions posed at the beginning of the paper. Various drivers of the cloud are summarised in Table 4.

The cloud has a potential to change the competitive landscape of some industries. Upfront investment and economies of scale have hindered small businesses' implementation of advanced e-commerce applications. As noted above, cloud computing has helped Chinese software start-ups access infrastructures and data centres, which would not be possible in traditional models.

Bhagwati's theory of kaleidoscopic comparative advantage argues that 'the nature of comparative advantage is becoming thin, volatile, and kaleidoscopic and is creating vulnerabilities for industries, firms and workers'.(90) An obvious example to illustrate how cloud-led revolutions may erode the comparative advantage of industrialised world-based companies is to consider the market for productivity tools, in which Zoho is flexing its muscles.

In the least developed economies the potential benefits have been limited by weak forward and backward linkages. When multinationals enter, however, labour mobility, stimulation of knowledge and technology transfer and other spillover effects may help develop local capabilities.(91) Cloud applications may help create a virtuous circle to positively reinforce further development. In Vietnam the cloud's use to develop education programmes should strengthen backward linkages.

TABLE 4. Revisiting the research questions

Article question	Findings and implications
Q1: Drivers of the cloud industry in the developing world	<ul style="list-style-type: none"> • Development and structure of related industries that produce forward, backward and horizontal or inter-sectoral linkages are tightly linked to the development and diffusion of the cloud. • Local firms' technological capabilities generate positive externalities for the cloud industry. • Institutional legitimacy issues such as the government's support and institutional preferences affect the development of the cloud.
Q2: Potential impacts in the developing world	<ul style="list-style-type: none"> • The cloud makes it easier to install, maintain and update software ^δ and enables third parties to provide cost-effective security for SMEs. • Changing the competitive landscape of some industries: upfront investment and economies of scale hinder small businesses' implementation of advanced e-commerce applications. The cloud has helped Chinese software start-ups access infrastructures and data centres, which would not be possible in traditional models. • Performance indicators related to export activities (eg cloud-related entrepreneurship) point to developing world-based technology firms' shift into a higher gear, which may erode the industrialised world's comparative advantages. • Market for productivity tools: currently Microsoft dominates this market in the USA as well as in the developing world. Zoho has emerged as a strong challenger, emphasising lower price and broader accessibility.
Q3: Roles of businesses and policy makers	<ul style="list-style-type: none"> • Strengthen forward and backward linkages: helps attract global cloud players and maximise the benefits of the cloud computing to the local economy. • Measures to create a virtuous circle: Vietnam, the cloud is being used to develop education programmes, which would help further strengthen backward linkage. • Measures to increase awareness among potential users would create forward linkages. • Promotion of business models that leverage existing infrastructure: cellphones are the primary computing device and means for accessing the internet for a large proportion of the population.

Notes: ^δG Gruman & E Knorr, 'What cloud computing really means', *InfoWorld*, April 2008.

Nonetheless, the overriding reality is that only a small segment of the economy is currently cloud-ready. it-intensive industries (eg software development) or those dealing with it-enabled processes (eg offshoring) are benefiting from the cloud more than other sectors. With improving connectivity and awareness, however, cloud computing may gain momentum.

Cloud business models are still evolving. For cloud providers success in developing economies hinges on business models focusing on affordability and considering the unique needs of small-scale consumers. Governments can collaborate with domestic and foreign players to develop software and other products appropriate for local needs.

Perhaps the greatest barrier to adoption and effective utilisation centres on low PC penetration and low bandwidth speeds. Cloud-related innovations and business models that leverage existing infrastructure and technologies in novel ways undoubtedly have potential practical benefits. Cellular technology is one area that needs special attention.

Since cellphone penetration in the South is higher than that of the PC, the mobile-based cloud presents an enormous potential. Mobile clouds' increasing pervasiveness is set to transform the way cellphones are used. One estimate suggested that the number of cellphone users accessing applications via the cloud will increase to one billion in 2014 from 43 million in 2008.(92)

Limitations and future research

Several limitations must be recognised in a balanced discussion of our findings. One limitation is that we have reviewed the development of the cloud only in major economies with well developed IT industries. The cloud is almost non-existent in economies at the bottom of the global pyramid. An additional limitation is that the discussion lacks primary data.

These issues obviously need further study to shed more light on cloud computing. One issue raised above but not fully developed is cloud entrepreneurship. It would be interesting to study the determinants of entrepreneurship, such as regulatory framework, market conditions, R&D and technology and entrepreneurial capabilities.(93) In future conceptual and empirical works, scholars need to compare and contrast cloud-related entrepreneurship, and its impacts and determinants in the South and the North.

Future research might also examine organisations' cloud adoption decisions. Researchers could also examine whether the cloud's perceived benefits and the adoption process vary across organisations with different backgrounds, expertise and resources.

Finally, prior research indicates that organisations differ in terms of the timing of adoption of new technologies,(94) known as the rank effect.(95) An analysis of this effect for the cloud and comparison with previous generations of technologies would provide insights into organisational characteristics linked with technology adoption.

Concluding remarks

Cloud computing is in the infant stage of development. Rather than viewing it as a self-contained phenomenon, it must be seen against the backdrop of economic and institutional realities facing the developing world. In theory there are many possible uses of the cloud and several channels and mechanisms through which developing economies may benefit. In practice, however, serious problems related to the 'determinants' box (see Figure 1) stand in the way of implementation and practical results. Cloud-based innovations and business models are as yet far from inclusive of SMEs in the South, especially in the least developed small nations.

Currently cloud usage has been shallow, narrow and vanishingly small in developing economies. Except for South Africa, the cloud's use in Africa is limited to e-education. It would thus be unreasonable to expect it to help the South catch up with the North in one big leap. However, as economic and institutional factors improve in the South, it certainly holds promise for bridging the digital divide. The developing world must thus exploit the opportunities afforded by the cloud while minimising the associated risks to allow access to advanced IT infrastructure, data centres and applications, and to protect sensitive information.

We have argued that the cloud may erode the comparative advantage of Western companies. While some developing world-based companies such as Zoho have challenged Western multinationals, in the present context, cases like these are rare.

Notes on contributor

Nir Kshetri is associate professor at the Bryan School of Business and Economics, University of North Carolina–Greensboro and research fellow at the Research Institute for Economics & Business Administration, Kobe University, Japan. His recent publications are *The Global Cyber-Crime Industry: Economic, Institutional and Strategic Perspectives* (2010) and *The Rapidly Transforming Chinese High Technology Industry and Market: Institutions, Ingredients, Mechanisms and Modus Operandi* (2008).

Notes

1 VC Silva, 'African NGO taps it to help prevent HIV transmission', *IDG Magazines Norge AS*, 28 January 2011, at <http://news.idg.no/cw/art.cfm?id=E669CBCD-1A64-67EA-E47FFECA76A12C2A>.

2 L Apotheker, 'Opinion: connectivity is no longer a tool but a global way of life', *Mercury News*, 12 March 2011, at http://www.mercurynews.com/opinion/ci_17596575?nclick_check=1.

3 MA Goodburn & S Hill, 'The cloud transforms business', *Financial Executive*, 26(10), 2010, pp 34–39.

4 B Walton, 'Do it and prove it—information technology opens up the water sector', *Circle of Blue*, 10 January 2011, at <http://www.circleofblue.org/waternews/2011/world/do-it-and-prove-it%E2%80%94information-technology-opens-up-the-water-sector/>.

5 Ibid.

6 N Kshetri, 'Cloud computing in developing economies', *IEEE Computer*, 43(10), 2010, pp 47–55.

7 S Zhoudong, 'Venture capital eyes Chinese software sector', *chinadaily.com.cn*, 4 July 2008, at http://www.chinadaily.com.cn/bizchina/2008-07/24/content_6874313.htm.

8 'The long nimbus', *The Economist*, 25 October 2008, special section, pp 15–17.

9 Irani, 'Cloud computing: new rage among net community', 5 September 2008, at <http://economictimes.indiatimes.com/articleshow/msid-3446192,prtpage-1.cms>.

10 TS Parikh, 'Engineering rural development', *Communications of the ACM*, 52(1), 2009, pp 54–63.

11 RL Grossman, 'The case for cloud computing', *IT Professional*, 11(2), 2009, pp 23–27.

12 S Bhanoo, 'Cloud computing may curb video game piracy', *CIO*, 26 March 2009, at http://www.cio.com/article/486979/Cloud_Computing_May_Curb_Video_Game_Piracy.

13 Ibid.

14 C Hiar, 'How green is facebook, Microsoft push into cloud computing?', 12 January 2011, at <http://www.pbs.org/mediashift/2011/01/how-green-is-facebook-microsoft-push-into-cloud-computing012.html>.

15 R Jones, 'A technological revolution', *Middle East Economic Digest*, 54(53), 31 December 2010, p 31.

16 L Dignan, 'Cloud computing market: \$241 billion in 2020', 22 April 2011, at <http://www.zdnet.com/blog/btl/cloud-computing-market-241-billion-in-2020/47702>.

17 focustaiwan.tw, 'Asia well-poised to join global society: Trend Micro', 11 January 2011, at http://focustaiwan.tw/ShowNews/WebNews_Detail.aspx?Type=aALL&ID=201101110047.

18 N Dholakia & N Kshetri, 'Mobile commerce as a solution to the global digital divide: selected cases of e-development in the digital challenge—information technology in the development context', in S Krishna & S Madon (eds), *The Digital Challenge: Information Technology in the Development Context*, Aldershot: Ashgate Publications, pp 237–250.

19 A Lopez, 'The south goes mobile', *UNESCO Courier*, July/August 2000, at http://www.unesco.org/courier/2000_07/uk/connex.htm.

20 'Providing rural phone services profitably in poor countries', *Businessweek.com*, 2001, at <http://adsections.businessweek.com/digital/profit.htm>.

21 E Yujuico & BD Gelb, 'Marketing technological innovation to LDCs: lessons from one laptop per child', *California Management Review*, 53(2), 2010, pp 50–68.

22 Ibid.

23 Hiar, 'How green is facebook, Microsoft push into cloud computing?'.

24 'Seeing the world for the trees', *The Economist*, 18 December 2010, pp 153–154.

25 'China's cloud computing market size to top RMB60.7 bln in 2012', *istockanalyst.com*, 24 February 2011, at <http://www.istockanalyst.com/article/viewiStockNews/articleid/4921198>.

26 Goodburn & Hill, 'The cloud transforms business'.

27 Beijing Infobird Software (BIS), 'The future of China's software industry', 5 March 2009, at <http://www.earthtimes.org/articles/show/infobird-pioneers-saas-the-future-of-chinas-software-industry,739043.shtml>.

28 'Shanghai invests in being "smarter"', *peopledaily.com.cn*, 24 January 2011, at <http://english.peopledaily.com.cn/90001/90778/7269851.html>.

29 S Deffree, 'IBM extends China research', *Electronic News*, 20 October 2008.

30 D Wilson, 'China readies cloud computing city: IBM and 6.2 million square feet', 7 February 2011, at <http://www.techeye.net/hardware/china-readies-cloud-computing-city>.

31 P Tontsi, 'IBM partners with Chinese vendor', 3 February 2011, at http://www.itweb.co.za/index.php?option=com_content&view=article&id=40717:ibm-partners-with-chinese-vendor&catid=69.

32 Wilson, 'China readies cloud computing city'.

33 M Cleverley, 'Viewpoints: emerging markets—how ICT advances might help developing nations', *Communications of the ACM*, 52(9), 2009, pp 30–32.

34 AM Ariff, 'My bit: business trends spur cloud computing', *The Edge Malaysia*, 6 October 2008.

35 N Peng, 'IBM, iPark announce launch of PangooSky', *chinadaily.com.cn*, 29 July 2009, at http://www.chinadaily.com.cn/bizchina/2009-07/29/content_8486819.htm.

36 'IBM opens Africa's first "cloud computing" center, second cloud center in China', *foxBusiness.com*, 4 June 2008, at <http://www.foxbusiness.com/story/markets/industries/technology/ibm-opens-africas-cloud-computing-center-second-cloud-center-china>, accessed 1 December 2009.

37 E Yu, 'Sun: we're not late in cloud game', *ZDNet Asia*, , *zdnetasia.com*, 19 March 2009, at <http://www.zdnetasia.com/news/business/0,39044229,62052326,00.htm>.

38 'IBM corporation launches health record system for south China's hospital', *Moneycentral.msn.com*, 26 February 2009, at <http://moneycentral.msn.com/news/ticker/sigdev.aspx?Symbol=IBM>.

39 Yujuico & Gelb 'Marketing technological innovation to LDCS'.

40 L Sun, 'Baidu (BIDU) claims 75.5% of China's search market as Google continues to slide', 27 January 2011, at <http://www.investorguide.com/article/7667/baidu-bidu-claims-75-5-of-chinas-search-market-as-google-continues-to-slide/>.

41 Goodburn & Hill, 'The cloud transforms business'.

42 D Pett. 'China's rising internet usage bodes well for tech stocks', 24 June 2009, at <http://network.nationalpost.com/np/blogs/tradingdesk/archive/2009/06/24/china-s-rising-internet-usage-bodes-well-for-tech-stocks.aspx>, accessed 1 December 2009.

43 'XIBM launches cloud computing center in India', Channelworld, 25 September 2008, at <http://www.infoworld.com/news/feeds/08/09/25/IBM-launches-cloud-computing-center-in-India.html>.

44 D MacMillan, 'Google, Zoho challenge Microsoft abroad, too', 13 September 2009, at http://www.businessweek.com/technology/content/sep2009/tc20090911_644394.htm.

45 'Microsoft evaporating to a cloud', *Hindustan Times*, 9 November 2009.

46 'Intel, partners enter into alliance for cloud computing', *Economic Times*, 28 October 2010, at <http://economictimes.indiatimes.com/infotech/software/Intel-partners-enter-into-alliance-for-cloud-computing/articleshow/6829239.cms>.

47 J Lamont, 'Financial services: shuttered too long', 25 January 2011, at <http://www.ft.com/cms/s/0/690b0d9a-28c0-11e0-aa1800144feab49a.html#axzz1D1Z8HD5B>.

48 'Intel, partners enter into alliance for cloud computing'.

49 Apotheker, 'Opinion'.

50 'VMware inaugurates new development center in Pune, India', *eeherald.com*, 31 July 2009, at <http://www.eeherald.com/section/news/nw10000706.html>.

51 S Desai, 'Significant part of India will adopt cloud', 31 July 2008, at http://www.channeltimes.com/India/News/Significant_Part_of_India_will_Adopt_Cloud/551-105021-819.html.

52 'Dr Reddy's sales process with salesforce.com', *efytimes.com*, 3 February 2011, at <http://www.efytimes.com/e1/58149/fullnews.htm>.

53 M Cleverley, 'Viewpoints'.

54 Ariff, 'My bit'.

55 KB Leong, 'VNTT rides on cloud to deliver new services, search SMB Asia', 31 August 2009, at <http://www.searchsmbasia.com/en/content/vntt-rides-cloud-deliver-new-services?page=0%2C0>, accessed 1 December 2009.

56 R Firth, 'Use the cloud to work from home', *ITWeb*, 13 August 2009, at <http://www.itweb.co.za/sections/techforum/2009/0908130807.asp?S=Virtualisation&A=VRT&O=google>, accessed 1 December 2009.

57 'The long nimbus'.

58 L Joseph, 'TCS offers cloud to small companies, hopes for billion-dollar rain', 16 February 2011, at http://www.dnaindia.com/money/report_tcs-offers-cloud-to-small-companies-hopes-for-billion-dollar-rain_1508458.

59 Joseph, 'TCS offers cloud to small companies'.

60 M Kakkar, 'Cloud computing's latest battlefield, India', *zdnet.com*, 13 September 2010, at <http://www.zdnet.com/blog/india/cloud-computings-latest-battlefield-india/179>.

61 S Sanyal, 'Behold the Indian SaaS entrepreneur', *Siliconindia*, 11(9), 2008, p 38.

62 Goodburn & Hill, 'The cloud transforms business'.

63 'Huawei's enterprise business revenue to double', *China Daily*, 3 March 2011, at <http://english.peopledaily.com.cn/90001/90778/7306394.html>.

64 P Abrar, 'Managed services spell big it business', *indiatimes.com*, 27 July 2009, at <http://economictimes.indiatimes.com/Infotech/Managed-services-spell-big-IT-business/articleshow/4823813.cms>, accessed 1 December 2009.

65 'Microsoft evaporating to a cloud'.

66 C Otis & P Evans, 'The internet and Asia-Pacific security: old conflicts and new behaviour', *Pacific Review*, 16(4), 2003, pp 549–550.

67 N Kshetri, 'Cloud computing and cybercrime2.0', paper prepared for an ITU-T Workshop on 'Addressing Security Challenges on a Global Scale', International Telecommunication Union (ITU), Geneva, 6–7 December 2010.

68 N Kshetri, 'Diffusion and effects of cybercrime in developing economies', *Third World Quarterly*, 31(7), 2010, pp 1057–1079.

69 Grossman, 'The case for cloud computing'.

70 H Gatignon & TS Robertson, 'A propositional inventory for new diffusion research', *Journal of Consumer Research*, 11, 1985, pp 849–867.

71 Ibid.

72 R Dholakia, N Dholakia & N Kshetri, 'Gender and the internet usage', in Hossein Bidgoli (ed), *The Internet Encyclopedia*, New York: Wiley, 2004, pp 12–22.

- 73 N Ahmad & AN Hoffmann, 'A framework for addressing and measuring entrepreneurship', *OECD Statistics Working Paper*, January 2008, at [http://www.oilis.oecd.org/olis/2008doc.nsf/LinkTo/NT000009FA/\\$FILE/JT03239191.PDF](http://www.oilis.oecd.org/olis/2008doc.nsf/LinkTo/NT000009FA/$FILE/JT03239191.PDF), accessed 1 December 2009.
- 74 R Vernon 'International investment and international trade in the product cycle', *Quarterly Journal of Economics*, 80, 1966, pp 190–207.
- 75 M Porter, *The Competitive Advantage of Nations*, London: Macmillan, 1990.
- 76 M Beise, *Lead Markets: Country-specific Success Factors of the Global Diffusion of Innovations*, Heidelberg: Physica-Verlag, 2001.
- 77 J R Markusen & AJ Venables, 'Foreign direct investment as a catalyst for industrial development', *European Economic Review*, 43(2), 1999, pp 335–356.
- 78 Parikh, 'Engineering rural development'.
- 79 A Marshall, *Principles of Economics*, London: Macmillan, 1920.
- 80 Ibid; KJ Arrow, 'The economic implications of learning by doing', *Review of Economic Studies*, 29, 1962, pp 155–173; and PM Romer, 'Increasing return and long-run growth', *Journal of Political Economy*, 94, 1986, pp 1002–1037.
- 81 MJG Bun & AE Makhloufi, 'Dynamic externalities, local industrial structure and economic development: panel data evidence for Morocco', *Regional Studies*, 41(6), 2007, pp 823–837.
- 82 J Jacobs, *The Economy of Cities*, New York: Vintage, 1969.
- 83 B Dudley, 'Is India the future for tech?', *BostonHerald.com*, 1 April 2009, at http://www.bostonherald.com/business/general/view/2009_04_01_Is_India_the_future_for_tech_/srvc=business&position=recent_bullet, accessed 1 December 2009.
- 84 US National Academy of Science (NAS), *Allocating Federal Funds for Science and Technology*, Washington, DC: National Academy Press, 1995.
- 85 Kshetri, 'Cloud computing in developing economies'.
- 86 L McCreary, 'What was privacy?', *Harvard Business Review*, 86(10), 2008.
- 87 J Zittrain, 'Lost in the cloud', *nytimes.com*, 19 July 2009, at <http://www.nytimes.com/2009/07/20/opinion/20zittrain.html?bl&ex=1248235200&en=7d30b8c05442733a&ei=5087%0A>, accessed 1 December 2009.
- 88 J Adams, 'Virtual defense', *Foreign Affairs*, 80(3), 2001, pp 98–112.

89 Goodburn & Hill, 'The cloud transforms business'.

90 J Bhagwati, *A New Epoch: A Stream of Windows*, Cambridge, MA: MIT Press, 1998, pp 20–21.

91 Markusen & Venables, 'Foreign direct investment as a catalyst for industrial development'.

92 J Twentyman, 'One cloud fits all', *Wall Street Journal*, 2011, p R2.

93 Ahmad & Hoffmann, 'A framework for addressing and measuring entrepreneurship'.

94 EM Rogers, *The Diffusion of Innovations*, New York: Free Press, 1983.

95 G Gotz, 'Monopolistic competition and the diffusion of new technology', *Rand Journal of Economics*, 30(4), 1999, pp 679–693.