Knowledge economies in Russia and the UK

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Hardly any economist or economic historian now disputes that technical progress and advances in scientific knowledge underpin all long-term, sustained economic growth. Sure, in the short run, sharp spurts of improvement in economic performance can arise from investing in factories, streamlining transportation and distribution networks, bettering market structure, and removing impediments to production and trade. But significant and desirable though such policy actions might be, by themselves they at best move society only towards a static and fixed state of increased economic welfare; further gains eventually grind to a halt. Only through improvements in technology can enduring growth continue.

In such an interpretation all successful economies are knowledge economies.

This note undertakes three tasks. First, it presents a conceptual depiction of knowledge in economic growth, within which framework it flags measurements needed to assess performance and evaluate policy in a knowledge economy. Second, this note provides evidence on the extent and success of knowledge economies in Russia, the UK, and elsewhere. Third, it raises questions for discussion.

1. The structure of a knowledge economy

Figure 1 depicts the standard stylization of knowledge in economic growth. Society's skilled, educated workforce—the human capital in an economy—sees competing demands for its time and energy. Such people contemplate different occupations: Some, on the left in Figure 1, choose to become scientists, engineers, technologists, and inventors who advance the state of knowledge. Others, on the right in Figure 1, choose to be managers, financiers, and accountants who make the economy run efficiently, taking as given the current state of science and technology.

On the left in Figure 1 science, technology, and engineering developments raise economic productivity levels, ultimately driving economic growth. Those innovations do not, of course, occur in an empty void but build on previous developments. On the right in Figure 1 skilled managers put into productive economic activity the results from scientific discoveries and engineering innovations, and thus provide goods and services to consumers.

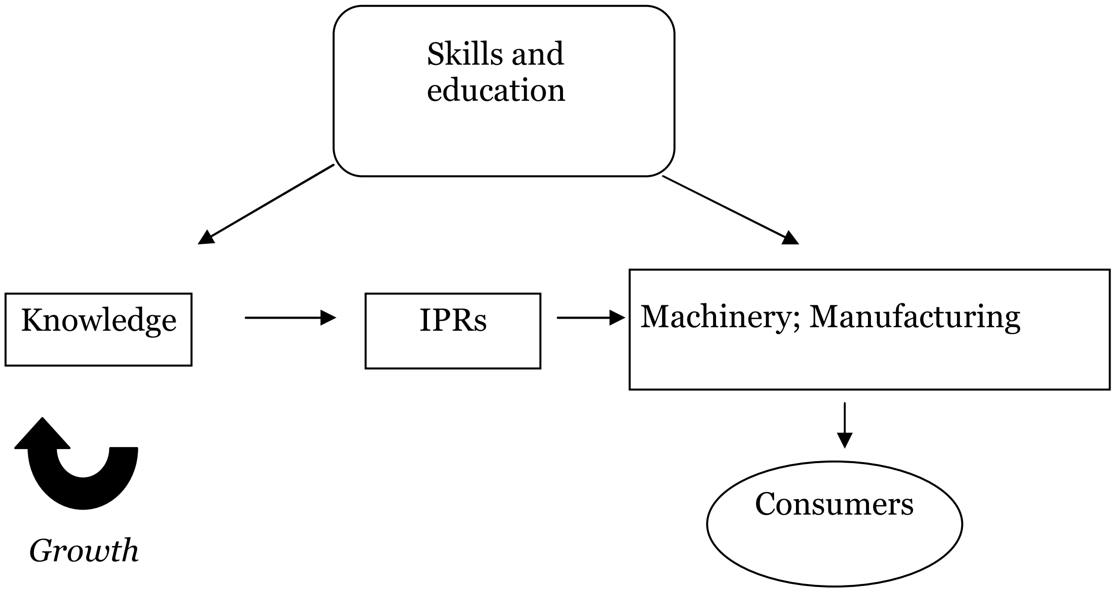

Figure 1: The structure of economic growth through advances in knowledge

Mediating between the knowledge and production sectors on the two sides of Figure 1 is a system of *intellectual property rights*, or IPRs. Typically, for industrial activity, these IPRs will be patents, but more generally we can interpret copyrights and trademarks using broadly similar economic reasoning. Because knowledge is *nonrival*—knowledge is just a string of 1s and 0s, so that handing it over to someone in economic exchange does not exhaust its supply but merely makes a perfect copy costlessly—the use and exchange of knowledge has to be specially protected by a social institution other than just that of ordinary property rights.

A feature not used in Figure 1 is that knowledge is also *aspatial*: its geographical extent is simultaneously both everywhere and nowhere. The laws of thermodynamics, say, or engineering algorithms for optimally re-routing road traffic work the same whether in London, Moscow, New York, Paris, or Tokyo, provided only that basic assumptions hold. When such algorithms or laws are applied, the original instantiation of them has a perfect copy silently and seamlessly created, and that is instantly transported wherever needed.

Three critical conclusions emerge from Figure 1's stylization of a knowledge economy. First, the ultimate source of both innovativeness and management efficiency, and thus long-run growth, is an economy's human capital—the collection of skills and expertise embodied in the work force. What drive this are the scale and quality of schooling available to an economy's young people and the training and creativity in its citizens more generally. But it is not just the total measure of these characteristics in an economy that matters for economic growth and performance, but how that total divides into science and production sectors.

Second, scientific development and engineering innovation require investment of real resources, where the fruits of that expenditure need not always be immediately apparent. The randomness of scientific progress and discovery means, moreover, that substantial resources might be expended in following an eventual dead end from any given collection of scientific ideas. But, in a free society, making the knowledge sector economically worthwhile is necessary to attract skilled and creative individuals to choose occupations there.

Third, the IPR system is double-edged in its effects on economic performance. On the one hand, without strong IPRs the knowledge sector might not be viable, as sufficient economic rewards cannot then be raised to entice people to work there. On the other hand, strong IPRs distort decision-making in the production sector, leading to under-utilization of knowledge and ideas, and thus lowering economic efficiency.

The ideas thus far discussed surrounding Figure 1 are general: they apply to 19th-century Industrial-Revolution England just as they do to 20th-century United States. By contrast Figure 2 illustrates a possible refinement to these ideas that focuses on the increasing significance of knowledge *and* knowledge-like products in a modern economy. Knowledge-like products are those goods and services in a modern economy that share the nonrival and aspatial properties of knowledge. For this reason they also usefully called *digital goods*. Computer software, digital music and entertainment media, and pharmaceutical products are examples. These are not, in themselves, typically considered scientific knowledge the same way that, say, theorems and blueprints are. But they nonetheless behave like knowledge in production and exchange. Their roles differ, potentially, from the productivity-enhancing one highlighted for scientific knowledge and technology in Figure 1. Yet, at the same time, digital goods are undoubtedly high-technology in character and occupy increasingly important shares of the total value produced and consumed in modern economies.

Unlike scientific knowledge and engineering technology, such digital goods are directly marketed to final consumers. Now, instead of knowledge-producers dealing with a well-organized commercial production sector—a sector having formal structures to deal with IPRs—knowledge-producers sell their output to a mass public of final consumers. The sheer number of such purchasers makes difficult and potentially infeasible the monitoring and enforcing of IPR rules on usage and copying. Controlling the circulation of commercial movies, music, or computer software was easy when significant distribution channels were few in number, but progressively difficult when the digital technology embedded in the 1.8 billion cellphones and 0.8 billion PCs worldwide make their owners each a potential distribution channel.

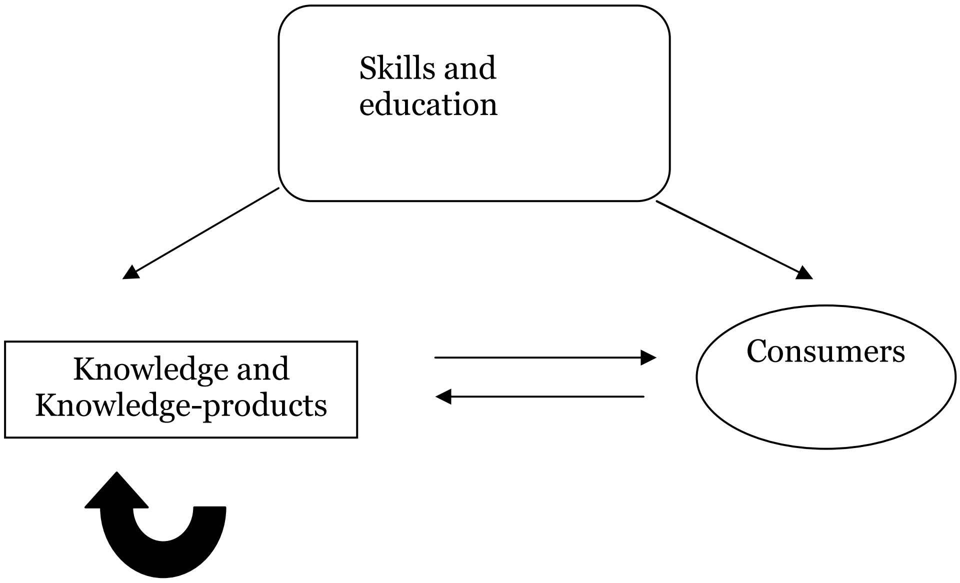

Figure 2: Knowledge and digital goods in modern economies

Figure 2 further shows that the interaction is two-way between final consumers and the producers of knowledge and knowledge-products. This refers to the possibility of "user-generated content", facilitated by digital goods on Internet networks. Even a small fraction of the world's 0.9 billion Internet users already provides significant influence on customization and personalization of computer software, social networking, entertainment, pharmaceutical design, business-process outsourcing, and other digital goods and services.

Summarizing, this section has provided in Figure 1 a stylized description of the workings of a knowledge economy. It has described three critical dimensions of such an economy: first, the human capital embodied in the economy's workforce; second, the real resources expended on training and education, R&D, and scientist and engineer employment; and third, the IPR system providing incentives for ongoing innovation and discovery but at the same time restricting usage of those innovations and discoveries to below socially efficient intensities.

This section has also pointed, in Figure 2, to how that stylized description can be usefully modified to take into account the rising significance of both knowledge and digital goods in modern economies. This has indicated how the workings of such economies will potentially generate increasing tensions in IPR systems, and thus seek to alter long-standing economic mechanisms that have historically guided reward and exchange.

A fourth important message to take forwards is one that has been alluded to briefly but not conveniently shoehorned into the model's description. This is that while knowledge is aspatial, the distribution of its production and consumption over geography is far from random or uniform. Indeed, knowledge economies seem to function best when they form clusters, such as in universities, research laboratories, or concentrations such as Silicon Valley in the US. While any given item of knowledge ought to be immediately global, in many instances, its application remains local. Thus, studying patent applications or scientific publications in different economies can still be informative for the strength of specific knowledge economies.

On all four of these conclusions, policy potentially plays a critical role. But to assess their significance, we need to turn to empirical evidence, for Russia and the UK primarily, but also in comparison with developments elsewhere.

2. *Evidence on knowledge economies*

Statistics on Russian and UK knowledge economies can be usefully organized and interpreted along the lines highlighted in Figures 1 and 2 of Section 1. For comparison, this section will provide data also on a selection of other countries (specifically Brazil, China, India, and the US) and in different country groupings across the world by per capita incomes.

In 2005 the UK economy produced $1.72 trillion in GDP at purchasing power parity (PPP) adjusted prices. With its population of 60.2 million, UK per capita GDP therefore amounted to $28.6 thousand. That same year, at PPP-adjusted prices, Russia's GDP was $1.40 trillion, lower than the UK's; its population 143.2 million, nearly 2 ½ times that of the UK. The Data Appendix presents, in Table 7, summary statistics on other economies in the sample.

Evidence is presented sequentially, as if on a chain of production: human capital development (Tables 1–3); research and development inputs (Table 4, Figures 3–4); knowledge outputs (Table 5, Figures 5–6); and digital technologies (Table 6, Figures 7–9). Again, the Data Appendix contains more detailed description where necessary.

2.1 Human capital

Tables 1–3 break down into primary, secondary, and tertiary levels the labour force composition, school enrolment, and education spending in the UK and Russia, and other countries in the sample.

Table 1 shows that the Russian labour force is relatively skewed towards high education levels, with a greater fraction at secondary and tertiary level than the UK. In the countries in the sample, only the US has a higher concentration of its workforce trained at tertiary level.

The education flows given in Table 2 suggest this Russian advantage is likely to continue. Average enrolment at tertiary level in Russia is nearly 70% of the population in that age group, while the UK's figure of 60% falls below the average of high-income countries worldwide. The US enrols at tertiary level 76% of its population in that age group, but then all the other countries in the sample have enrolment rates there less than 20% (with China's and India's only 10%).

Unfortunately, data on school expenditures are unavailable for Russia. But Table 3 shows that, relative to other countries, the UK has spent little on education at *all* levels. Certainly, tertiary education is costly: on average the world spends 34% of per capita GDP on each such student; high-income countries, 31%; middle-income countries, 36%. But the UK's expenditure of only 16% and 26% of per capita GDP on each secondary and tertiary student, respectively, falls below the counterpart averages for India, the US, the world as a whole, for high-income countries, and for middle-income countries. The figure for tertiary students is the lowest for all countries in the sample for which data are available.

2.2 R&D expenditure, researchers

Consistent with its high tertiary enrolment, Russia has managed to employ a relatively high fraction of its population in research and development (Table 4). Despite spending only 1.1% of GDP on R&D (less than 2/3 of the UK ratio), Russia employs nearly 3500 researchers per million people, over 1/3 higher than the UK. Compared to Brazil and China, each spending about the same ratio on R&D, Russia's researcher population intensity is higher by 7–10 times. However, this reliance on brain-power, without corresponding financial or expenditure support might be showing strain: Figures 3–4 show that researcher employment declining over the last decade, although R&D expenditure is rising. China's R&D spending has risen sharply, while its researcher intensity has remained low.

2.3 Output

How knowledge influences economic performance has not been easy to see empirically. If those effects are truly pervasive then looking for their efffects on measured productivity alone, say, likely misses their true impact.

More direct proxies might, therefore, be more useful. Table 5 shows, as percentages of world totals, average numbers of scientific and technical journal articles, and patent applications filed for the different economies and country groupings in the sample. Figures 5–6 contain the dynamics of these percentages.

The first noteworthy fact is the striking success that the UK has enjoyed in both of these indicators. Despite its low school enrolment, dismal education spending, not unusual R&D spending and employment, and relatively low population, the UK has produced a remarkably impressive 8% of the world's scientific publications. Russia, by contrast, has produced only 3%. However, in patent application, to put scientific ideas into economic application, the UK's and Russia's patent applications about match, at 3%. Put another way, Russia has managed to exploit a good proportion of its scientific ideas; the UK, much less.

The UK's scientific output, moreover, has been steadily declining (Figure 5), as has Russia's, while that of China's has been sharply rising. Even more striking (Figure 6) patent applications in China have, since 1998, overtaken those in all countries in the sample outside of the US.

2.4 Digital technologies

Three indicators of attainment in digital technologies are useful: Internet users, mobile phone subscribers, and personal computers (PCs). Table 6 shows averages in a number of economies over the last decade of the fraction of world totals.

Despite its relatively favourable performance in the more traditional knowledge economy indicators described earlier re, Russia's use of digital technologies lags considerably behind those of Brazil and China, and even that of India for Internet usage.

On every one of these indicators, China's rise is apparent in Figures 7–9.

2.5 Spatial clusters

Evidence has been difficult to get on this [perhaps in a latter draft].

3. Conclusions

This note has provided a conceptual framework to assess the significance of knowledge economies. It has provided counterpart measurements and assessed the state of knowledge economies, both traditional and digital, in the UK and Russia, and drawn comparison across Brazil, China, and India, as well as with country blocs worldwide, defined by levels of per capita income.

The Russian knowledge economy is a traditional one, driven by raw brain power but perhaps without as much financial and resource support.

The UK knowledge economy is, historically, successful, but from traditional schooling and R&D expenditure evidence, is seriously under-resourced and gradually withering. There has been movement towards newer, digital technologies recently.

In almost all indicators, the rise of China is the most singularly striking feature of recent developments.

4. Questions for discussion

Issues that arise from this presentation include:

1. How can Russia maintain its traditional success in brain-power? Is it a worthwhile model to maintain?
2. Is the relative slowness in adopting and using more modern digital technologies a problem for Russia?
3. How can the UK develop the political will to expend more on education and R&D?
4. How will China's competitive progress, on all fronts, be dealt with by the UK and Russia?

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Tables

% Labour force with education	Primary	Secondary	Tertiary
UK	20.9	46.5	24.1
Russia	15.6	55.4	29.0
Brazil	38.7	18.6	15.0
China	na	na	na
India	35.0	9.5	4.0
US	17.1	39.5	43.3

Table 1: Human capital in the labour force. The Table reports percentages averaged over time of the total labour force trained at primary, secondary, and tertiary education levels. Numbers in each row need not sum to 100% as there might be workers altogether unschooled. The UK data are for 1994–2001; Russia, 1992–1998 (excluding 1997); Brazil, 1989 and 1999 only; India 1988 only; US 1989 only. Source: International Labour Organization, World Bank, and author's calculations.

% gross enrollment	Primary	Secondary	Tertiary
UK	102.2	154.1	60.4
Russia	112.0	93.0	66.7
Brazil	147.8	104.3	18.1
China	116.6	66.6	11.8
India	102.4	48.6	11.0
US	100.7	94.0	76.0
World	102.3	64.2	21.8
High-income	100.3	103.7	63.4
Middle-income	112.8	72.6	20.2
Low-income	95.0	42.7	8.7

Table 2: Human capital development. The gross enrollment ratio is the ratio of total enrollment regardless of age to the population of the age group that officially corresponds to a given level of education. The Table reports percentages averaged over 1999–2004, except Russia primary 2002–2004, tertiary 2003–2004; China primary 2001–2004; India all 1998–2004 except tertiary 2000–2004; and the US including 1991 on top of the basic sample. Source: UNESCO, World Bank, and author's calculations.

Expenditure per student (% GDP per capita)	Primary	Secondary	Tertiary
UK	15.7	16.0	25.9
Russia	na	na	na
Brazil	11.4	11.0	55.7
China	na	na	na
India	11.5	20.8	73.9
US	20.4	24.2	27.9
World	14.6	19.1	34.5
High-income	19.0	24.0	31.0
Middle-income	12.5	16.9	35.5
Low-income	na	na	na

Table 3: Expenditures are averaged over 1999–2003, except for India where 2002 is omitted for all levels, and 2001 additionally for tertiary; the US, omitting 2000. Source: UNESCO, World Bank, and author's calculations.

R&D environment	R&D expenditure (% GDP)	Researchers in R&D (per 10^6 population)
UK	1.86	2572
Russia	1.10	3458
Brazil	0.94	344
China	0.98	539
India	0.72	138
US	2.66	4487
World	2.15	na
High-income	2.40	3622
Middle-income	0.69	707
Low-income	0.68	na

Table 4: Research and development. R&D expenditure is averaged over 1996–2003 (except Russia, China, and the US through 2004; Brazil excluding 1997–1998; and India only through 2000). For R&D researchers, the UK figure is averaged over 1997–1998; Russia and China, 1996–2004; Brazil, 2000 only; India 1996 and 1998; US 1997, 1999–2002. Russia has managed to maintain a high researcher intensity, despite spending relatively little on R&D. Figures 3–4, however, show that intensity declining over the last decade, even though R&D expenditure is rising. China's R&D spending has risen sharply, overtaking that of Russia's as a fraction of GDP even though its researcher intensity in the population remains relatively low. Source: UNESCO, World Bank, and author's calculations.

Percentage of world totals	Scientific and technical journal articles	Patent applications
UK	8.1	3.1
Russia	3.0	2.6
Brazil	0.7	0.7
China	1.8	3.0
India	2.0	0.5
US	36.0	20.3
High-income	88.4	83.8
Middle-income	9.3	12.5
Low-income	2.4	3.7

Table 5: Knowledge economy output proxies. The Table reports percentages of world totals, averaged 1985–2003 (Russia, 1993–2003). Figures 5–6 contain the dynamics of these figures. Source: National Science Foundation – Science and Engineering Indicators, World Intellectual Property Organization, World Bank, and author's calculations.

Percentage of world totals	Internet users	Mobile phone subscribers	PCs
UK	3.8	5.3	4.8
Russia	0.8	1.0	1.6
Brazil	1.3	2.6	1.6
China	4.1	10.8	3.6
India	1.3	0.8	0.9
US	42.6	23.4	36.7
High-income	83.2	74.0	81.6
Middle-income	14.9	28.7	16.2
Low-income	1.9	1.7	2.0

Table 6: Digital technologies. The Table reports percentages of world totals, averaged over 1993–2004 (for Mobile phone subscribers, 1994–2004). Figures 7–9 contain the dynamic evolution of these percentages. Source: International Telecommunication Union, World Telecommunication Development Report, World Bank, and author's calculations.

Figures

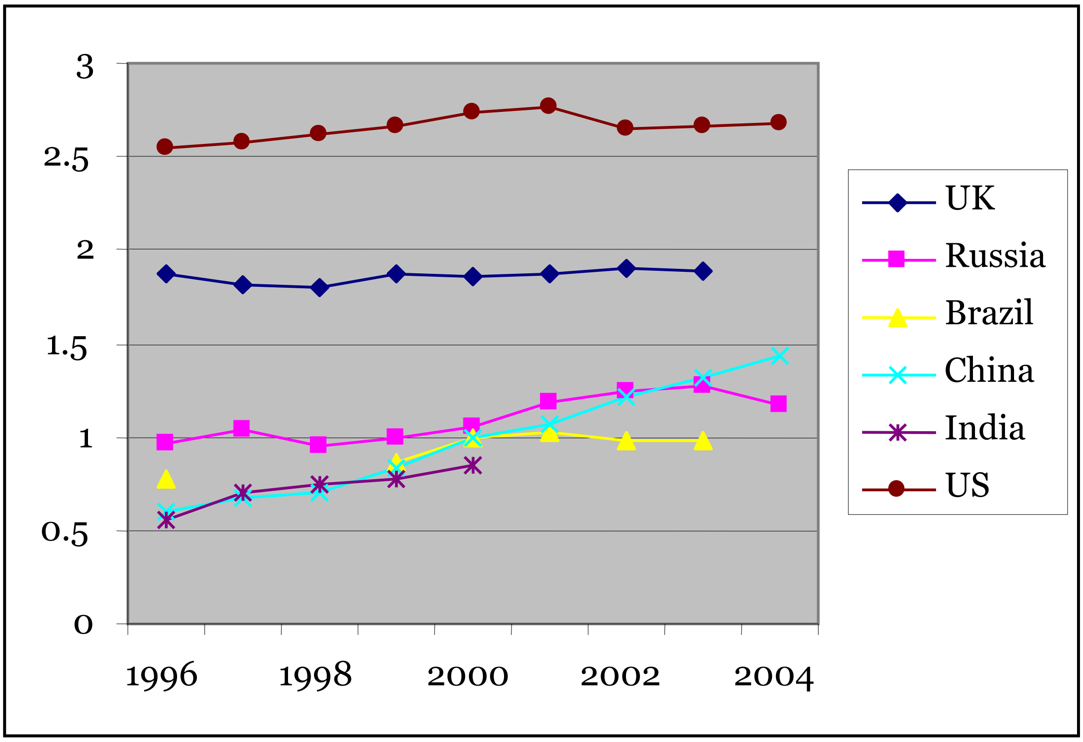

Figure 3: R&D expenditure (% GDP). The UK series has been relatively constant while Russia's has been rising and China's even more so. Source: UNESCO, World Bank, and author's calculations.

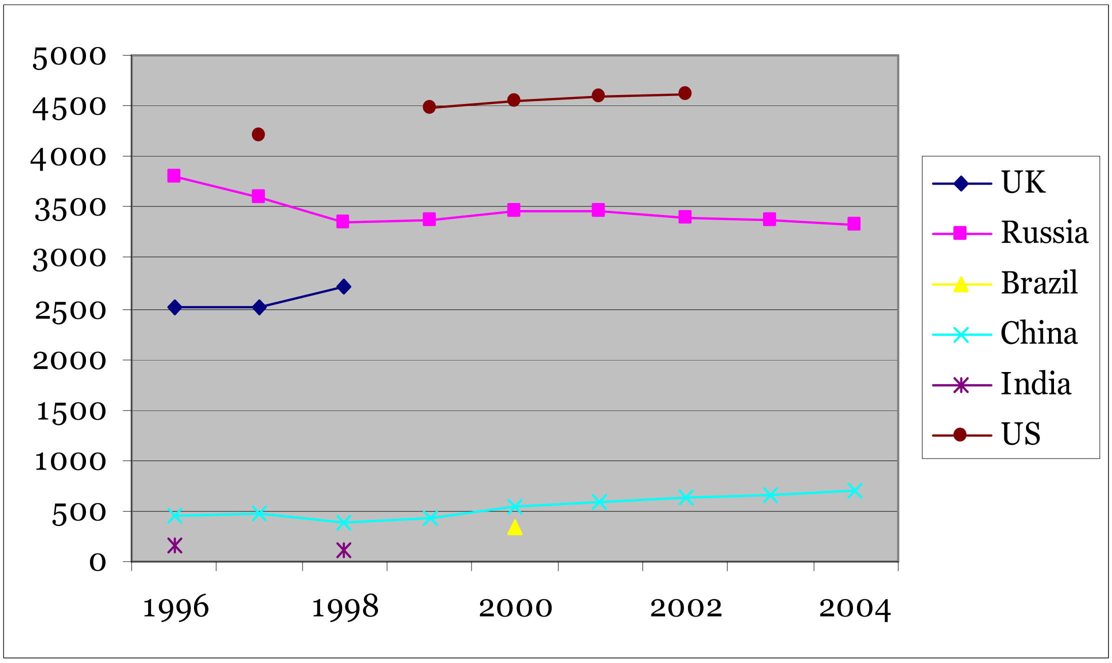

Figure 4: R&D researchers (every 10^6 **people).** Of all the knowledge economy indicators, it is the fraction of R&D researchers out of population where Russia scores highest. That ratio, however, has been declining steadily over the last decade. ChinaSource: UNESCO, World Bank, and author's calculations.

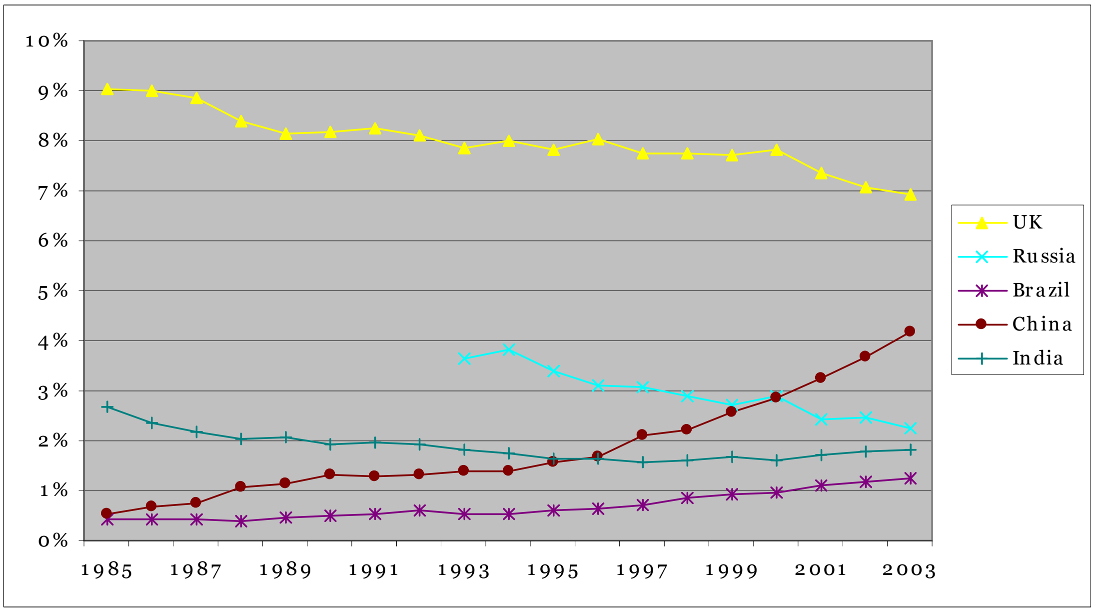

Figure 5: Science and technology publications (% world total). Despite having a relatively small population, the UK share of science and technology publications has historically been relatively high. However, that share has gradually declined, as has Russia's, while in contrast China's has sharply risen. Source: UNESCO, World Bank, and author's calculations.

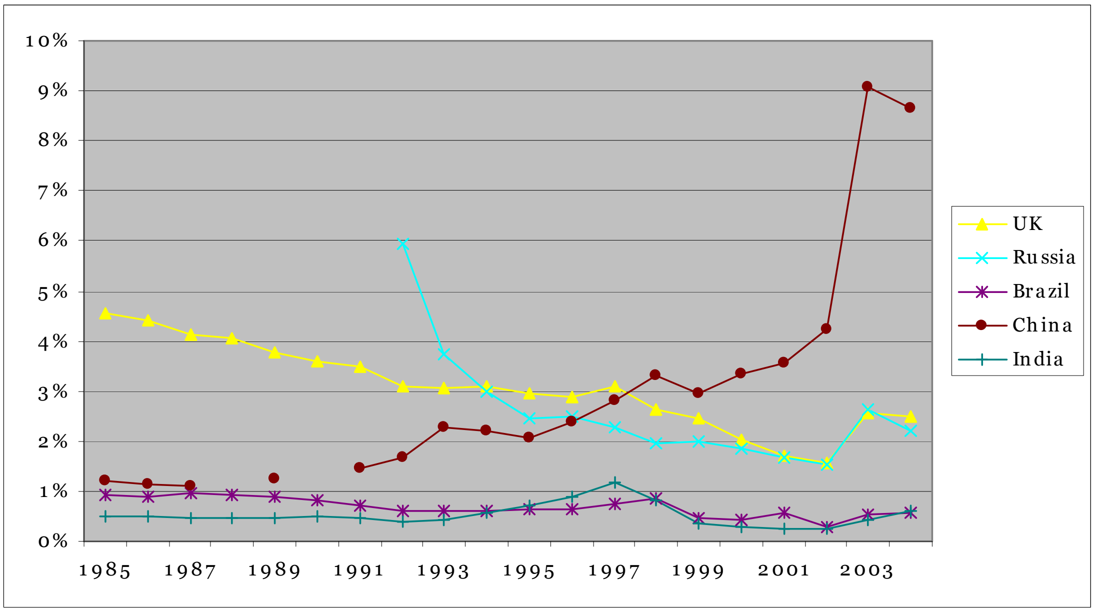

Figure 6: Patent applications (% world total). Beginning from relatively high levels, shares of patent applications in both UK and Russia have declined while that in China has increased sharply, to more than three times that of either the UK or Russia. Source: UNESCO, World Bank, and author's calculations.

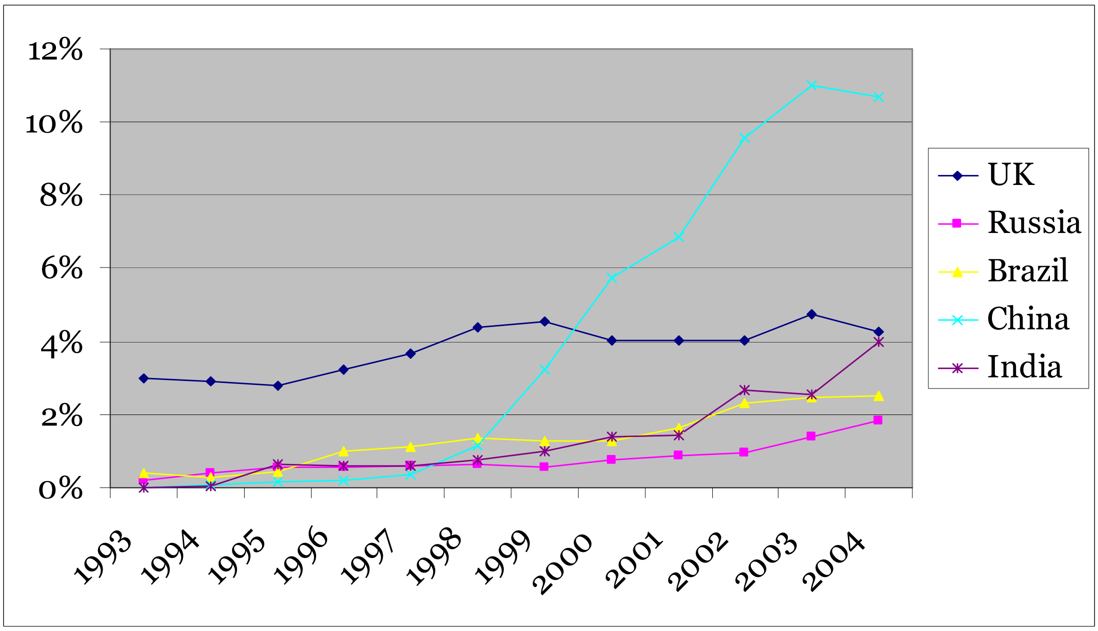

Figure 7: Internet users (% of world total), 1993-2004. While the numbers for both the UK and Russia (and indeed all economies depicted here) have increased, the most striking change is the dramatic rise in China's Internet population, overtaking all other countries depicted here. Source: ITU, World Bank, and author's calculations.

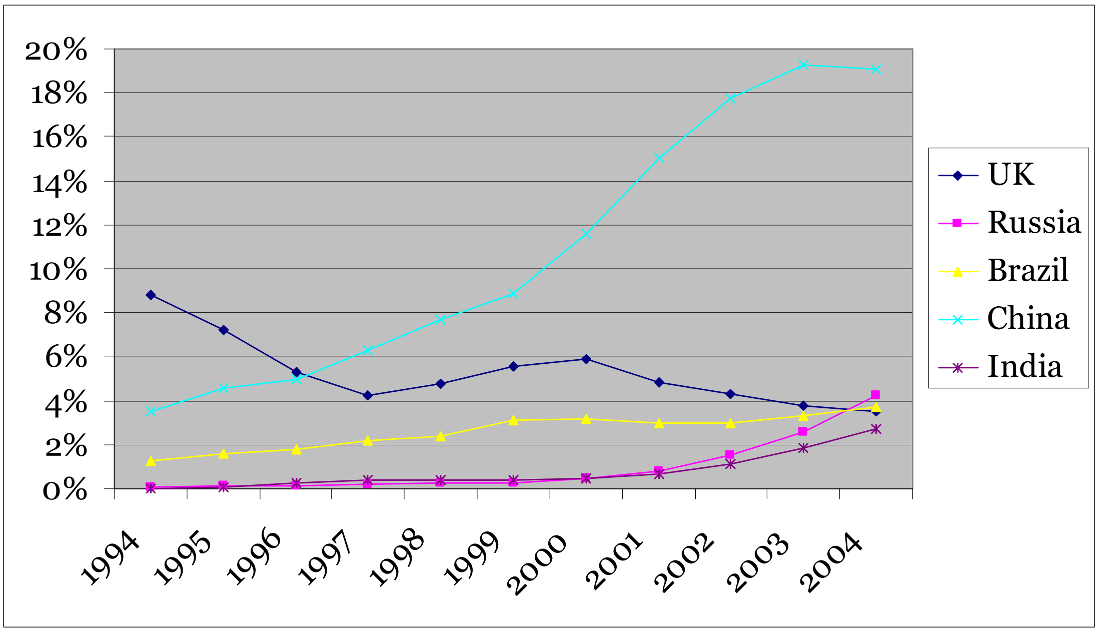

Figure 8: Mobile subscribers (% of world total), 1994–2004. The UK's declining and Russia's increasing shares, respectively, have led to Russia's overtaking the UK by 2004. But again the most striking feature is the dramatic increase in China's numbers, to now nearly five times each of the others' depicted. Source: ITU, World Bank, and author's calculations.

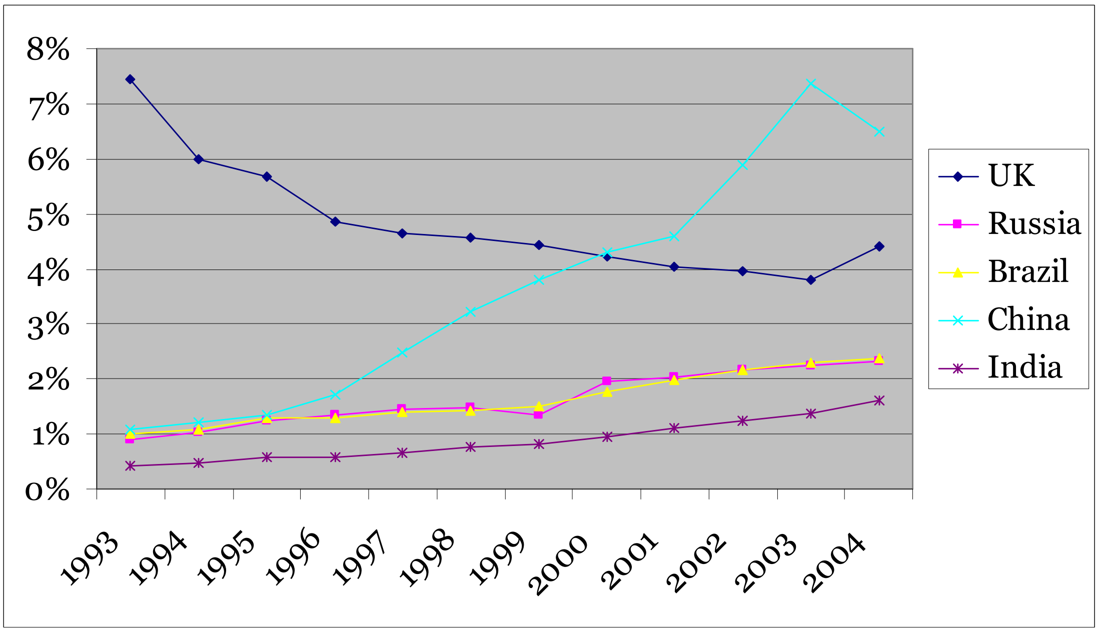

Figure 9: PCs (% of world total), 1993-2004. The UK's share has declined gradually, with Russia and all the other countries depicted converging from below. China's share, again, has risen sharply to overtake the UK and all other economies depicted. Source: ITU, World Bank, and author's calculations.

Data Appendix

For convenience the definitions of high-, middle-, and low-income economies follows the 2005 definitions given by the World Bank. High-income economies are those with annual per capita incomes no less than $10,725; low-income economies, no greater than $875.

2005	GDP ($\$10^{12}$)	Per-capita GDP ($\$10^{3}$)	Population (10^{6})
UK	1.72	28.6	60
Russia	1.40	9.8	143
Brazil	1.46	7.8	186
China	7.67	5.9	1304
India	3.41	3.1	1095
US	11.10	37.4	296
World	54.57	8.5	6438
High-income	29.37	29.0	1011
Middle-income	20.08	6.5	3073
Low-income	5.30	2.2	2353

Table 7: Aggregate statistics, 2005. Income figures are adjusted for purchasing power parity. (Classification into high-, middle-, and low-income economies, however, does not adjust for PPP.) Source: World Bank

Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.

R&D expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. This includes postgraduate PhD students (ISCED97 level 6) engaged in R&D.

Scientific and technical journal articles are those articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

Patent applications are applications filed with a national patent office for exclusive rights for an invention--a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years.

Internet users are people with access to the worldwide network. Mobile telephone subscribers are subscribers to a public mobile telephone service using cellular technology. Personal computers (PCs) are self-contained computers designed to be used by a single individual.