IV. The arms industry facing rising demand

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The global arms industry is experiencing an increase in demand. This can be attributed primarily to the Russia–Ukraine war and is true in particular for the two parties to the conflict. However, to a significant extent it is also due to the consequent assessment by many other countries in Europe that they need to replenish and modernize their military equipment. The rising demand is reflected in the development in military spending throughout Europe—with 39 of the 43 European countries increasing their expenditure in 2023 (see sections I and II of this chapter)—and in the increase in imports of major weapons by European states (see chapter 6).[1]

An issue widely discussed in this regard is how the arms industry can meet the increased demand. The fact that the total arms revenue of the SIPRI Top 100 arms-producing and military services companies declined in 2022 (see section III) highlights the often lengthy time lag between the initial demand for weapons and the subsequent scaling up of production and delivery by arms companies. These delays have been exacerbated by severe capacity constraints. Thus, while the full-scale invasion of Ukraine in February 2022 prompted several European governments to announce large-scale procurement plans, the effect on arms revenue in 2022 remained limited.

This section explores the response to date of the arms industry to this increased demand. It begins with an overview of the difficulties in ramping up—that is, suddenly and sharply increasing—arms production. It then looks in turn at how these difficulties have been manifested in Western efforts to supply Ukraine with 155-millimetre artillery ammunition and in Russia's arms production under sanctions. The section then illustrates the different experiences of arms industries in other parts of the world, using the examples of the Republic of Korea (South Korea) and Türkiye, before drawing brief conclusions.

Ramping up arms production efforts in the West

Increasing arms production generally takes time and is costly.[2] Building new production capacity is a major endeavour that can take a long time and requires substantial investments, such as for establishing new factories,

[1] On other aspects of the Russia–Ukraine war see chapter 1, chapter 2, section I, chapter 6, section I, chapter 10, sections II and III, and chapter 12, section II, in this volume.

[2] Cranny-Evas, S., 'Ramping up: What will it take to boost the UK's magazine depth', Royal United Services Institute (RUSI), 6 Dec. 2022; and Gould, J., 'Pentagon, industry wrestle with how to boost weapons production for Ukraine', *Defense News*, 19 Apr. 2022.

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buying the required machinery and hiring and training additional workers.[3] It can be faster to expand production through increased utilization of existing facilities, whether through increasing the workforce and adding work shifts or by improving efficiency through automation. However, this still takes time and resources and may be hindered by constraints in the supply chain, reinforced by high reliance on international supply chains.

In 2022 many arms companies in Europe and the United States were still grappling with the enduring impact of the Covid-19 pandemic, which hindered efforts to accelerate the pace of production to meet increased demand. For example, Lockheed Martin attributed lower arms revenue to ongoing pandemic-related supply chain disruptions and labour shortages.[4] Dassault Aviation reported that the effects of Russia's invasion of Ukraine on, for example, access to raw materials and inflation had worsened existing supply chain problems.[5]

Another explanation for the difficulties in expanding output is the limitation of the lean production approach that is common in modern manufacturing. This approach relies on low inventory and the just-in-time delivery of parts and components directly from suppliers to the prime contractor at the time and in the quantity needed. This reduces costs, especially for storage, and increases the reliability of supplied components.[6] However, it also creates a strong dependence on the pace of supply chain delivery, which is a major constraint in meeting a sudden and rapid rise in demand. Efforts to ramp up production can entail increasing the stockpiles of required parts and components, which is a lengthy and costly process, not least in terms of warehousing.[7] Arms companies have been reluctant to make the financial investment needed for new facilities or to augment capacity of existing plants without firm commitments from governments that the high demand would be sustained beyond the war in Ukraine.[8] These constraints and challenges

[3] Cook, C., 'Reviving the arsenal of democracy: Steps for surging defense industrial capacity', Center for Strategic and International Studies (CSIS), Mar. 2023; and Aries, H., Giegerich, B. and Lawrenson, T., 'The guns of Europe: Defence-industrial challenges in a time of war', *Survival*, vol. 65, no. 3 (June–July 2023).

[4] Lockheed Martin Corporation, *2022 Annual Report* (Lockheed Martin: Bethesda, MD, 2023), p. 16.

[5] Dassault Aviation, *Annual Report 2022* (Dassault: Paris, Mar. 2023), p. 2.

[6] Singh, G. and Ahuja, I. S., 'Just-in-time manufacturing: Literature review and directions', *International Journal of Business Continuity and Risk Management*, vol. 3, no. 1 (Jan. 2012); and Baluch, A. and Bottorff, C., 'What is just in time inventory (JIT)?', *Forbes*, 12 May 2023.

[7] Cook, C. and Aldisert, A., 'Don't blame "just-in-time" production for challenges in US manufacturing industrial base', Center for Strategic and International Studies (CSIS), 19 July 2023; and Chávez, S., 'Munitions put into focus as stockpiles dwindle', *Financial Times*, 19 July 2023.

[8] Mille, R., 'Boom in the woods: Inside a munitions group's fight to boost production', *Financial Times*, 25 Aug. 2023; and Martin, T., 'Nammo warns ammo industry could "break their neck" without longer production contracts', Breaking Defense, 10 Oct. 2023.

have led to emerging calls for reshaping, or abandoning, just-in-time inventory management in the arms industry.[9]

This explains why the growth in global demand for arms, while not yet reflected in revenue in 2022, was more visible in companies' orders and backlogs, which are likely to correspond to future revenue. Some companies whose arms revenue declined in 2022 expect substantial growth in the short and medium terms based on their orders during the year. For example, Saab (with US$3.7 billion in arms revenue) reported having taken orders totalling $6.2 billion in 2022—up by 35 per cent on the previous year.[10] The company also had a record backlog of $12.6 billion (including a small proportion of non-military products) in 2022, of which $4.0 billion was expected to be realized as revenue within one year. According to one survey, the order backlogs of 15 major arms companies, including Northrop Grumman, BAE Systems and Hanwha Aerospace, had increased from $701 billion in 2020 to $778 billion at the end of 2022.[11]

In contrast to their European and US counterparts, many Top 100 companies in Asia and the Middle East were able to translate higher demand in 2022 directly into increased revenue. Israel's Rafael, Türkiye's Baykar and South Korea's Hyundai Rotem all reported growth in their arms revenue and benefited from increased orders from Europe driven by the Russia–Ukraine war. Companies based in Israel and South Korea often possess more flexible manufacturing capacity than companies in other countries and can scale up production more rapidly to fulfil a sudden increase in orders.[12] Some Asian and Middle Eastern companies are also supported by governments with long-term goals of increasing self-reliance and indigenization in arms production, such as those in China, India and Türkiye.[13]

[9] Wall, R., 'Defence production: Is just-in-time just too late?', *Military Balance* Blog, International Institute for Strategic Studies (IISS), 9 June 2023; Vergun, D., 'Official says just-in-time deliveries fail in high-end competition', US Department of Defense, 16 Mar. 2023; and Phogat, S., 'The trouble with JIT in military operations: A review', *International Journal of Latest Research in Science and Technology*, vol. 2, no. 6 (Nov.–Dec. 2013).

[10] Saab, 'Year-end report 2022: Strong order intake and delivering on our outlook', Press release, 10 Feb. 2023. Saab generated almost 90% of its revenue from military sales.

[11] Pfeifer, S. and Sugiura, E., 'Global defence orders surge as geopolitical tensions mount', *Financial Times*, 27 Dec. 2023.

[12] Arthur, G., 'How South Korea's defense industry transformed itself into a global player', Breaking Defense, 6 Dec. 2023; and Bogaisky, J., 'South Korea has quietly become one of the world's biggest weapons suppliers' *Forbes*, 7 Nov. 2022.

[13] Béraud-Sudreau, L. et al., *Arms Production Capabilities in the Indo-Pacific Region: Measuring Self-reliance* (SIPRI: Stockholm, Oct. 2022); and Indian Ministry of Defence, 'Self reliance in defence sector', Press release, 19 Dec. 2022.

Responding to Ukraine's urgent needs for 155-millimetre ammunition

US and European arms companies' difficulties in ramping up arms production have been particularly visible in the case of 155-mm artillery shells.[14] This category of ammunition is fired by artillery (e.g. howitzers), which has become one of the most used types of weaponry in Ukraine.[15] Since the Russian invasion Western suppliers have provided Ukraine with artillery systems that use 155-mm ammunition—a standard calibre for the North Atlantic Treaty Organization (NATO)—thereby making it less reliant on Soviet-era standard 152-mm ammunition. Ukraine's demand for 155-mm ammunition has accordingly surged and has become a major focus of its Western suppliers.[16]

Ukraine's demand was initially met with ammunition supplies from existing US and European stocks.[17] This was followed by orders by the supplier states for new production, both for delivery to Ukraine and to replenish their own stocks. Estimates of Ukraine's requirements for 155-mm ammunition vary in open sources and differ over time. In April 2023 Ukrainian officials estimated that Ukraine was firing 6000–8000 rounds of 155-mm artillery shells a day.[18] Extrapolated, this would suggest a requirement of 180 000–240 000 rounds per month and 2–3 million each year. In early 2022 the total production capacity of the United States, the United Kingdom, Norway and the member states of the European Union (EU) stood at about 350 000 per year—less than 20 per cent of Ukraine's projected annual requirements as of April 2023.[19]

The drawdown of stocks thus depleted Western arsenals at a higher rate than industry could replenish them. For example, by December 2023 the USA had provided Ukraine with about 2 million 155-mm ammunition rounds

[14] Ryan, M., Horton, A. and DeYoung, K., 'As Ukraine flies through artillery rounds, US races to keep up', *Washington Post*, 21 Aug. 2023; and Clapp, S. and Przetacznik, J., 'Question time: State of play—Ammunition plan for Ukraine', European Parliamentary Research Service, Nov. 2023.

[15] Copp, T., 'Why the 155 mm round is so critical to the war in Ukraine', AP, 23 Apr. 2023.

[16] Copp (note 15); Warrick, T. S., 'Jets and rockets are important, but Ukraine also needs faster munitions deliveries', Atlantic Council, 29 Sep. 2023; and Saw, D., 'The 155 mm artillery marketplace evolves', European Security & Defence, 27 Mar. 2023.

[17] Lendon, B. et al., 'Western ammo stocks at "bottom of the barrel" as Ukraine war drags on, NATO official warns', CNN, 4 Oct. 2023.

[18] Levy, M., 'Unprepared for long war, US Army under gun to make more ammo', AP, 23 Apr. 2023; Martin (note 8); and Hall, B., '"Bottom of barrel": Ukraine's counteroffensive at risk from US aid delays', *Financial Times*, 12 Oct. 2023.

[19] Davis, M. T., 'American industrial mobilization: We're now learning what we already knew', RealClear Defense, 22 Sep. 2022; Clapp, S., 'Act in support of ammunition production (ASAP)', European Parliament Research Service, 4 Sep. 2023; and 'Rheinmetall: Ammunition shortage keeps orders rolling in', *Financial Times*, 10 Aug. 2023.

and as of May 2023 it had reportedly given Ukraine more 155-mm rounds than it had procured in the past 10 years.[20]

This discrepancy between arms companies' capacity to produce 155-mm ammunition and Ukraine's needs can be explained by the fact that munitions are not in high demand during peacetime or for the types of military operation conducted by Western countries since the end of the cold war (e.g. expeditionary warfare). The USA had assumed that major conflict would no longer involve much artillery requiring 155-mm ammunition.[21] Since recent conflicts involving Western states have mostly been asymmetric conflicts in Afghanistan, the Middle East and sub-Saharan Africa that mainly used precision-strike capabilities, the industrial capacity was tailored accordingly.[22] During peacetime, ammunition is mainly needed for training purposes. Because munitions are costly to store and their shelf life is limited, companies worked with low production volumes and long lead times.[23] In France, the time lag between orders and deliveries of 155-mm shells ranged between 10 and 20 months.[24]

By the end of 2023, almost two years since Russia's full-scale invasion of Ukraine, arms manufacturers and governments had undertaken several measures to adjust the production of 155-mm ammunition to more closely meet the consumption rate required. These are outlined below.

The United States response

The US government has introduced several measures to increase the production of 155-mm ammunition for Ukraine. Most US production of 155-mm rounds takes place in government-owned, contractor-operated facilities.[25] In 2023 the US Army started building new plants and assembly lines, purchased new equipment, and invested in automation.[26] In addition, it assigned ammunition contracts to non-US manufacturers, including deals with Bulgaria and

[20] US Department of State, Bureau of Political-Military Affairs, 'US security cooperation with Ukraine', Fact sheet, 27 Dec. 2023; and Pettyjohn, S. and Dennis, H., *Production is Deterrence: Investing in Precision-guided Weapons to Meet Peer Challengers* (Center for New American Security: Washington, DC, 28 June 2023), p. 18.

[21] US Marine Corps, *Force Design 2030* (US Department of the Navy: Washington, DC, Mar. 2020), p. 3; and Lynn, S. M., 'Learning not to kick with our Achilles heel: The case against a counterinsurgency-focused military', *Journal of Public and International Affairs*, vol. 21 (spring 2010), pp. 77–78.

[22] Ismay, J. and Lipton E., 'Pentagon will increase artillery production sixfold for Ukraine', *New York Times*, 24 Jan. 2023.

[23] Taylor, T., 'Implications of the Ukraine war for US munitions supply management', Royal United Services Institute (RUSI), 19 Apr. 2023; and Cancian, M. F., 'Rebuilding US inventories: Six critical systems', Center for Strategic and International Studies (CSIS), 9 Jan. 2023.

[24] French National Assembly, National Defence and Armed Forces Committee, 'Rapport d'information sur les stocks de munitions' [Report on ammunition stocks], 15 Feb. 2023, p. 57.

[25] Pettyjohn and Dennis (note 20).

[26] Hurd, C., 'Strengthened army industrial base doubles artillery production', US Army News Service, 14 Nov. 2023.

South Korea for the supply of 155-mm ammunition directly to Ukraine.[27] It also awarded production contracts to non-US firms—Nitro-Chem of Poland, Solar Industries India and IMT Defence of Canada—as a means to boost global 155-mm shell production capacity.[28]

For the longer term, the US government has waived certain procurement requirements and authorized multi-year contracting for ammunition to incentivize industry to expand capacity without fear of being left with excess capacity when the war is over.[29] The US Department of Defense (DOD) has also established a Joint Production Accelerator Cell to help capability to surge and to overcome supply chain and manufacturing limitations for key weapon systems and supplies, including 155-mm ammunition.[30]

As a result of these efforts, US production of 155-mm ammunition had doubled to 28 000 rounds per month by November 2023, with the aim being to reach 60 000 per month by mid 2024 and 100 000 per month by 2025.[31] Under the assumption that this entire production is going to Ukraine and not being partly diverted to replenish US stockpiles, this would still supply only about 40–55 per cent of the estimated requirements for Ukraine. As such, additional support is required from European and other ammunition-producing countries (such as South Korea, as discussed below).

US longer-term efforts to overcome the challenges of a rapid expansion of arms production, including for ammunition, are reflected in its first full-scale national defence-industrial strategy, which was drafted in 2023 and released in January 2024.[32] With the long-term goal of creating a 'more diverse, dynamic, and resilient modern defense industrial ecosystem', it focuses on four key areas: resilient supply chains, workforce readiness, flexible acquisition and economic deterrence.[33] Priorities for addressing supply chain challenges include increasing stockpiles of critical systems, diversifying

[27] Schwartz, F. and Miller, C., 'US faces hurdles in ramping up munitions supplies for Ukraine war effort', *Financial Times*, 1 Aug. 2023.

[28] Judson, J., 'US Army awards $1.5B to boost global production of artillery rounds', *Defense News*, 6 Oct. 2023.

[29] Cancian (note 23); Harris B., 'Congress supersizes munitions production with emergency authorities', *Defense News*, 13 Dec. 2022; and Roque, A., 'House, Senate defense authorizers agree to multi-year munitions buys', Breaking Defense, 7 Dec. 2022.

[30] LaPlante, W. A., US under secretary of defense for acquisition and sustainment, 'Establishment of the Joint Production Accelerator Cell', Memorandum, US Department of Defense, 10 Mar. 2023; and Weisgerber, M., 'Pentagon creates cell to oversee expansion of weapon production lines', Defense One, 15 Mar. 2023.

[31] Hurd (note 26); and Judson (note 28).

[32] US Department of Defense (DOD), *National Defense Industrial Strategy* (DOD: Washington, DC, 16 Nov. 2023).

[33] US Department of Defense (note 32), pp. 8, 10.

the defence-industrial supplier base, expanding production methods and addressing cyber threats to the supply chain.[34]

Central and West European responses

The EU, Norway and the UK have all made efforts to meet Ukraine's needs for 155-mm ammunitions.

On 20 March 2023 the Council of the EU agreed to jointly procure and deliver 1 million rounds of 155-mm artillery to Ukraine before March 2024, and to expand the EU's annual production capacity to 1 million from then onwards.[35] The plan had three tracks. The first track aimed to support urgent deliveries to Ukraine. This led to an additional €1 billion ($1.1 billion) being added to the European Peace Facility (EPF) to reimburse states for their donations of military equipment to Ukraine.[36] For the second track, either a member state or the European Defence Agency (EDA) would lead the joint procurement of 155-mm artillery rounds for delivery to Ukraine.[37] Reimbursement of the costs of any contracts under this two-year fast-track procedure would be made via the EPF.[38] A third track, to be implemented by the European Commission, aims at increasing future production capacity in Europe. This is to be facilitated by the Act on Supporting Ammunition Production (ASAP), adopted in July 2023.[39]

The key measure of the ASAP regulation is to allocate €500 million ($540 million) in 2023–25 to finance an expansion of arms company capacity to manufacture both 155-mm ammunition and missiles.[40] Activities eligible for support include the improvement or upgrading of existing production facilities or the establishment of new capacity; 'the establishment of cross-border industrial partnerships'; and 'the building-up and making available of reserved surge manufacturing capacities of relevant defence products'.[41]

Despite the relatively rapid adoption by the EU of these new instruments, the tight timescale and physical constraints made the goal of 1 million rounds by March 2024 ambitious. Already in April 2023 it was estimated that there

[34] Vergun, D., 'DOD aims to publish 1st national defense industrial strategy', US Department of Defense, 20 Oct. 2023; and Clark, J., 'DOD releases first defense industrial strategy', US Department of Defense, 12 Jan. 2024.

[35] Council of the European Union, General Secretariat, 'Delivery and joint procurement of ammunition for Ukraine', 7632/23, 20 Mar. 2023.

[36] Council of the European Union, 'Ukraine: Council agrees on further support under the European Peace Facility', Press release, 17 Oct. 2022. On the EPF see also chapter 12, section IV, in this volume.

[37] European Defence Agency (EDA), 'Collaborative procurement of ammunition: Frequently asked questions (FAQ)', 30 June 2023.

[38] European Defence Agency (EDA), 'EDA brings together EU countries and Norway for joint procurement of ammunition', 20 Mar. 2023.

[39] Regulation (EU) 2023/1525 of the European Parliament and of the Council of 20 July 2023 on supporting ammunition production (ASAP), *Official Journal of the European Union*, L 185, 24 July 2023.

[40] European Commission, 'Defence: €500 million and new measures to urgently boost EU defence industry capacities in ammunition production', Press release, 3 May 2023.

[41] Regulation (EU) 2023/1525 (note 39), Article 8(3).

could be a lead time of 1–3 years for the supply of artillery shells under the initiative.[42]

As of August 2023 the UK had delivered around 300 000 artillery shells to Ukraine.[43] To continue this supply and also to replenish the UK's own stocks, in September 2023 the British government expanded its original £280 million ($340 million) contract with BAE Systems to £410 million ($500 million) to build additional facilities for manufacturing 155-mm ammunition.[44] Under the new contract, it expects to significantly increase the production of 155-mm artillery shells and 30-mm and 5.56-mm ammunition.

The Norwegian government has also provided financial support to increase Norway's arms-production capacity, mainly through co-financing of ASAP projects for acquisition of artillery ammunition from Nammo.[45]

The Ukrainian arms industry's adjustment to war requirements

In an effort to adapt its arms industry to war requirements, in June 2023 the Ukrainian government transformed its large national arms-producing conglomerate from a state concern, known as UkrOboronProm, into a joint-stock company, Ukrainian Defense Industry (UDI).[46] The main reasons given by the Ukrainian government for the transition were to expand the production capacity for ammunition and a range of military equipment including armoured vehicles and rocket launchers; to continue structural reforms; and to address corruption.[47] While remaining in state ownership, the new structure will open the company to investors.[48]

By June 2023, UkrOboronProm had the capacity to produce 122-mm ammunition and 152-mm ammunition and was developing capacity to manufacture its own 155-mm ammunition.[49] In addition, it has increased

[42] Armament Industry European Research Group (ARES), *War in Ukraine: How to Gear up European Defence and Propel the European Defence and Technological Industrial Base?*, Seminar report (ARES: Brussels, May 2023).

[43] British Ministry of Defence, 'Defence Secretary pledges tens of thousands of more artillery shells for Ukraine', Press release, 19 Sep. 2023.

[44] McNeil, H., 'BAE Systems secures boost as UK MOD expands munitions contract to £410m', Army Technology, 18 Sep. 2023.

[45] Norwegian Government, 'Norway allocates two billion Norwegian kroner to increase production capacity of ammunition', 17 Jan. 2024; and Norwegian Government, 'The Norwegian government will increase the production capacity of ammunition and missiles with one billion Norwegian kroner (NOK)', 13 Dec. 2023.

[46] Ukrainian Government, 'UkrOboronProm will be transformed into the Ukrainian Defence Industry Joint Stock Company, says Denys Shmyhal', 21 Mar. 2023; and Ponomarenko, I., 'Ukraine's state defense conglomerate UkrOboronProm transformed into stock company', *Kyiv Independent*, 29 Mar. 2023.

[47] Shandra, A., 'Goodbye UkrOboronProm, hello Ukrainian Defense Industry', Euromaidan Press, 2 July 2023.

[48] UkrOboronProm, [About the reform], [n.d.] (in Ukrainian).

[49] 'UkrOboronProm to set up production of NATO-type 155mm artillery rounds', Army Recognition, 8 June 2023; and Helfrich, E., 'Ukraine's locally produced artillery shells have reached the front', War Zone, 3 Jan. 2023.

international collaboration, exemplified by the establishment of joint ventures between several European companies and Ukrainian firms. For instance, in October 2023 Rheinmetall and UDI created a joint venture, initially for the maintenance of military vehicles and then for joint production in Ukraine of some Rheinmetall products, including 155-mm artillery ammunition.[50] UDI has developed similar arrangements with BAE Systems.[51] The US government has also stepped-up efforts to support the Ukrainian arms industry through joint production of weapons, specifically air defence systems.[52]

Russian arms production under sanctions

Unsurprisingly, the 2022 invasion of Ukraine has had consequences for Russian arms production. The main post-February 2022 trend in Russian arms production has been that, while output quantity has generally either stayed the same or increased, much of it is refurbished and modernized war stocks, rather than new production.[53] As well as having to adjust their supply chains in response to sanctions, many arms companies have been struggling with hiring new workers to keep up with contracts for new equipment and for repairs of equipment returning from Ukraine.[54]

Labour shortages have particularly complicated Russia's ability to increase production.[55] For the entire Russian arms industry, the deputy prime minister, Yuri Borisov, estimated in mid 2022 the shortage to be around 400 000 workers, with an especially strong lack of qualified workers such as machine operators.[56]

[50] Fiorenza, N., 'Ukraine conflict: Rheinmetall and Ukrainian Defense Industry form joint venture', Janes, 26 Oct. 2023; and Rheinmetall, 'Joint venture with Ukrainian partner: Rheinmetall to produce artillery ammunition in Ukraine', Press release, 19 Feb. 2024.

[51] 'Ukraine says it's working with BAE to set up weapons production facility', Reuters, 30 May 2023.

[52] Gill, J., 'Pentagon "beginning to pivot" to rebuilding Ukraine's industrial base: LaPlante', Breaking Defense, 25 Oct. 2023; and Harmash, O., 'Ukraine to launch joint weapons production with US, Zelenskiy says', Reuters, 22 Sep. 2023.

[53] Watling, J. and Reynolds, N., 'Russian military objectives and capacity in Ukraine through 2024', Royal United Services Institute (RUSI), 13 Feb. 2024; Bergman, M. and Dolbaia T., 'Russia is gearing up for a long war: Will the West follow suit?, *Defense News*, 4 Dec 2023; and Levichev, D. Y., [How many and which kinds of tanks, infantry fighting vehicles and armoured personnel carriers were produced in Russia in 2021, 2022 and 2023], Dzen, 2 May 2023 (in Russian).

[54] [Personnel shortage in the defence industry assessed], Lenta.ru, 24 July 2023 (in Russian); and Sidorkova, I., [Defence companies identify the main difficulties due to new sanctions], RBC, 30 May 2022 (in Russian).

[55] Starchak, M., 'Russia's maxed-out arms makers face labor, tech shortages', *Defense News*, 22 Feb. 2024; Kozlov, A. and Grinkevich, D., [Staff shortage and local unemployment: What is in store for the labour market in 2023], *Vedomosti*, 18 Jan. 2023 (in Russian); and [Russia's military plants face shortage of 20,000 workers amid war in Ukraine], *Moscow Times*, 25 Nov. 2022 (in Russian).

[56] [Borisov: Personnel shortage at defence industry enterprises in the Russian Federation will be about 400 000 people], TASS, 29 June 2022 (in Russian); and Shukaeva, E., ['They hardly see him at home': Ekaterinburg is short of labourers], Radio Svoboda, 23 Oct. 2023 (in Russian).

The surge in demand for labour in Russia's arms industry has broader societal repercussions. With the allure of higher wages and an exemption from military service, workers are moving en masse from civilian industries to the arms industry.[57] The result has been labour shortages in civilian sectors such as information technology (IT), mining and transportation.[58] Despite more workers moving to arms companies and most factories switching to an around-the-clock schedule, arms companies remain understaffed and most are not operating at full capacity.[59]

Russia's ability to produce new and especially high-technology systems, such as combat aircraft, has also been limited by the trade restrictions and other sanctions measures imposed by the USA, the EU and other like-minded states.[60] However, the Russian arms industry has managed to adapt to the sanctions system relatively well, with the import of certain goods such as semiconductors continuing in 2022.[61] The restrictions on transfers of arms and dual-use items to Russia have only been adopted by 39 states, and companies in some of those countries are still able to supply parts and components to Russia.[62] In addition, many companies in other countries have been accused of acquiring sanctioned goods and technologies in the 39 countries that have adopted trade restrictions and then re-exporting them to Russia.[63]

The restricted access to high-tech components is a particular obstacle to production output. While access to advanced technology and controlled items was still possible in 2023, albeit through different trade routes than prior to the war, Russian firms were often forced to rely on less advanced and

[57] Khlebov, D., [The labor market crisis is turning Russia into a country of working poor], Eurasianet, 31 Mar. 2023 (in Russian); Stognei, A. and Ivanova, P., 'Russia's war economy leaves businesses starved of labour', *Financial Times*, 9 Nov. 2023; and Roth, A., 'A lot higher than we expected: Russian arms production worries Europe's war planners', *The Guardian*, 15 Feb. 2024.

[58] Shukaeva (note 56).

[59] Luzin, P., 'Western sanctions and personnel shortages plague Russia's aircraft industry', *Eurasia Daily Monitor*, 8 Sep. 2023; Luzin, P., 'Russia's defense industry growing increasingly turbulent', *Eurasia Daily Monitor*, 17 Nov. 2022; and 'Russia defense industrial companies to adopt a 12-hour working schedule', Defense Express, 21 Dec. 2022.

[60] Sytas, A., 'Sanctions hamper Russia's ability to make advanced weapons, NATO says', Reuters, 17 Sep. 2022; US Department of State, 'Responding to two years of Russia's full-scale war on Ukraine and Navalny's death', 23 Feb. 2024; and Lyngaas, R., 'Sanctions and Russia's war: Limiting Putin's capabilities', US Department of the Treasury, 14 Dec. 2023.

[61] Gilchrist, K., 'How US microchips are fueling Russia's military—Despite sanctions', CNBC, 7 Aug. 2023. On the content of the trade restrictions and circumvention efforts see also chapter 12, section II, in this volume.

[62] Bienkowski, S. et al., *Effectiveness of US Sanctions Targeting Russian Companies and Individuals* (Free Russia Foundation: Washington, DC, Jan. 2023), pp. 46–61.

[63] Moller-Nielsen, T., 'EU sanctions on Russia "massively circumvented" via third countries, study finds', Euractiv, 26 Feb. 2024; and Ruffino, G., 'Turkey faces scrutiny as exports to Russia surge, fueling concerns of sanctions evasion', Euronews, 27 Nov. 2023.

often Chinese-made alternatives.[64] A report that assessed Russian companies whose products were identified in Russian weapons found that roughly three-quarters of the shipments to these companies were imported through China as an intermediary, compared to 22 per cent pre-2022.[65] Moreover, Russia could still obtain US components: according to a separate study on the flow of US-made semiconductors into Russia, 75 per cent of these chips that came into Russia during 2022 were shipped from China and through small- or medium-sized companies set up after the full-scale invasion of Ukraine.[66] By evading sanctions through countries such countries as China and Türkiye, Russia increased the value of imports from $1.8 billion in 2021 to $2.4 billion in 2022 as well as the number of transactions.[67]

In other cases, Russia has been forced to rely on stockpiles of older equipment that it can repurpose for use in its current systems. One example is optical systems. Until the late 2010s, Russia relied heavily on French arms producers, such as Thales, for its high-end sights; it has subsequently been forced to rely on either scavenged optics from older vehicles or less sophisticated alternatives.[68]

In addition to a shortage of weapon system components, Russia has also faced a shortage of the components of the machines that make the weapons. Examples include bearings and machine tools that have historically been imported from Western manufacturers.[69] From 2014 Russia tried to diversify away from Western manufacturers of these components, but with little success.[70] Since 2022 it has had to rely entirely on domestic producers via import-substitution initiatives and on imports from countries such as China.[71] The sudden and forced shift from Western producers to Chinese-made parts has raised concerns from sector experts and analysts about the

[64] Fabino, A., 'Russia dramatically increased weapons production in 2023 despite sanctions', *Newsweek*, 1 Jan. 2024; and Williams, M. and O'Donnell, J., 'Ukraine says it is finding more Chinese components in Russian weapons', Reuters, 17 Apr. 2023.

[65] Bilousova, O. et al., International Working Group on Russian Sanctions, 'Strengthening sanctions to stop Western technology from helping Russia's military industrial complex', Working Group Paper no. 12, 3 July 2023, pp. 20–21.

[66] 'Special report: How US-made chips are flowing into Russia', Nikkei Asia, 12 Apr. 2023.

[67] Bienkowski, S. et al., *Effectiveness of US Sanctions Targeting Russian Companies and Individuals* (Free Russia Foundation: Washington, DC, Jan. 2023).

[68] European Parliament, 'French shipments of military equipment to Russia despite EU embargo and the violation of rule of law principles', Priority question to the Commission for written answer P-001087/2022, 16 Mar. 2022; AFP, 'France's Thales accused of selling to Russia despite sanctions, denied by company', Barron's, 22 Apr. 2022; and Bergmann, M. et al., *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry* (Center for Strategic and International Studies: Washington, DC, Apr. 2023), p. 13.

[69] Aris, B., 'Russia's sanctions soft underbelly: Precision machine tools', Intellinews, 13 June 2021; and [Sanctions and the development of the machine tool industry in Russia], PanorHub.ru, 23 Nov. 2022 (in Russian).

[70] Bergmann et al. (note 68), p. 14.

[71] Luzin, P., 'Chinese machine tools serve as Russia's safety net', *Eurasia Daily Monitor*, 22 Jan. 2024.

compatibility of these parts within the production process, which could have an impact on the quality and reliability of the equipment produced.[72]

Parts of the Russian arms industry are less affected by Western sanctions. According to Russian officials, the production of basic ammunition has increased 12-fold when compared to 2021.[73] Similarly, Russia is estimated to have doubled the production of artillery shells.[74] According to open-source data, production of the advanced T-90M main battle tank increased by 54 per cent from around 26 tanks in 2021 to at least 40 between February 2022 and March 2023.[75] Another example is the production of hypersonic missiles, which has increased compared to pre-war production according to the head of Rostec, a Russian state-owned arms-industry conglomerate.[76]

The Russian arms industry has adapted substantially following the country's full-scale invasion of Ukraine. Despite the observed boost in arms production, the amount of resources that Russia has dedicated to its military sector (see section II) and the countrywide concerns about labour shortages raises questions about the long-term effect of such policies on Russia's economy and society.

Rising arms production in other parts of the world

Arms production in other parts of the world has faced a different dynamic. For some countries—as exemplified by South Korea—a history of conflict and tensions has led to the development of a flexible manufacturing capacity that can ramp up arms production if required. In other countries—such as Türkiye—the arms industry has benefitted from government support for self-reliance, meaning a less constrained supply chain for some aspects of production.

South Korea: Geared to meet increased demand

The South Korean arms industry had been growing even prior to Russia's full-scale invasion of Ukraine. The combined arms revenue of the four South Korean companies that ranked in the SIPRI Top 100 for 2022 rose by 27 per cent between 2015 and 2022, while the volume of South Korea's exports of

[72] Leahy, J. et al., 'China's advanced machine tool exports to Russia soar after Ukraine invasion', *Financial Times*, 2 Jan. 2024.

[73] [Government reports 12-fold increase in ammunition production], *Moscow Times*, 24 July 2023 (in Russian).

[74] Barnes, J. E., Schmitt, E. and Gibbons-Neff, T., 'Russia overcomes sanctions to expand missile production, officials say', *New York Times*, 13 Sep. 2023.

[75] Miller, S., 'T-90Ms are appearing on the Eastern front—What is the threat?', Wavell Room, 10 Mar. 2023.

[76] Kurilchenko, A., [Rostec head Chemezov says production of Kinzhals has increased since the beginning of the special military operation], Zvezda, 18 Feb. 2023 (in Russian). On Russia's use of missiles in the war see chapter 10, section III, in this volume.

major arms increased by 12 per cent between 2014–18 and 2019–23.[77] The growth in production was driven partly by rising demand from the South Korean armed forces in response to threat assessments related to the Democratic People's Republic of Korea (DPRK, or North Korea). Externally, many governments, especially in South East Asia, are turning to South Korean companies to supply military aircraft and naval ships, considering them a more cost-effective alternative to Western systems.[78] Since early 2022, South Korean companies have secured deals with various European members of NATO (including Estonia, Finland, Norway and Poland), as well as other countries (e.g. Australia and Egypt) that have traditionally relied on US and European companies.[79] These new orders are related primarily to ammunition, artillery and other land systems used in the Russia–Ukraine war.[80]

As was the case for their counterparts in the United States and Europe, most revenues generated by South Korean firms in 2022 were from orders that predated the war in Ukraine. However, what set these firms apart was their ability to overcome supply chain challenges and production constraints to convert orders into increased revenues more quickly. LIG Nex1 and Hyundai Rotem—the two South Korean companies that specialize in systems such as ammunition, artillery and other land systems that have been in high demand since the 2022 invasion of Ukraine—achieved double-digit growth in 2022. After signing a deal with Poland in July 2022 for tanks and howitzers, Hyundai Rotem delivered the first batch in December 2022.[81] In addition, by diverting production originally intended for the Korean Air Force, Korea Aerospace Industries (KAI) managed to deliver 12 FA-50 trainer/light combat aircraft to Poland within 10 months of signing an agreement in September 2022.[82]

South Korea's ability to scale up or modify production lines can be mainly attributed to two factors. First, North Korea's unpredictable military activities have required South Korean companies to maintain 'ever-warm' production lines to swiftly ramp up capacity for the South Korean armed forces in an emergency.[83] This enabled Hanwha Aerospace to double its annual

[77] On the South Korean companies ranked in the SIPRI Top 100 arms-producing and military services companies see section III of this chapter. On South Korea's arms exports see chapter 6, section II, in this volume.

[78] Wezeman, S. T., *Arms Flows to South East Asia* (SIPRI: Stockholm, Dec. 2019), p. 18; and Lee, J., 'Understanding the recent Southeast Asian arms build-up: A commitment to a minimum military response capability', Asan Institute for Policy Studies, 20 Dec. 2023.

[79] Behrendt, P., 'South Korea makes good on chink in European arms market', Institute for Security and Development Policy, 17 Feb. 2023; Yeo, M., 'Australia selects South Korea's Hanwha in military vehicle competition', *Defense News*, 27 July 2023; and 'Egypt signs major arms deal with South Korea', Egypt Defence Expo, 8 Feb. 2023.

[80] 'Czołgi, haubice i samoloty z Korei dla Sił Zbrojnych RP' [Tanks, howitzers and planes from Korea for the Polish Armed Forces], Polish Armed Forces, [n.d.].

[81] 'Poland received the first K2 tanks and K9 Thunder self-propelled guns', Ukrainian Military Center, 6 Dec. 2022.

[82] Donald, D., 'KAI unveils first "gap-filler" light fighter for Poland', AIN, 11 Mar. 2023.

[83] Arthur (note 12).

production of K9 self-propelled howitzers in 2022, with plans for another doubling in 2023.[84] Second, South Korea's unique security posture has also led the industry to prioritize the production of ammunition and artillery to match North Korea's large inventories of these weapon categories.[85] While this degree of manufacturing flexibility and product specialization is intended primarily for domestic demand, it can easily be diverted to export sales to meet surging demand at short notice.[86]

Türkiye: Indigenization of supply chains

Türkiye's exports of uncrewed aerial vehicles (UAVs) skyrocketed in 2019–23.[87] In 2022 alone, the arms revenue of Baykar jumped by 94 per cent, driven largely by sales of the Bayraktar TB2 UAV, notably used by Ukraine during the war with Russia.[88] Baykar's ability to quickly meet the demand was due to a long process of state-led indigenization of the Turkish arms industry. Over the past two decades, Türkiye has increasingly prioritized domestic sourcing and the development of proprietary designs in arms production.[89] Such efforts went in tandem with the more assertive foreign policy adopted by the Justice and Development Party of President Recep Tayyip Erdoğan, dominant in Turkish politics since 2002. Strengthening the arms industry became critical to Türkiye's ambitions of being a regional power.[90]

Türkiye has managed to become largely self-sufficient in the production of UAVs.[91] The production of the TB2, for example, has been largely domestic. In 2021 Baykar encountered difficulties in importing components and technologies from Canada due to concerns over the possible use of its technology in conflicts such as that in Nagorno-Karabakh.[92] By 2022, Baykar managed to successfully integrate domestically manufactured alternatives

[84] Arthur (note 12).

[85] Lee, M. Y. and Kim, M., 'South Korea faces "Sophie's choice" over sending weapons to Ukraine', *Washington Post*, 13 Apr. 2023.

[86] Shin, H., 'South Korea to lend 500,000 rounds of artillery shells to US: Report', Reuters. 12 Apr. 2023.

[87] SIPRI Arms Transfers Database, Mar. 2024, <https://www.sipri.org/databases/armstransfers>. On Türkiye's arms exports see also chapter 6, section II, in this volume.

[88] Masri, L. and Ismail, A., 'Western firms have supplied critical components to Turkish drones', Reuters, 10 Oct. 2023.

[89] Bağcı, H. and Kurç, Ç., 'Turkey's strategic choice: Buy or make weapons?', *Defence Studies*, vol. 17, no. 1 (2017).

[90] Bağcı and Kurç (note 89).

[91] Gurini, F., 'Turkey's unpromising defense industry', Sada, Carnegie Endowment for International Peace, 9 Oct. 2020.

[92] Sevunts, L., 'Armenia claims it found Canadian tech on downed Turkish drone', CBC, 20 Oct. 2020; and Walker-Munro, B., 'The dual-use conundrum', The Interpreter, Lowy Institute, 24 Oct. 2023. On the conflict in Nagorno-Karabakh see chapter 2, section I, in this volume.

into the production of the TB2, such as the TEI-PD170 engine produced by Turkish Aerospace Industries (TAI).[93]

While the Turkish arms industry has certainly made progress in the indigenization of UAV production, it more generally remains far from achieving self-sufficiency. The country still relies heavily on foreign involvement, as evidenced by the National Combat Aircraft (TF-X) project. The TF-X is being developed by TAI with the UK's BAE Systems, and its engine is being produced by a joint venture between Türkiye's Kale and the UK's Rolls-Royce.[94] Economic woes have further exacerbated this reliance. Rising inflation and external debt in recent years have led Türkiye to seek foreign partners, such as Malaysia, to join the TF-X project to lessen its costs.[95]

This enduring dependence on foreign suppliers has occasionally allowed them to restrict Türkiye's access to key technologies or weapons. For example, after Türkiye acquired the Russian S-400 air defence system in 2019, the USA removed it from the F-35 Joint Strike Fighter programme, and some European countries embargoed sectors of the Turkish arms industry because of Türkiye's military operations in Syria in 2020.[96] Because of these vulnerabilities, Türkiye may find it difficult to replicate its success in quickly expanding the production of UAVs for more complex weapon systems.

Conclusions

The global arms industry is experiencing a pivotal phase of increased demand driven by the Russia–Ukraine war and the resultant reassessment of military needs. Overall, the country-specific developments outlined here reflect the ways in which the global arms industry has reacted to the rapid shifts in demand and geopolitical upheaval since February 2022. Despite structural issues—such as long lead times, constrained production capacity and the just-in-time production model—affecting Western producers and the weight of sanctions on Russia, arms production has started to increase around the world. The expectation is thus that global arms production, in volume and value, is likely to surge in the years to come, following the trend of increased global military expenditure.

[93] Aksan, S., 'Gökyüzünün yeni oyuncusu yerli motorla gelecek' [New player of the sky will come with domestic engine], TRT Haber, 30 Oct. 2020; Weapon Detective, 'Bayraktar TB2 unmanned combat aerial vehicle: The banner bearer of the Turkish defence industry', Medium, 31 Mar. 2022; and Dangwal, A., 'TB-3 drones: After Bayraktar TB2, Turkey ready to unleash its cutting edge naval UAVs very soon—Reports', *Eurasian Times*, 6 Nov. 2022.

[94] Bekdil, B. E., 'Rolls-Royce, Kale to develop engine for Turkish fighter', *Defense News*, 14 Mar. 2022.

[95] Bekdil, B. E., 'Turkey seeks partners for TF-X fighter program amid fiscal uncertainty', *Defense News*, 31 Aug. 2023.

[96] Davis, I. and Fazil, S., 'Armed conflict and peace processes in Iraq, Syria and Turkey', *SIPRI Yearbook 2021*, pp. 147–59; and Mehta, A., 'Turkey officially kicked out of F-35 program', *Defense News*, 17 July 2019; and Gurini (note 91).