5

Role of High-Technology Industries

KEITH CRANE AND ARTUR USANOV

Politicians worldwide are fond of supporting high-technology industries—that is, industries that develop and deploy new technologies to create products or services not previously available. These industries, where expenditures on research and development (R&D) as a share of total sales are much higher than average,[1] are considered especially attractive because demand for their products often grows rapidly. These industries also tend to pay wages substantially higher than average. Production processes often have less impact on the environment than some traditional industries. In some instances, R&D undertaken by high-technology industries has spillover effects that benefit other sectors in the economy.

Russia is no different. Both President Dmitri Medvedev and Prime Minister Vladimir Putin envision increased output from high-technology industries as driving Russia's economic growth.[2]

This chapter assesses whether these hopes are likely to be fulfilled. We first assess Russia's heritage in high-technology industries, then evaluate five high-technology industries with significant sales in Russia and abroad: software, nanotechnology, nuclear, aerospace, and armaments. We look at

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1. T. Hatzichronoglou, "Revision of the High-Technology Sector and Product Classification," OECD Science, Technology and Industry Working Paper (Paris: Organization for Economic Cooperation and Development, 1997), http://puck.sourceoecd.org.

2. Russian Federal Government, *Concept of Long-Term Social and Economic Development of the Russian Federation Until 2020* (November 2008); Dmitri Medvedev's article, "Go Russia!" September 10, 2009, http://eng.kremlin.ru/speeches (accessed on November 3, 2009).

each sector's organization, sales, strengths, weaknesses, and impediments to growth and how policies pursued by the Russian government would affect that sector. We conclude with an assessment of likely prospects for growth for each sector and the likely future role of high-technology industries in the Russian economy.

Russia's Heritage in High-Technology Industries

One of the legacies that Russia inherited from the former Soviet Union was a large cadre of well-trained scientists and engineers, a system of national laboratories and research institutes, and design bureaus and enterprises that had succeeded in building some highly sophisticated machinery and equipment. With these resources, the Soviet Union managed to achieve notable technological feats, including launching the first satellite, Sputnik 1, into space; putting the first human into space; manufacturing the world's first supersonic transport aircraft; and building the world's first nuclear power plant to generate electricity for a power grid. The Soviet Union also produced a number of sophisticated weapons systems, including advanced fighter aircraft, intercontinental ballistic missiles, and nuclear weapons. In fact, most of the Soviet Union's major achievements in civilian technologies were tied to its military program.

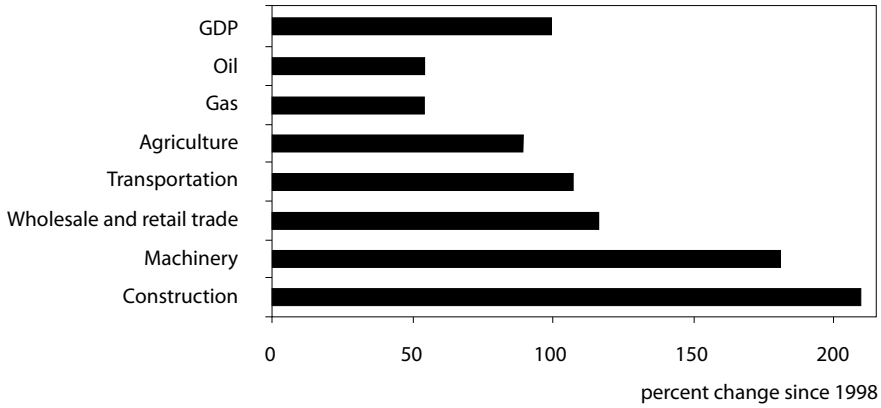
After the collapse of the Soviet Union, high technology was no longer the key focus of Russian policymakers. With the exception of software, output from high-technology industries fell sharply (along with output from most other industries). Aerospace and armaments were hit especially hard, as domestic procurement fell by 80 percent in the 1990s.[3]

High-technology industries played a small role in driving the increases in Russian GDP between 1998 and 2008, when growth in GDP averaged 6.8 percent per year. However, growth in output of machinery and equipment—the sector where most high technologies are lodged—has been rapid since 1998, eclipsing the overall rate of growth in GDP.

Russia's recovery was primarily driven by the same factors driving growth in other transition economies: market disciplines and shift from state to private ownership. These changes massively improved the efficiency with which capital and other resources were used. During this period, labor productivity in manufacturing rose at double-digit rates. Sectors of the economy that had been relatively neglected during the Soviet era or suffered the most severe declines in output during the first decade of the transition led the recovery: retail and wholesale trade, construction, transportation, and telecommunications (figure 5.1). Despite the importance of oil, refined oil products, and natural gas in Russian exports and tax revenues, changes in output of oil and natural gas did not directly drive growth

3. Institute for International Strategic Studies, *Military Balance* (London, various years).

Figure 5.1 Sectoral contributions to Russia's growth in GDP between 1998 and 2008



Note: For machinery production, data on "machine building and metal processing" are used for 1999 and 2000 and "production of machinery and equipment" for 2001 to 2008.

Source: Rosstat, *Annual Statistical Yearbook*, various years.

in output, although revenues from these exports played an important role in attracting the financial flows that boosted construction and retail trade.

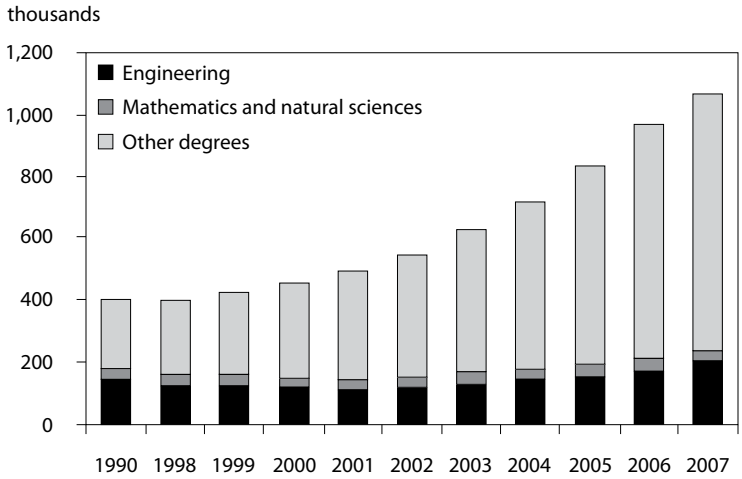
The Soviet industrial base still forms the core of Russia's high-technology industries: advanced materials, nuclear power, aerospace, and other sectors of the defense industry. Software is the only substantial high-technology sector to have emerged since the collapse of the Soviet Union.

The Soviet education and research establishment remains the source of human capital for Russia's high-technology sectors. Russia inherited the Soviet Union's extensive system of science and technology education. Although the educational system has changed, Russia still scores well in various international comparisons of high school and college students' knowledge of science, mathematics, and engineering—the educational basis of high-technology industries. Moreover, the number of students graduating with university degrees has risen sharply since Soviet times (figure 5.2). Although the number of graduates with degrees in mathematics and natural sciences has stagnated, those with engineering degrees has increased in recent years, from 146,000 in 1990 to 207,000 in 2007.

The Soviet Union's massive system of research laboratories and development institutes shrank following the country's collapse. Of the countries that emerged from the Soviet Union, Russia has done the best job of maintaining at least some of these laboratories, but employment and the number of active laboratories have fallen sharply. The number of R&D personnel in Russia shrank from 1.94 million in 1990 to 793,000 in 2008.[4]

4. Ministry of Education and Science of the Russian Federation, *National Innovation System*

Figure 5.2 Graduates from Russian private and public universities, 1990, 1998–2007



Source: Authors' calculation based on data from the Russian Education Statistics website, http://stat.edu.ru.

For example, the total number of individuals employed in the Soviet nuclear industry (weapons and civilian uses) was estimated at 200,000 to 222,000 in 1991. Research is now confined to a few core laboratories.

R&D expenditures also shrank. In 2008 they amounted to 1.14 percent of GDP, well below the average OECD level but above that of most countries with a similar level of per capita GDP. The Russian Federal Space Agency (Roscosmos) has been the main recipient of public funds for nondefense R&D, followed by the Russian Academy of Sciences, the Federal Agency for Science and Innovation, and the Russian Academy of Medical Sciences.[5] The share of universities in R&D funding remains small. Unlike in most OECD countries, the public sector finances most Russian R&D—61 percent—while the business sector accounts for 29 percent and foreign sources, 9 percent.[6]

The Russian Academy of Sciences inherited most of the All-Union facilities for basic science research after the collapse of the Soviet Union. However, it too has shrunk over the past two decades. Laboratories not associated with the academy have experienced even sharper reductions.

While traditional sources of support for high-technology industries

and State Innovation Policy of the Russian Federation (background report to the OECD Country Review of the Russian Innovation Policy, Moscow, 2009), chart 5.6, http://mon.gov.ru (accessed on January 14, 2010).

5. Ibid, chapter 5.

6. Ibid., chart 5.5, data for 2006, but the composition has not changed significantly since then.

have faltered in Russia, a number of new sources have sprung up over the course of the transition. Foreign companies have spurred growth in Russia's high-technology industries through subcontracting, joint ventures, wholly owned research laboratories, or funding research by independent laboratories or academic institutions. Russian scientists are also frequently engaged as consultants. These new activities have markedly changed R&D in Russia and the nature of Russian high-technology industries.

Current Role of High-Technology Industries

According to the Organization for Economic Cooperation and Development (OECD), nine main product groups (based on the Standard International Trade Classification [SITC] codes) encompass products produced by high-technology industries: (1) aerospace, (2) computers and office machines, (3) electronics and telecommunications, (4) pharmaceuticals, (5) scientific instruments, (6) electrical machinery, (7) chemicals, (8) nonelectrical machinery, and (9) armaments.[7] Of these, Russia has internationally competitive products in

1. software in the computer and office machines industry;
2. specialty materials, including nanotechnologies;
3. nuclear technologies in the nonelectrical machinery sector;
4. aerospace; and
5. armaments.

We investigate each of these five industries in this section. The Concept for Long-Term Social and Economic Development of the Russian Federation until 2020 adopted by the Russian government in November 2008 adds shipbuilding and radioelectronics to these sectors. However, outside some specialized applications in defense, these two sectors are well behind their international competitors. Moreover, shipbuilding is not usually considered a high-technology industry. President Medvedev has also mentioned pharmaceuticals, an industry in which Russia has not registered substantial exports or shown much innovation.

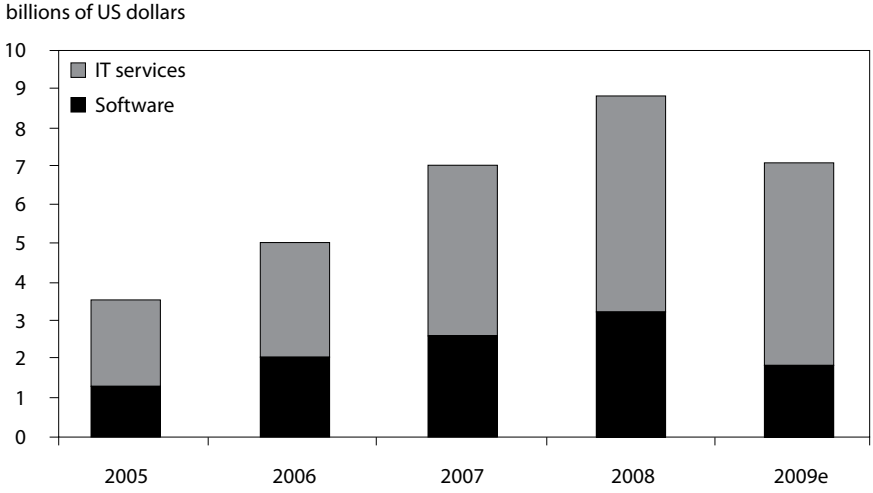
Software and Information Technology (IT) Services

The Russian software industry has been a success story. From a humble beginning in the early 1990s, the industry's dollar revenues have grown at double-digit rates. In 2008, gross revenues ran about $5.5 billion, almost half of those from exports.[8] The total Russian market, as shown in

7. Hatzichronoglou, "Revision of the High-Technology Sector and Product Classification."

8. Russian Software Developers Association (Russoft), *6th Annual Survey of the Russian*

Figure 5.3 Russian market for software and information technology services, 2005–09e



e = estimate

Source: CNews Analytics, 2009, www.cnews.ru.

figure 5.3, is substantially larger because of sales by foreign firms like Oracle and Microsoft in Russia. However, the Russian industry is smaller than India's; the Indian software and IT services industry had revenues of $60 billion in 2008.[9]

The Russian software and IT services industry is young. Almost all existing IT companies are startups by Russian entrepreneurs. Initially, most of these entrepreneurs had worked in government-owned IT centers, research institutions, or defense companies. The industry benefited from its young age, absence of legacy assets, and small size—the government did not bother to regulate it, which would likely have hindered its growth. The low capital intensity of the industry kept barriers to entry and exit low.[10] As a consequence, the IT sector has always been one of the most open industries in Russia.

Software Export Industry (St. Petersburg, 2009), 20, www.russoft.org (accessed on January 14, 2010). This number includes sales by Russian companies only, which might be tricky to define in offshore software development. Normally these are companies that have either headquarters or most of their developers located in Russia.

9. Data from NASSCOM, the trade body of India's IT industry, www.nasscom.org (accessed on January 14, 2010).

10. McKinsey Global Institute, *Unlocking Economic Growth in Russia* (Moscow, 1999), www.mckinsey.com (accessed on January 14, 2010).

In 1999, McKinsey Global Institute found the software sector had the highest labor productivity in the Russian economy, at 38 percent of the US level, double the average of the ten sectors studied.[11]

Russia's rapid growth between 1999 and 2008 substantially increased demand for the industry's products and services from business, government, and consumers. Another factor driving growth in the software industry was more robust enforcement of intellectual property rights and antipiracy measures: Software piracy declined from 87 percent in 2004 to 68 percent in 2008.[12] As a result, from 2005 to 2008, sales of software and IT services in the Russian market more than doubled, although the economic crisis in 2009 resulted in a large drop in IT spending (figure 5.3).

Probably the best indicator of the Russian software industry's competitiveness and strength is its rapidly growing exports (figure 5.4). Offshore programming in Russia began to gain momentum after the dot-com bubble burst in 2000–01 when US and European companies aggressively sought ways to cut costs.[13]

While lower labor costs were the main initial driver of offshore programming, IDC, a global research firm that focuses on the information and communications technology (ICT) sector, finds "strong technical skills, sound methodologies, and high education levels, which allow delivery of high-end, technically complex projects, as key strengths of the Russian software and services industry."[14] Russia has higher wages in the IT sector than India or China and so is unlikely to challenge India's leadership in the offshore information technology–business process outsourcing (IT-BPO) market. However, it is likely to continue to increase its presence in the high-end segment of the offshore development market and in packaged software.

The Russian Software Developers Association (Russoft) divides software exports from Russia into three groups:

1. *Packaged software.* This consists of commercially available programs for sale or lease. The largest Russian packaged software company is

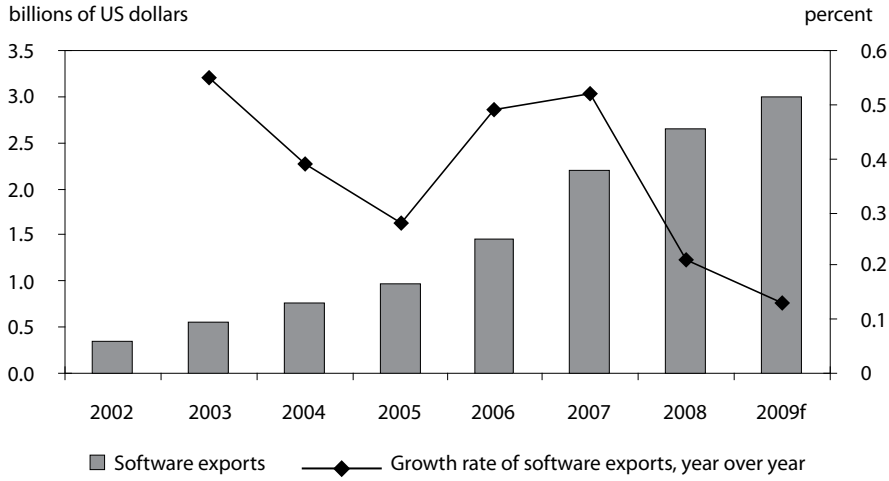
11. The McKinsey Global Institute found that in project services (consulting, implementation, including offshore programming, and training in IT) labor productivity was 72 percent of the US level while it was only 13 percent in packaged software due to the small scale of operations, piracy, and low value added; see McKinsey Global Institute, *Unlocking Economic Growth in Russia.*

12. Data are from BSA and IDC, quoted in Russoft, *6th Annual Survey of the Russian Software Export Industry,* 16.

13. D. J. Petersen, *Russia and the Information Revolution* (Santa Monica, CA: RAND, 2005), www.rand.org.

14. Marianne Kolding and Vladimir Kroa, *Russia as Offshore Software Development Location: Should You Consider This Your Next Move?* (White Paper sponsored by Russoft, March 2007), www.russoft.org. This white paper was based on in-depth, executive-level interviews with 20 Western European and US-based companies that have used Russian software and services companies for offshore development projects.

Figure 5.4 Exports of Russian software, 2002–09f



f = forecast

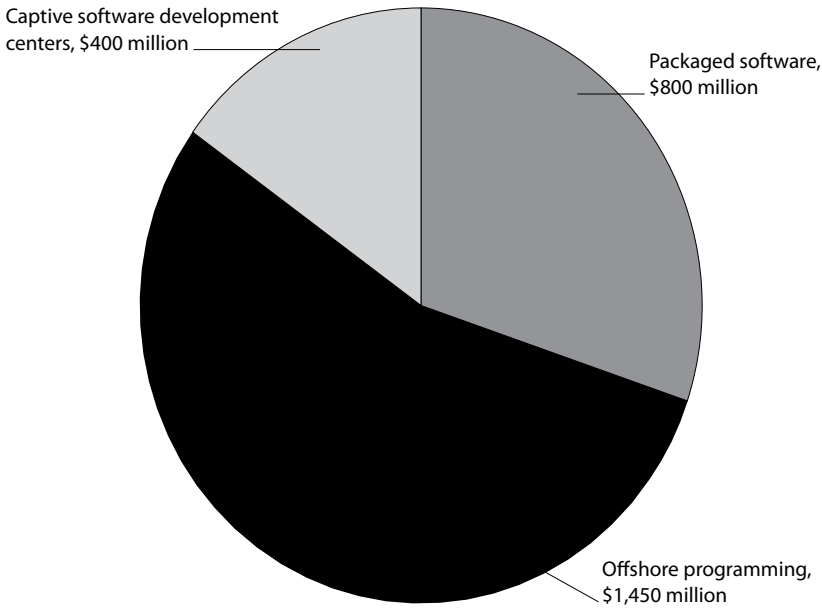
Source: Survey of software companies by Russoft, 2009.

Kaspersky Lab, which develops antivirus software and had revenues of $360 million in 2008, of which $260 million were from exports.[15] Its products regularly receive high ratings from major software publications. Agnitum and Doctor Web are two smaller Russian antivirus software developers. Other Russian software companies with significant sales in international markets are Transas (navigational systems, training simulators, and fleet management systems), ABBYY (provider of document conversion, data capture, and linguistic software), PROMT (automated translation systems), and Parallels (virtualization and automation software).

2. *Offshore programming (software development services).* In this case, a foreign company contracts with Russians for software development or IT services for its clients. The foreign company keeps the resulting intellectual property. This is the largest source of Russian software exports (figure 5.5). Companies engaged in subcontracting are less well known, but some, such as EPAM Systems, Exigen Services, and Luxoft, work with thousands of programmers and development centers across the world. They are truly global companies. There are also hundreds of Russian companies with fewer than 100 employees. Russoft estimates total employment in this sector at about 50,000 in 2008.
3. *Captive software development centers.* Attracted by Russia's research expertise in some areas and its large pool of highly skilled professionals

15. Russoft, *6th Annual Survey of the Russian Software Export Industry*, 20.

Figure 5.5 Composition of Russian software exports, 2008



Source: Survey of software companies by Russoft, 2009.

with scientific backgrounds, a number of major international firms have established dedicated offshore programming and R&D centers in Russia. These companies include Alcatel, Ericsson, Google, Intel, Motorola, Samsung, and Sun Microsystems, among others.

The development of Russia's IT sector will depend on making the country's business environment friendlier, especially for offshore software companies, which have to compete in the global market. A common theme across most indices measuring Russia's performance is that Russia scores well on its highly educated population. As noted earlier, Russian education in science and mathematics remains strong as demonstrated by the performance of Russian students in international contests. However, some software companies complain that university curricula do not reflect the requirements of today's marketplace. On the other hand, as the CEO of a large Russian software company observed in an interview with one of us, in general the industry is very pleased with the quality of recent Russian graduates. He saw no decline in the competitiveness of Russian students. Rather, students had an increased appreciation for and knowledge of the software industry.

Russia's overall rating, however, is dragged down by unfriendly business regulations and corruption (table 5.1). For example, Russia does rela-

Table 5.1 Russia's ranking in selected information and communication technology surveys

Survey	Rank	Percentile
IT Industry Competitiveness Index (Economist Intelligence Unit, 2009)	38/66	42
A.T. Kearney Global Services Location Index, 2009	33/50	34
International Telecommunications Union, Information and Communication Technology Development Index, 2009	50/154	68
World Economic Forum, Networked Readiness Index, 2008–2009 rankings	74/134	46

tively well on the International Telecommunications Union's Information and Communication Technology Development Index, which measures ICT access, use, and skills, but on ratings that take into account regulation and government policies it scores much more poorly.[16]

A key barrier to the development of the industry is Russia's lax tax administration.[17] The tax authorities do not closely audit companies, which is sufficient incentive for companies to use independent contractors—who avoid paying payroll taxes (pension and health care taxes) or value-added tax (VAT)—as opposed to hiring full-time employees, which is more expensive. In this business environment, traditional incentives like promotions, stock options, or other means of inducing loyalty and commitment are much less effective. This proclivity to use independent contractors rather than full-time employees makes it difficult for companies to build project management skills, as companies lack the staff and loyalty needed to run large projects.

However, the greatest barrier to the development of the industry is thuggery and corruption that Russian entrepreneurs face from the police and other government officials.[18] Bribing inspectors, tax collection agents, and the police places a substantial burden on companies. The police penalize companies by demanding years of records on flimsy grounds. If no irregularities are found, the police have been known to manufacture irregularities and threaten company managers with imprisonment unless they are bribed. Some police officers have threatened to kidnap or beat up family members if they are not bribed. This climate of intimidation and fear discourages entrepreneurs from expanding their businesses and puts a premium on moving assets outside of Russia.

16. Ibid.

17. Keith Crane's interview with CEO of a Russian software company, November 16, 2009.

18. Ibid.

Table 5.2 Public and private spending on nanotechnology, 2008–15
(billions of rubles)

Category	2008	2009	2010	2011	2012–15
R&D	8.2	9.8	11.2	13.1	25.7
Infrastructure	10.9	9.1	9	2	0
Rusnano spending	20.3	21	22.8	19.5	80.5
Private investment in Rusnano projects	n.a.	n.a.	6.5	7	40
Other	0.1	0.3	0.4	0.6	0
Total	39.5	40.2	49.8	42.2	146.2
In billions of US dollars (30 rubles = $1)	1.3	1.3	1.7	1.4	4.9

n.a. = not available

Source: Ministry of Education and Science of the Russian Federation, Federal Target Program for Development of Nanoindustry until 2015, 2008, http://mon.gov.ru.

Nanotechnology

The Russian government has made development of nanotechnology a state priority. Nanotechnology has received more attention than almost any other technological sector in post-Soviet Russia. The push to make Russia a technological leader in this field comes from the very top.

The government has set up several programs to support and direct the development of nanotechnology, providing substantial sums of money for research and related infrastructure (table 5.2). In 2007, it created a state-owned corporation, Rusnano, with chartered capital of 130 billion rubles ($5 billion) to support commercial initiatives in this area. By the end of 2009, Rusnano had approved investments of 91 billion rubles in 61 projects (including in other investment funds)[19] and become the largest investor in high-technology industries in Russia. However, the 2007–09 crisis has set back the company's and the Russian government's plans for nanotechnology. In 2009, at the request of the Russian government, Rusnano transferred approximately half of its funds back to the federal budget to help cover other government expenditures.[20]

The current state of nanotechnology in Russia reflects both the strengths and weaknesses of Russia's research and innovation system. Russian scientists have been relatively productive in theoretical research on nanotechnology. Russia ranked sixth in the number of nanotechnology publications in

19. "Rusnano Recaps 2009," press release, December 23, 2009, www.rusnano.com.

20. "Rusnano transferred 66.4 billion rubles to the state budget," press release, December 17, 2009, www.rusnano.com. The government plans to return these funds to Rusnano in 2010–12.

1995–2007, behind the United States, China, Japan, Germany, and France.[21] The Russian Academy of Sciences began publishing its *Journal of Nano and Microsystem Techniques* in 1999. Russian public spending on nanotechnology projects and initiatives in 2008 exceeded $1 billion, behind only the United States and Japan.[22]

Russia's performance has not been as strong in the commercialization stage of the innovation process: It ranks 16th in the number of patents related to nanotechnology, 0.2 percent of the global total.[23] Innovation activity in nanotechnology by Russian firms has been modest. President Medvedev lamented the lack of interest of Russian businesses in nanotechnology at a forum organized by Rusnano in October 2009.

In addition to Rusnano, Russia is home to some private companies engaged in nanotechnology. NT-MDT (www.ntmdt.com) was set up in 1989 by Viktor Bykov, head of a research laboratory at the Physical Problems Research Institute. NT-MDT specializes in designing and manufacturing scanning probe microscopes and other equipment for nanotechnology research. The firm has about 10 percent of the world market for these microscopes and 90 percent of the market in Russia and countries in the Commonwealth of Independent States (CIS). In 2007, it had revenues of about $65 million. The *National Report on Innovations* in 2008 singled out this firm as possibly the best commercial success of Russia in the nanotechnology market. NT-MDT has a large network of international suppliers and two branches abroad, one in the Netherlands and the other in Ireland. The firm invests 15 to 20 percent of revenues in R&D and actively collaborates with outside research laboratories or organizations.[24]

Optogan (www.optogan.com) was founded in Finland in 2004 by a team of Russian scientists from the Ioffe Institute in St. Petersburg. Optogan develops and produces high-brightness light-emitting diodes (LEDs). Its proprietary technology and product designs have enabled tangible improvements in performance and reductions in the cost of LED lighting. Optogan has R&D facilities in Finland and a pilot manufacturing line in Germany. Rusnano together with the private investment fund Onexim Group, owned by billionaire Mikhail Prokhorov, and another Russian company bought Optogan in December 2008. Optogan is currently ramping up volume manufacturing in St. Petersburg. Total investment in the project is 3.4 billion rubles. The investors hope that the company's revenue will reach 6 billion rubles in 2013.

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21. Lux Research as quoted in *Innovatsionnoe razvitie—osnova modernizatsii ekonomiki Rossii* [*Innovation Development—Foundation for Russia's Economy Modernization*] *National Report*, State University—Higher School of Economics, 2008), 127, available at www.hse.ru.

22. Ibid., 120.

23. Ibid., 127.

24. Ibid., 151–55.

Nuclear Industry

Russia's civilian nuclear industry is broad-based, encompassing nuclear power plant design and construction, power-sector equipment, and the entire nuclear fuel cycle. It is the direct outgrowth of the Soviet nuclear weapons program. In 2007, both the civilian and military sides of the industry were integrated under the State Atomic Energy Corporation, Rosatom. One of the goals set by the federal government for the corporation was to strengthen the country's position on the global market for nuclear technology. Most of the civilian assets in the nuclear sector have been transferred to a joint-stock company, Atomenergoprom, which is a subsidiary of Rosatom.

Atomenergoprom is a vertically integrated holding company. It owns companies at all stages of the value chain in the nuclear power sector, from uranium mining and fuel fabrication, nuclear reactor design and manufacture to design and construction of nuclear power plants. Total sales were 290 billion rubles ($11.7 billion) in 2008.

Atomenergoprom is one of the world's largest nuclear companies. It is the largest in the world in terms of exports of nuclear power plants. It is currently constructing five reactors outside Russia. It owns and operates ten power plants with a total capacity of over 23 GW, making it the second largest company in the world in terms of electricity generated by nuclear power plants. It is also the second largest company in the world in terms of uranium reserves, including joint ventures abroad, and the fourth in terms of production of uranium ore.[25]

Russia has a strong competitive position in the nuclear fuel cycle, especially in uranium conversion and enrichment. It has the world's largest uranium enrichment capacity (40 percent of the global total).[26] It owns 100 percent of the shares of Russia's four enrichment plants: Angarsk Electrolysis Chemical Complex (Angarsk, Irkutsk region), Electrochemical Plant (Zheleznogorsk, Krasnoyarsk region), Urals Electrochemical Combine (Novouralsk, Sverdlovsk region), and Siberian Chemical Combine (Seversk, Tomsk region). The companies have a total capacity of 26 million kilograms separative work units (SWU).

Uranium enrichment adds the largest value to uranium in its transformation into nuclear fuel, accounting for 30 to 50 percent of the final reactor fuel price.[27] Russia has the lowest costs of enrichment in the world, making it one of the most competitive Russian industries on the world

25. Atomenergoprom company profile, www.atomenergoprom.ru/en.

26. Rosatom, Uranium Enrichment Division, www.rosatom.ru/en.

27. Commonwealth of Australia, *Uranium Mining, Processing and Nuclear Energy—Opportunities for Australia?* (report to the Prime Minister by the Uranium Mining, Processing and Nuclear Energy Review Taskforce, December 2006), 35–37.

market.[28] Russia's competitive advantage in this sector is based on its efficient gas centrifuge technology and large scale of facilities and is due in part to decisions made on R&D and investment in the 1990s. Russia invested in the development and deployment of a new generation of gas centrifuges in the 1990s; other industrial sectors did not enjoy this support.[29] In addition, uranium enrichment is a capital-intensive business, and the large scale of production facilities in Russia helps to reduce average costs.[30]

Price is the main factor in determining competitiveness in uranium enrichment. Two of Russia's major competitors—USEC in the United States and the European consortium controlled by Areva—use a different technology, gas diffusion, which requires much more electricity and therefore is costlier.

Because it is the lowest-cost producer, Russia has enjoyed growing exports of uranium enrichment services and radioisotopes to all major markets (figure 5.6). These exports are carried out through another Atomenergoprom subsidiary, Tenex, which supplies nearly one-third of Europe's nuclear reactor fuel needs. It also takes highly enriched uranium extracted from nuclear warheads and mixes it with less enriched uranium to create fuel for civilian use in the United States. These sales are made through the Megatons to Megawatts contract also known as the HEU-LEU agreement. However, Tenex's further expansion on the European and American markets is limited by quotas and other trade barriers protecting domestic enrichment companies.

Russia has proposed an International Uranium Enrichment Center at the existing enrichment plant in Angarsk. This center would provide assured nuclear fuel cycle services to states on a nondiscriminatory basis. Russia has proposed to enrich uranium for Iran in such a facility in exchange for Iran ending its nuclear enrichment activities. The center would be jointly owned by Russia and other states. It would help to increase demand for Russia's uranium enrichment services.

Russia exported its enrichment technology to China in the 1990s. It built centrifuge enrichment plants in Shaan-xi and Lanzhou.[31] However, these plants used an older generation of centrifuges. Russia built these plants with an understanding that they would serve only China's domestic customers.

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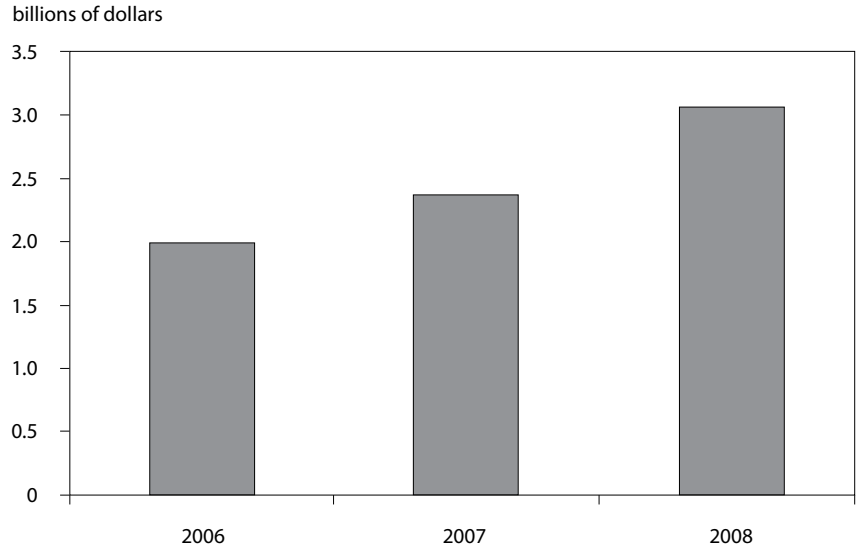
28. G. Rothwell, "Market Power in Uranium Enrichment," SIEPR Discussion Paper no. 08-32 (Stanford Institute for Economic Policy Research, March 2009), http://siepr.stanford.edu.

29. O. Bukharin, "Understanding Russia's Uranium Enrichment Complex," *Science and Global Security* 12 (2004): 193–218.

30. Urals Electrochemical Combine is the largest enrichment plant in the world with a capacity of 12.5 million kilograms SWU (Rothwell, "Market Power in Uranium Enrichment").

31. Bukharin, "Understanding Russia's Uranium Enrichment Complex."

Figure 5.6 Exports of enriched uranium and enrichment services by Tenex, 2006–08



Source: Tenex, 2008 Annual Report, 61, www.tenex.ru (accessed on January 14, 2010).

Retirement of less efficient gas diffusion plants by Areva and USEC is likely to increase competitive pressure in the industry but in the medium term is unlikely to undermine Russia's cost advantage. Emerging new technologies, such as laser isotope separation, may present a bigger threat in the long term.

Russia is also a major producer of nuclear fuel assemblies for nuclear power stations. It has 17 percent of the global nuclear fuel market, supplying every sixth reactor in the world with assemblies. However, in this sector its supplies are limited mainly to Soviet- or Russian-built reactors.

Russia also has considerable experience in nuclear reactor design and construction. Concerned about scarcity and sustainability of uranium supplies, it has been interested in fast neutron reactors. These reactors would allow the world to extend existing uranium resources by up to a factor of 60 and potentially to use thorium, which is much more abundant in nature than uranium, as nuclear fuel.[32] Russia's BN-600 (560 MWe) reactor in Beloyarsk is the largest fast neutron reactor in the world and has supplied electricity to the grid since 1980. Russia is building an even larger reactor, BN-800, which is scheduled to start commercial operation in 2012. In October 2009 Russia announced it would design and build two similar reac-

32. World Nuclear Association, "Fast Neutron Reactors," www.world-nuclear.org.

tors in China, which would be the first time commercial-scale fast neutron reactors have been exported.[33]

Another sign that Russian nuclear reactor technology has some advantages is the decision by German engineering giant Siemens to leave its nuclear reactor joint venture with Areva and form one with Rosatom. This venture will develop a new-generation nuclear reactor that will compete with Areva's Evolutionary Power Reactor.[34]

The United States and Russia have cooperated on a gas turbine-modular helium reactor.[35] However, this and other possible cooperation projects between Russia and the United States in the nuclear sector are hindered by the fact the US Congress has not yet ratified the US-Russia Agreement for Peaceful Nuclear Cooperation (123 Agreement) signed on May 6, 2008.[36]

Until recently, the depressed state of the world market for new nuclear power plants limited Russia's exports of nuclear reactor technology. The Chernobyl catastrophe seriously damaged market confidence in Russian-designed reactors. Nevertheless, Rosatom's operator for constructing Russian-design nuclear power plants in other countries, Atomstroyexport (ASE), has won several recent tenders. Its main successes had been in countries where competition was limited and where the host government lent support to Russian nuclear plants, such as Iran, China, and India. However, in recent years, a number of other countries have expressed interest in nuclear power, which has increased Russian exports (figure 5.7). In October 2006 ASE was chosen over a Skoda-led consortium to build a plant in Bulgaria consisting of 1060-MWe AES-92 VVER units with third-generation reactors, making it the first Russian nuclear power project in the European Union.

Russia's political leadership has made a strong commitment to nuclear power. On the one hand, it sees nuclear power as a way to free more natural gas for export by replacing gas-fired electricity generation with nuclear power plants. On the other hand, nuclear power and related industries are one of just a few high-technology sectors in which Russia has a serious R&D development base and can compete with more developed countries on the world market. The state has invested substantial sums in R&D, funded construction of new nuclear plants in Russia, and provided strong political support for Russian nuclear power projects abroad. Recent consolidation of all nuclear assets under Rosatom is aimed at strengthening the international position of Russia's nuclear sector.

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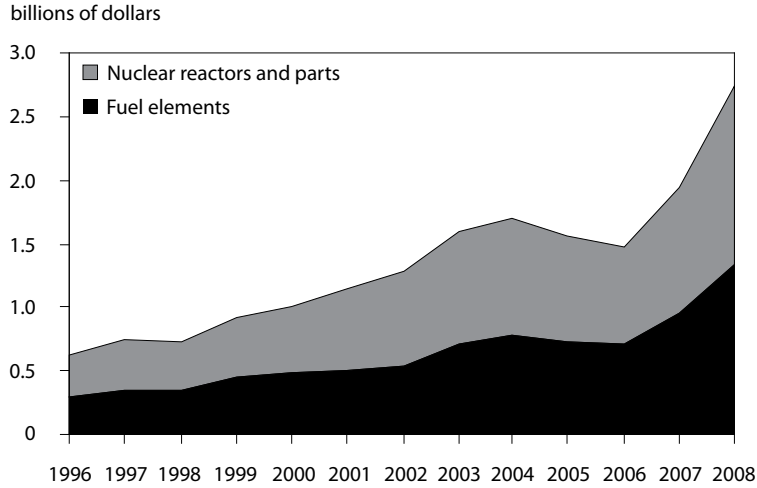
33. "China Signs Up Russian Fast Reactors," *World Nuclear News*, October 15, 2009, www.world-nuclear-news.org.

34. "Siemens, Rosatom may sign JV deal in 2009," Reuters, October 1, 2009, www.reuters.com.

35. General Atomics Energy Group, "GT-MHR: Inherently Safe Nuclear Power for the 21st Century," http://gt-mhr.ga.com.

36. Anton Khlopkov, "U.S.-Russian Nuclear Energy Cooperation: A Missed Opportunity," *Bulletin of the Atomic Scientists*, August 31, 2009, www.thebulletin.org.

Figure 5.7 Russian exports of nuclear fuel and nuclear power plants, 1996–2008



Source: UN Comtrade Database.

Aerospace

Russia's aerospace industry consists of rockets, satellites, and civilian aircraft. Of these, Russia's rocket industry is the strongest. Russia remains a leader in launchers; once the US space shuttle is retired in the next decade, Russia's Proton rocket will remain the only well-tested rocket capable of ferrying people and heavy payloads into space. It has the best record among major launchers.

Since the 1990s, the Russian space program has depended upon commercial launch contracts and collaborative activities with other countries and foreign companies for survival. For example, Pratt and Whitney markets Russia's RD-120 rocket engine in the United States. Although the Russian government funded the program in the 1990s, budgets were small. In recent years, revenues have recovered as the Russian federal government budget has grown. Even in the crisis year of 2009, the budget for space programs ran 82 billion rubles, roughly $2.5 billion.

The space industry remains primarily under government control. The Russian Federal Space Agency (RKA) is in charge of all civilian space operations. NPO Energia, a company in which private shareholders have a controlling stake, and two state-owned companies, Khrunichev and TsSKB-Progress, manufacture Russia's rockets.

In addition to rockets, Russia has produced communications, geopositioning, and other satellites. In contrast to launchers, communications satellites have not been competitive internationally. Wider use of GLONASS,

Table 5.3 Russian aircraft industry, military and civilian, 2008

	Aircraft industry	United Aircraft Corporation
Number of companies	106	18
Sales (billions of rubles)	226.6	105.3
Export sales (billions of rubles)	65.7	44.7
Gross profit (billions of rubles)	7.1	0.9
Number of employees (thousands)	355.3	92.1

Source: United Aircraft Corporation, 2008 Annual Report.

a Russian satellite navigation system, is, for example, hindered by inferior quality and the higher cost of GLONASS receivers. Other satellites tend to be for military use only.

Russia's civilian aircraft industry has not fared well since the collapse of the Soviet Union. Under central planning Soviet aircraft were never competitive internationally. Fuel-thirsty engines, lack of amenities, and inferior controls and avionics confined Soviet makes to captive markets among Soviet allies. After the collapse of the Soviet Union, former allies stopped purchasing these models. Even Russian airlines preferred Western makes. Consequently, Russia has succeeded in exporting just a few Soviet-era planes since the collapse of the Soviet Union, even though the industry has experimented with putting Western engines on its airframes. Civilian transport aircraft manufacturers have survived through sales of military transport aircraft, tankers, and other military aircraft.

The Russian government has attempted to consolidate the aircraft industry by creating a holding company, United Aircraft Corporation (UAC). The major Russian transport aircraft design bureaus (Sukhoi, Tupolev, Ilyushin, and Yakovlev) and production facilities have been merged into this company. Table 5.3 shows the composition of the entire industry, military as well as civilian, and the role that UAC plays in the industry.

In UAC, as in the other new agglomerates that the Russian government has fashioned out of the disparate companies that emerged from the former Soviet military complex, the new chief executive officers have had a hard time establishing control. The managers of the individual plants still wield a substantial amount of power.[37]

Russia has attempted to reenter the commercial aviation market. Sukhoi has embarked on a commercial airline venture, entitled Sukhoi Superjet, a modern regional jet seating 75 to 95 people. Characteristic of most commercial civilian aircraft activities in Russia, the venture involves a Western partner, Finmeccanica, an Italian aerospace and mechanical engineering firm. Design and manufacturing of the aircraft are led by Sukhoi

37. Conversation with an aircraft manufacturing executive in Moscow, October 2006.

Civil Aircraft, in which Alenia Aeronautica, a subsidiary of Finmeccanica, owns 25 percent plus one share.[38] In addition, Finmeccanica owns 51 percent in SuperJet International, which is responsible for marketing, sales, and aircraft delivery for the Sukhoi Superjet in Europe, North and South America, Africa, Japan, and Oceania as well as for worldwide logistics support. The engine for the aircraft was developed by PowerJet, a 50-50 joint venture between France's SNECMA and Russia's NPO Saturn. The consortium has received a number of orders for the plane, for example, from Aeroflot as well as several airlines outside Russia, including Hungary's Malev, Armenia's Armavia, and Indonesia's Kartika Airlines. The first deliveries will reportedly be made in 2010.

Russia has had more success in providing design services and components to the civilian aerospace industry. United Technologies' Pratt and Whitney division has invested in Russian aircraft engine turbine manufacturers. Boeing has a large design bureau in Moscow. EADS also subcontracts design and other activities to Russian companies.

Armaments

Russia's defense industry is emerging from a rough period. After the collapse of the Soviet Union, the industry experienced an initial fall in domestic funding for procurement of at least 80 percent compared with Soviet times.[39] Domestic procurement funding fell sharply again after the 1998 financial crash; it recovered to 1997 levels only in 2007. The part of the former Soviet industry located outside of Russia suffered even deeper declines.

The Russian defense industry survived by cutting salaries, often by not paying wages, and reducing production. Employment fell as workers left for jobs with a higher or steadier paycheck and because the cash-strapped defense industry hired few new workers. Closing plants and consolidating enterprises proceeded much more slowly. Outright layoffs, however, were rare. The industry stayed alive only due to exports.

Today the industry is composed of fewer than 1,500 enterprises, consisting of research institutes, design bureaus, and production facilities, a heritage of Russia's Soviet past.[40] The sector has been partially privatized, primarily through insider privatizations that took place in the 1990s. Roughly two-fifths of the enterprises are mainly private (the state has less than a 25 percent stake) and two-fifths are 100 percent state-owned. The state maintains sizable shares in the rest. These enterprises are often

38. Sukhoi Company, "Sukhoi Superjet 100," www.sukhoi.org.

39. Institute of International Strategic Studies, "Russian Military-Industrial Overview," *Military Balance* (London, various years).

40. Global Security, "Military Industry Overview," www.globalsecurity.org (accessed on January 14, 2010).

only partially independent; most are affiliated with large consortia like the Sukhoi group. Because these enterprises sell almost all their output to these consortia, revenue figures for Russia's largest defense firms provide a lower bound for the final output of Russia's defense industry.

Russia's defense companies are relatively small. The largest, Almaz-Antei Air Defense Concern, had military sales of $4.3 billion in 2008, placing it 16th on a list of the world's largest defense firms. Sukhoi, the next largest company, had revenues less than half those of Almaz-Antei (table 5.4).

The Putin administration made a concerted effort to consolidate the industry by creating large holding companies. The Russian government has continued these efforts under Medvedev. Initially, the government used Russia's state-controlled arms export company, Rosoboroneksport, as the vehicle to consolidate the industry, especially in aerospace. The government also created the United Shipbuilding Corporation by merging a large number of naval shipbuilding companies. OPK Oboronprom, partially owned by Rosoboroneksport, took stakes in a number of helicopter manufacturers to consolidate that industry. At the end of 2007, the government created Russian Technologies and transferred its stakes in 439 firms to this company, including Rosoboroneksport and Oboronprom, almost all of which are in the defense sector. Russian Technologies now accounts for 23 percent of all sales in the defense sector.[41]

Although the industry was overdue for rationalization and has done a poor job of consolidating on its own, this new policy has already had some negative consequences. Russian military analysts complain about large price increases for weapons now that procurement budgets are rising again.[42] A single seller makes it more difficult for the Russian government to negotiate lower prices.

In the immediate aftermath of the collapse of the Soviet Union, Russian arms manufacturers saw exports fall along with domestic procurement. Eastern European clients disappeared along with the Warsaw Pact; Iraq ceased to be a customer because of the embargo; and the superiority of US weaponry to Soviet models during the first Gulf War turned former Soviet customers to arms from other countries. In 1991, exports reportedly fell to $6.6 billion compared with $19.8 billion in 1989. Russian exports continued to fall for most of the 1990s.

During the 2000s, exports have provided a lifeline to Russia's defense industry. Russian arms exports have exceeded procurement expenditures in every single year since 1998 (figure 5.8). In some years, arms exports were more than double domestic spending on procurement.

41. Russian Technologies, www.rostechnologii.ru/company.

42. Viktor Baranets, "Will Russia Buy American Tanks?" *Komsomolskaya Pravda*, April 25, 2007, 7.

Table 5.4 Russian armaments industry, 2008 (millions of US dollars)

Company	Rank	2008 defense revenue	2008 total revenue	Percent of revenue from defense
Almaz-Antei	16	4,335.20	4,616.80	93.9
Aviation Holding Company Sukhoi[a]	40	2,039.20	2,169.40	94.0
Severnaya Verf	n.a.	n.a.	1,895.30	n.a.
Tactical Missiles	55	1,152.60	1,213.30	95.0
Irkut[a]	56	1,149.80	1,255.20	91.6
Russian Helicopters	64	845.10	1,657.10	51.0
Uralvagonzavod	80	646.80	1,848.10	35.0
KB Priborostroyeniya	84	607.00	610.00	99.5
Ufa Engine Building	89	541.00	601.00	90.0
Sevmash	n.a.	n.a.	539.50	n.a.
RTI Systems Concern	99	396.10	471.50	84.0

n.a. = not available

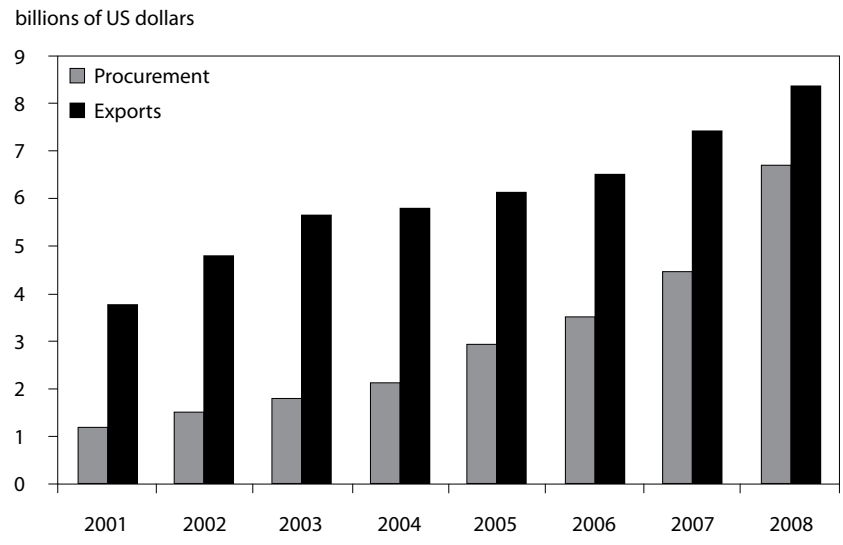
a. Sukhoi and Irkut are subsidiaries of the United Aircraft Corporation (UAC). However, they still report their results independently while UAC has not published its consolidated reports for the last two years.

Sources: Defense News, Top 100 for 2008, 2009, www.defensenews.com (accessed on January 14, 2010); for Severnaya Verf and Sevmash, Expert-400 Ranking of the Largest Russian Companies, available at http://raexpert.org (accessed on January 14, 2010).

Exports have grown rapidly in large part because of India and China. These two countries are Russia's two most important clients, accounting for as much as 70 percent of total sales in recent years. Rapid economic growth in both countries has permitted large increases in defense spending, especially on procurement. Moreover, both countries face difficulties in obtaining modern weapons from other sources: The European Union and the United States have embargoed arms exports to China; India's nuclear program has hindered its ability to import from the United States. In both countries, Russia has been seen as a less politically motivated arms supplier.

India has been a major customer of the Soviet and later Russian defense industry since 1959. In 1993, a new Treaty of Friendship and Cooperation was signed between the two countries, putting their relationship on firmer ground in the post-Soviet era. Part of this agreement was a defense cooperation accord aimed at ensuring continued supply of Russian arms and spare parts for India's military and the promotion of joint production of defense equipment. Since this agreement was signed, Russia has sold a vast array of high-quality military equipment to India. Among the Russian equipment purchased by India are land assault hardware such as T-90 tanks, the Smerch multiple-launch rocket systems (MLRS), long-range howitzers, and infantry vehicles. India has also worked with Russia

Figure 5.8 Russian procurement and exports of weapons, 2001–08



Sources: Procurement: International Institute for Strategic Studies, *The Military Balance*, various years; Exports: Federal Agency for Military-Technical Cooperation, www.fsvts.gov.ru.

on overhauling its diesel submarine fleet and has acquired the BrahMos antiship missile. India has also been a major buyer and joint producer of Russian aviation equipment. Of particular note, the Su-30MKI was specifically designed for India. In 2000 Hindustan Aeronautics Limited (HAL) signed an agreement with Rosoboroneksport for license manufacture of 140 Su-30s. This is in addition to the delivery of 50 of these aircraft purchased directly by Russia.

For its part, China has procured over $15 billion of Russian equipment since 1999, averaging at least $1 billion a year since 1992.[43] Among the systems China has obtained are Su-27 and Su-30 multirole fighters and Il-76 military transport planes. The Chinese navy has acquired Sovremenny class destroyers with Sunburn antiship missiles and Kilo class diesel submarines. The one weapon category Russia has been reluctant to sell to China is land assault hardware. Unlike India, Russia has not sold China tanks or MLRS.

Some attribute part of the rapid development of China's defense industrial base in recent years to its purchases from Russia, which have at times (though not always) come with access to the underlying military technology. Tai Ming Cheung's comprehensive study of the transforma-

43. Vladimir Paramonov and Aleksey Strokov, "Russian-Chinese Relations: Past, Present, and Future" (Defense Academy of the United Kingdom, September 2006).

tion of China's defense technology industrial base (DTIB) concludes that the ability of the DTIB "to learn and absorb already existing technologies and techniques has been significantly enhanced by the acquisition of civilian and foreign, especially Russian, defense technology and industrial hardware and knowledge."[44]

The preponderance of exports in sales of Russian arms manufacturers has begun to shift. On the one hand, rapid growth in defense budgets in Russia is pushing up domestic procurement spending. On the other, growth in arms exports to China and India may be leveling off as those two countries are attempting to replace imports from Russia with domestic production. In 2005 China decided not to import additional Su-30s and also stopped production under license of the Su-27, preferring to manufacture its own model.[45] In India, the Su-30 is being assembled under license, not imported directly from Russia. Russian officials have expressed some concern that Indian and Chinese demand for defense equipment will decline in the next five to ten years. The Chinese government is more interested in developing indigenous defense capabilities, rather than buying foreign equipment. Future purchases may be limited to imported components such as jet engines that will be used in Chinese aircraft.

Russian exports to India are under pressure for different reasons. Russian officials are concerned that India's improving relationship with the United States will lead to a shift in arms purchases from Russia to Western suppliers. The Russian press gave wide coverage to a comment by Nicholas Burns, former US undersecretary of state for political affairs, when he predicted that 2008 would represent a breakthrough for US-India relations, with "US firms well positioned" to compete in the Indian market.[46] The potential for future US-India arms deals is closely tied to the two nations' nuclear cooperation agreement, which will allow India access to US nuclear fuel and reactors.

With Russia's arms exports to China and India unlikely to grow, Russian firms have sought to expand their sales to other markets. In 2006 Russia exported arms or military services to 61 countries, including Venezuela, which signed a series of agreements with Russia for 24 Su-30 fighters, 53 military helicopters, and 100,000 Kalashnikov assault rifles for a total of over $3 billion. Russia and Venezuela have also been exchanging military personnel, such as pilots and technicians, with Russian instructors providing assistance to Venezuelan pilots. Russian defense officials have agreed

44. Tai Ming Cheung, "Leaping Tiger, Hybrid Dragon: The Search for Technological Innovation and Civil-Military Integration in the Chinese Defense Economy" (PhD thesis, Department of War Studies, Kings College, University of London, September 29, 2006).

45. Piotr Butowski, "Drop in Russian Aircraft Sales to Hit Industry Hard," *Jane's Defence Weekly*, July 13, 2005.

46. "Russian weapon makers switch sales tactics with China as Beijing slows arms shopping spree," *International Herald Tribune*, November 28, 2006.

to allow Venezuela to set up a factory capable of producing 50,000 Russian assault rifles annually.

Another region where Russia continues to sell arms is the Middle East. In 2000 President Putin cancelled an agreement with the United States to restrict Russia's arms and nuclear sales to Iran. Since then, Russia has been a major arms supplier to the Iranian military. In 2005 Russia agreed to sell Iran 29 Tor-M1 (SA-15 Gauntlet) surface-to-air defense systems and to upgrade Iran's Su-24 and MiG-29 aircraft. Russia has also had success in exporting arms to Algeria, Syria, the United Arab Emirates, Indonesia, and Yemen.

Future Role of High-Technology Industries

As Russia emerges from recession in 2010 or 2011, drivers of growth are likely to shift. On the one hand, red-hot growth in construction and wholesale and retail trade came to an abrupt end in 2009; output of oil and natural gas has fallen and shows little sign of rapid expansion. World oil prices are also down from their highs of 2008. On the other, the fall in the real effective exchange rate of the ruble has improved the competitive position of manufacturing, including high-technology industries. In addition, continued, if halting, integration of the Russian economy into the global economy has opened up new markets for these and other industries.

The perceptions and aspirations of Russia's current leaders are to a large extent based on previous Soviet technological achievements. Russian leaders worry that the concentration of Russia's exports in energy and raw materials might make it a "raw material appendage" not just to Europe but also to China. They perceive growth in high-technology industries as key to defining Russia's future place in the world economy, with implications for economic growth and national security.

In our view, Russian policy to encourage growth in high-technology industries has not been very effective. Russian policymakers have attempted to foster high-technology industries by consolidating existing manufacturers into large state-controlled agglomerates—"national champions." The creation of these "strategic" enterprises has been most pronounced in armaments, the nuclear industry, and aerospace. The major rationale for consolidation has been to achieve a larger scale (as many of these industries are capital-intensive) so these companies are better placed to invest in developing new products and to compete internationally. The government's desire to avoid competition among domestic high-technology companies has been palpable. Russian policymakers perceive such competition as wasteful as opposed to a force for innovation as it is in the United States. Russian policymakers have also pushed for greater cooperation between state-owned strategic companies and international companies. The Sukhoi Superjet project is an example of such cooperation.

The Russian government has greatly increased budgetary expenditures on high-technology sectors. In addition to larger budgets for aerospace and substantially larger procurement budgets for defense, it has made substantial investments in nanotechnology through Rusnano. It has also created an investment fund for ICT companies and the Russian Venture Company to encourage private investments in high-technology firms. The software industry, which until recently was below the radar of Russian policymakers, finally attracted government support at the end of 2009 in the form of reduced payroll taxes.

Despite the attention these industries have attracted, hopes that high-technology industries will be the main driver of Russian growth seem misplaced. Russia's Ministry of Education and Science report estimates that high-technology industries accounted for 9.8 percent of industrial output in 2008;[47] industry contributed 30.6 percent to Russia's GDP in 2008, suggesting that the share of high-technology industries in Russia's GDP may have run 3 percent of GDP. Software and telecommunications, which are not included in industrial output, would add to this total. Although not negligible, these industries are not of a size to drive aggregate economic growth. What then is the likely contribution of these industries to Russian economic growth in the coming years?

Software and Information Technology Services

The software and IT industry provides a number of lessons for other Russian industries on how to succeed in the global marketplace. The industry

- is closely integrated into the world economy;
- is characterized by substantial inward and outward foreign investment;
- competes with global players without government protection; and
- operates without excessive government regulation or involvement.

The software and IT industry is the healthiest of the five industries assessed in this chapter; it has registered the fastest growth. In contrast to the nuclear, aerospace, and armaments industries, this industry consists entirely of new startups, albeit many of these entrepreneurs were trained and worked in Soviet-era defense laboratories or enterprises. The industry depends heavily on foreign sales, especially to developed-country markets. Not surprisingly, sales dropped in 2009 because of the global downturn. However, the industry is poised to resume growth as the global economy recovers. The large number of companies, the high quality of

47. Ministry of Education and Science of the Russian Federation, *National Innovation System and State Innovation Policy of the Russian Federation*, table 1.5.

the workforce, and a good reputation for innovation and quality make this a vibrant sector that should do well in the coming years. Because of high salaries, it continues to attract and retain a highly trained, ambitious workforce.

As mentioned earlier, the key challenge to continued growth in Russia's software industry is corruption, especially within the Russian police.[48] Threats to corporate officers, including family members, to extract bribes create a precarious working environment. Other problems endemic to Russia are less threatening. Corporate raiders, who use illegal means to take control of Russian companies, have difficulty acquiring software companies because it is tough to seize intangible, as opposed to tangible, assets. Intellectual property rights are not a major impediment to growth.[49] Software companies farm out coding of software to freelancers, who do not have access to the entire product. Companies have been able to prevent product theft successfully.

Nanotechnology

Nanotechnology is difficult to define as an industry. Successful companies in Russia, like NT-MDT, are really manufacturers of scientific equipment. These market niches can be highly profitable. Market leaders need to invest heavily in R&D to maintain their positions. However, demand for scientific apparatus tends to be limited, so although profitable, companies in these industries often do not experience rapid growth in sales.

The amorphous nature of nanotechnology makes it difficult to predict future sales or even the development of the industry. However, Russian manufacturers of specialty materials and scientific equipment will continue to play a role in the global industry. This said, we are skeptical that nanotechnology sales will be so large or will grow so rapidly in the years ahead that they will provide a major boost to Russian growth.

Nuclear Industry

Russia's nuclear industry is well poised to continue to take market share in uranium enrichment. With its superior centrifuge technology and low electric power costs, Russia should do well in this segment of the industry, especially as countries become increasingly concerned about climate change and greenhouse gas emissions and opt for nuclear power. The Russian-US HEU-LEU agreement has helped create a market for Russian fuel. Once ratified by the US Congress, the US-Russia civilian nuclear power agreement, the 123 Agreement, should also be helpful.

48. Keith Crane's interview with CEO of a Russian software company, November 16, 2009.

49. Ibid.

Russia's nuclear industry faces greater challenges in selling new nuclear power plants. Even though it is constructing five plants in other countries, the Chernobyl disaster, competition from Western, Japanese, and Korean manufacturers, and concerns about dependability and safety are likely to hinder its ability to win substantial shares of the global market, especially in developed countries. Developing-country markets, the major area of growth, are likely to be easier, especially if the Russian industry collaborates with Western manufacturers, as it has in Bulgaria.

Aerospace

Space is not a dynamic industry in the global economy. Commercial satellite launches have been fewer than expected as fiber optic cables have satisfied most of the increased demand for communications capacity despite the extraordinary growth of the internet. Most launches are still purchased by governments. The space program in the United States appears to be in a period of retrenchment, and in Europe it also faces budgetary pressures. Although China and India have expanding programs, they tend to favor their own manufacturers. Russia's good track record and budgetary pressures in the United States provide room for continued sales of launches and rockets as demand for observation satellites remains, but the industry does not show signs of dynamic growth. New rocket designs appear to be keeping Russia competitive.

Civilian aviation presents a different story. Within Russia, there is a debate about whether the Russian industry will be able to maintain stand-alone capacity to assemble civilian aircraft or would be better off collaborating with Western manufacturers. Western companies have complimented Russian capabilities in design, precision engineering, especially turbine blades, and sophisticated materials but have difficulty in acquisitions or greenfield investments, in part because of security concerns and high levels of corruption. In our view, despite the concerns of Russia's military establishment, the answer is clear: Russian companies have done well collaborating with the international industry but have failed when they have attempted to go it alone. Russia's successes with joint ventures and the failure of former Soviet products on international markets show the future of the industry.

Armaments

As of 2008, Russia's defense industry was enjoying its best years since Soviet times. Export orders were up. The Russian government had promised to spend 5 trillion rubles ($190 billion) on procurement between 2007 and 2015. Industry sales ran close to $10 billion a year.

Although order books are full, the outlook is less rosy. The industry faces a number of challenges. The most important problems are techno-

logical, financial, and management-related. As noted earlier, Russia's defense companies are relatively small. European manufacturers like BAE Systems, Finmeccanica, EADS, and Thales had sales more than twice those of Russia's largest defense contractor, Almaz-Antei. US companies are even larger. These Western companies have the wherewithal and the client base to invest heavily in new technologies. They purchase components and designs from each other, stimulating technological change. They have experience in large projects involving integration of systems. They also face pressures from shareholders to increase profits by reducing costs and expanding sales.

Russian defense enterprises face competitive pressures to sell more and cut costs but lack the funding to keep pace with R&D in Western Europe and the United States. They have relied on existing technologies for most of their production for close to 20 years. R&D had been a small fraction of Soviet efforts. Russian companies are also financially weak: About a third are at risk of bankruptcy. Because of the lack of resources for the past two decades, the capital stock and workforce of the defense industry are aged: Seventy percent of its production assets are fully depreciated, and the average age of the workforce is over 55 in a country where male life expectancy hovers around 60 years. The three-quarters state-owned, one-quarter private ownership structure for the new defense holding companies does not promise improvements in efficiency. Whereas Russia's private companies have performed well even compared with established multinationals, its state-controlled companies have not. Companies like Gazprom are overstaffed, sluggish, and inefficient.

Russia's defense industry will increasingly suffer from the virtual hiatus in the development of new weapons systems during the 1990s. It will also suffer from the heavy hand of the state in enterprise management and reduced domestic competition. More importantly, unless Russia's defense industry interacts more closely with European and US manufacturers, the gap between most Russian technologies and those being developed by Western manufacturers will continue to widen. The efficiencies and technological benefits that Western companies enjoy from trade and exchanges of technologies, even in the face of export controls and other limitations, will give Western manufacturers a continued technological edge over their Russian competitors.

Conclusion

High-technology sectors of the Russian economy contributed roughly 3 percent to Russia's GDP in 2008 and, broadly defined, accounted for roughly 10 percent of industrial output. Growth in these sectors would provide tangible benefits to Russia, leading to increased high-wage employment and nonenergy exports and development of supplier industries.

This said, growth in high-technology sectors will not drive growth in aggregate output. The economic drivers of the past decade will remain the more important drivers of growth: rising productivity across all sectors; growth in services, especially financial and business services; retail and wholesale trade; telecommunications; and government expenditures financed by taxes on exported energy.

We find that those companies or sectors that are most integrated with and most open to the global economy have the most favorable outlooks. Russia has shown it has a comparative advantage in software, especially programming of more complex software. It has an established set of home-grown software companies, which are closely integrated into the global industry. In addition, Russia has dominant firms in markets for scanning probe microscopes (nanotechnology) and uranium enrichment, where Russian technology is at the forefront.

The record of the past two decades indicates that future success in these sectors will depend on increased integration into the global, especially European, economy. In aerospace, sales of rockets, aircraft components, aircraft design services, and the new Sukhoi Superjet have depended on collaborating with foreign manufacturers. Prospects for Russia's armaments companies are dimmer because they remain much more insular than firms in other sectors.

Despite concerns voiced by many Russians about the quality of the Russian education system, more people are graduating with university degrees than in the past, many with degrees in engineering and the sciences. Our interlocutors from Russian and foreign high-technology companies active in Russia praised the quality of new and existing Russian staff engaged in R&D. Russia's human capital is improving.

The Russian government's policy of consolidating enterprises into state champions does not appear to have been successful. In the case of the defense industry, where it has been pursued most aggressively, consolidation appears to have chiefly resulted in higher prices of weapons for the Ministry of Defense. These agglomerates do not appear to have aggressively rationalized their holdings. In some instances, the mergers may have provided a lifeline to failing plants, covering their losses with profits from more efficient factories.

The biggest impediment to growth of Russia's high-technology sectors is the pervasive corruption in tax collection and law enforcement. Threats of physical violence and incarceration by the Russian police discourage investment and provide compelling reasons for Russian entrepreneurs to invest abroad. Cleaning up the tax administration and police force by holding senior officials accountable and firing corrupt staff is the single most important near-term policy measure that the Russian government should undertake to foster this sector. In the long term, successful prosecution and incarceration of corrupt security services officials would significantly benefit this and other private-sector industries in Russia.