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Ukraine's Drone Industry

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Ukraine's Drone Industry

The role of volunteerism and policy in building an emerging UAV Industry

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Abstract

The full-scale Russian invasion of Ukraine in 2022 marked a profound disruption of the prevailing European security paradigm, which had long deprioritized large-scale conventional warfare. This shock not only revived defense policy across Europe but also catalyzed an urgent reconfiguration of Ukraine's own defense capabilities, most notably, the emergence of a vibrant domestic drone industry. This paper examines the evolution of Ukraine's drone sector through the framework of "reluctant innovations", where technological advancement is driven not by long-term strategy or commercial ambition but by the immediate demands of existential threats. While pre-war strengths in tech education and a robust IT workforce provided a foundation, the industry growth was propelled by several key drivers: widespread civilian and volunteer mobilization, fast-tracked government reforms, targeted procurement incentives, enforced capital retention, and foreign partnerships that facilitated technology transfer. Together, these forces activated a decentralized innovation ecosystem that bridged military and civilian spheres. Ukraine's experience illustrates a hybrid model of defense innovation, where necessity has spurred civilian entrepreneurship and state support to create a highly responsive war economy. This case offers broader insights into how societies can rapidly pivot toward technological self-reliance under extreme geopolitical pressure.

Key words: UAVs, drone industry, wartime innovation, dual-use technology, technological resilience, Ukraine

JEL codes: H56; O31; L52; L26; P16

1. Introduction

In the aftermath of the Cold War and particularly after the early 2000s, many European governments operated under the strategic assumption that large-scale military conflicts on the continent had become improbable. Security doctrines were increasingly oriented toward more adaptive strategies targeting "modern" threats, such as terrorism, peacekeeping challenges, and cyberattacks (Andreas & Price, 2001; Bailes, 2005; Caudle, 2009; Tuukkanen, 2011), rather than preparations for conventional warfare. As a result, many governments allowed their defense capabilities to atrophy, prioritizing social spending and economic modernization over military readiness (Cusack, 2006). This phenomenon is commonly referred to as the "peace dividend" (Gleditsch et al., 1996).

This strategic complacency was rooted in the belief that future conflicts would occur in peripheral regions, with minimal direct threat to European territory. Consequently, military stockpiles were reduced to levels sufficient only for short-term, low-intensity engagements (Mészáros, 2024). The full-scale invasion of Ukraine by the Russian Federation in February 2022 marked a significant break from this established paradigm. The war thus catalyzed a renewed focus on defense policy, prompting many European countries to initiate comprehensive modernization and expansion of their defense industries for the first time since the end of the Cold War. These developments have drawn attention to the critical role of military innovation, particularly in wartime conditions where urgent needs bypass conventional procurement and R&D processes.

Before the full-scale war, Ukraine possessed a robust civilian tech ecosystem, including a vibrant IT sector and an emerging startup culture. However, military-oriented technological development, particularly in unmanned aerial systems (UAS), remained relatively underfunded and underdeveloped (Bilousova et al., 2024; Gryga & Ryzhkova, 2022). Although there was some progress after 2014 with private initiatives such as Athlon Avia and Aerorozvidka, broader research and development in drone technologies were constrained by bureaucratic inefficiencies and limited government investment. The escalation of the conflict rapidly transformed this landscape. Confronted with an existential threat and significant asymmetry in conventional capabilities, Ukraine mobilized a diverse range of societal actors – including engineers, technologists, hobbyists, and volunteers – into a decentralized innovation network to enhance the country's defensive and offensive drone capabilities.

The rapid development of the drone industry, in both production volume and technological diversity, represents a reluctant innovation model. As conceptualized by Banks (2013), the term refers to innovation driven not by commercial ambition or strategic planning but by urgent necessity. While inter-organizational competition (DeVore, 2020) or pandemic-driven revenue resilience (Bellini & Raglianti, 2023) could lead some rivals to become reluctant innovators, the grassroots Ukrainian innovation ecosystem is fueled by patriotism and life-threatening challenges (Kutsenko, 2025; Stepanenko & Stewart, 2025). Furthermore, well-targeted policy initiatives have played a key role in supporting and encouraging self-organized structures. This positive development was not something to be taken for granted at the beginning of the war.

This study explores the evolution and transformation of Ukraine's UAV (unmanned aerial vehicles) industry as a case of wartime innovations under extreme conditions. It focuses on understanding how a decentralized, necessity-driven innovation ecosystem rapidly scaled from a handful of firms to over 200 active producers (Bilousova et al., 2024). Framed through the lens of "reluctant innovation," the analysis examines the synergy of precursors and the interplay of governmental policy, grassroots entrepreneurship, volunteer networks, and international support in driving this transformation. This study offers several new insights into the mechanism that prompted development in Ukraine and how different actors interacted to achieve the societal resilience characteristic of Ukrainian society. Additionally, it highlights how policy has supported more spontaneous and self-organizing processes, often driven by initiatives from individuals and volunteers, while also emphasizing the crucial role of policy measures in initiating the transformation of Ukrainian industry.

In the remainder of the paper, a brief presentation of previous research relevant to the current study (Section 2) is followed by a description of the precursors that were decisive for the emergence of the Ukrainian drone industry (Section 3). Thereafter, the policy measures undertaken to incentivize and stimulate the drone industry are discussed in section 4, whereas section 5 is devoted to initiatives to enhance international cooperation and transactions. Section 6 depicts the importance of volunteers and NGOs, while Section 7 concludes.

2. Previous research and framework

From a more general perspective, varying aspects of the economics of war are summarized in, for example, the Handbook of Defense Economics (Sandler & Hartley, 2007). Research on new technologies, business restructuring, increasing trade dependency, terrorism, economic

sanctions, and local conflicts, among other topics, is elaborated. More recent contributions also include issues such as the costs of war, reconstruction, macroeconomic implications, international consequences, and other areas are provided by Bruegel¹, Rogoff (2022), CEPR², and NBER³, among others. However, the current paper focuses specifically on drone manufacturing and the underlying mechanisms driving the rapid transformation of Ukraine's industry.

Exogenous shocks, such as war and significant geopolitical instability, obviously have a substantial influence on the business environment and the manner in which business activities are conducted (Candiya Bongomin et al., 2018; Govori, 2013; Marom & Lussier, 2014). Conditions related to socio-political, economic, and legal factors are all challenged during a severe crisis, e.g., as a war (Djip, 2014). Ecosystems tend to be severely affected by issues such as access to finance, competition, corruption, and government support. Other obstacles, such as high administrative costs, increased collateral requirements, and banks' general reluctance to lend to SMEs, may further exacerbate the situation.

Furthermore, innovation processes during a military conflict differ significantly from those during peace. In peacetime, innovation related to military purposes is predominantly driven by targeted funding and various governmental programs and initiatives, i.e., military promotion politics (Rosen, 1991). Hence, innovation is primarily driven by the government's capital availability, with firms actively involved in its implementation through R&D programs, defense contracts, and long-term technological planning. Additionally, peacetime innovation is more speculative and constrained by institutional inertia and bureaucracy. Civilian influence, while present through policy and funding, is generally minimal and indirect. Moreover, peacetime innovation often addresses hypothetical threats, or future capabilities projected 20 years into the future, creating a disconnect between innovation cycles and immediate utility (Rosen, 1988).

Conversely, innovation in wartime is marked by urgency and improvisation, and therefore differs substantially from the corresponding peacetime processes. While high-tech innovations often attract policy attention, equally vital are "low-end" (low-cost, low-tech) battlefield

¹ https://www.bruegel.org/search?search_term=Ukraine

² <https://cepr.org/search?search=Ukraine>

³ <https://www.nber.org/search?page=1&perPage=50&q=Ukraine>

modifications driven by frontline experiences and informal innovation networks that challenge the rigidity of traditional bureaucratic models (Kollars, 2014; Kunertova, 2023). Wartime innovation becomes not a matter of competitive advantage or profit margin but of national survival. Ukraine's war experience illustrates this transformation, where innovation is no longer optional, but for existence.

In another vein of the literature, it is claimed that a broader trend of civil-military technological fusion has emerged under wartime pressures over the last few decades (Mészáros, 2024). In this context, reluctant innovators, or reluctant entrepreneurs, have become pivotal contributors to national security, reconfiguring the boundaries between civilian and military technological domains. In the case of Ukraine, a conventional innovation trajectory was not followed; instead, a hybrid crisis strategy emerged, mobilizing efforts from a diverse group of contributors, echoing the "produce, buy, and repurpose" framework proposed by Leadbeater (2020). Ukraine simultaneously began producing drones domestically through grassroots and startup-led efforts, buying or receiving critical technologies from international partners, and repurposing civilian, commercial, and even hobbyist technologies for military use.

Previous research has emphasized that crises typically develop in multiple and unpredictable ways, stemming from various factors that evolve over time (Williams et al., 2017). Hence, preparing for a specific situation is challenging and risks leading to lock-in effects. Certain key sectors can be identified where specific preparations may be undertaken to enhance resilience, including agreements between the business sector and defense authorities, stockpiling of strategic items, and regional-level preparations to reduce dependence on other regions, etc (Alvinus & Hedlund, 2024; Eriksson, 2018; Lucas et al., 2024). However, the key to resilience appears to be flexibility that embraces both the business sector and the civil society organizations. Such adjustments and adaptations are contingent upon organizational design, industrial structure, and policies (Dligach & Stavytsky, 2024).

In summary, preparations for a military conflict largely involve i) implementing measures during peacetime that facilitate adaptation in the event of war; ii) devising plans for economic and political actions that can be rapidly deployed at the onset of hostilities, such as regulations, resource allocation, and public procurement; and iii) supporting effective cooperative frameworks among civilian organizations, the business sector, and the military sector (Alvinus & Hedlund, 2024; Jonsson et al., 2022).

3. Precursors: Tech talent pool and level of technical education

A nation's most valuable asset is its human capital – the collective skills, education, and innovative capacity of its people. Together with a proper institutional setup that enables an efficient utilization of such resources, it constitutes as the engine driving economic development and industrial transformation. Appropriately used and efficiently allocated across economic activities, human capital is thus the fundamental input driving economic growth and innovation, both in civilian and military contexts (Acs et al., 2009; Aghion & Howitt, 1990; Romer, 1990). This basic insight is vividly reflected in Ukraine's experience since 2022, where the swift mobilization and allocation of its substantial pool of engineers, IT specialists, and volunteer technologists has been instrumental in the explosive growth of its domestic UAV industry, which was critically important in halting the Russian invasion.

Before the war, Ukraine was strong in educational attainment and endowed with the largest engineering workforce in Central and Eastern Europe, producing approximately 130,000 engineering graduates and 16,000 information technology (IT) specialists annually (IFC, 2021). Despite the ongoing war and significant migration pressures, Ukraine's tech industry demonstrated remarkable resilience and growth, with over 300,000 professionals remaining in Ukraine 2024 whereof 87% hold a higher education degree (IT Ukraine Association, 2024). Ukraine is also home to 281 universities, of which 203 are public, many of which have historically been strong in science, technology, engineering, and mathematics (STEM).

Another notable feature of Ukraine's human capital advantage is the scale and dynamism of its non-formal IT education ecosystem, which complements and often outpaces formal institutions in producing job-ready skills. In recent years, non-formal IT education in Ukraine has trained over four times as many people as formal university programs (IT Ukraine Association, 2024). Private tech schools and bootcamps including but not limited to Step IT Academy, Beetroot Academy, GoIT, ITEA, and SkillUp, are especially responsive to wartime needs, helping civilians and veterans retrain quickly to contribute to national defense in technical roles such as UAV piloting, drone programming, telemetry, and AI-assisted targeting systems.

The Ukrainian government and military recognize that tech professionals often have greater value when applying their skills to drone development, cyber defense, surveillance, AI, and battlefield communications than they would as standard infantry. While general mobilization

remains in effect, Ukraine's draft system includes exceptions and deferments for personnel employed in sectors deemed essential to the national defense or economy (The Ministry of Strategic Industries of Ukraine, 2024). In 2025 the regulations were revised and presently companies can pursue one of two options to exempt personnel from being drafted: the first allows up to 50% of eligible employees to be exempt if the firm meets at least three of seven economic or structural criteria; the second option provides for exemptions above 50% but requires a valid government defense contract and proof that over half the company's output is military related. By late 2024, approximately 1,470 Ukrainian IT companies had attained official recognition as Diia.City residents (Counteroffensive, 2024), implying several advantages including exemption from conscription (see below, Section 4). This designation is increasingly associated with critical enterprise status, particularly for firms specializing in cybersecurity, defense technologies, and infrastructure support.

However, many small and medium-sized drone manufacturers in Ukraine struggle to access important exemptions due to their reliance on charitable foundations or non-governmental organizations rather than formal state contracts. This hinders their ability to gain critical enterprise status and leaves them vulnerable to mobilization, despite their contributions to Ukraine's defense (Counteroffensive, 2024).

4. Policy measures to promote the Ukrainian UAV industry expansion

4.1 Government incentives and procurement reforms

The Ukrainian government, particularly the Ministry of Digital Transformation, has actively reformed policies and boosted investment to catalyze domestic UAV production. Recognizing the vital role drones play in national defense, authorities have moved quickly since 2022. The government has deregulated the drone market, enhanced funding and streamlined or abolished regulations, to accelerate military production and bolster the Ukrainian armed forces. Unlike Russia, where drone production is primarily state-controlled and reliant on imported Iranian "Shahed" drones, Ukraine's drone manufacturing is predominantly private, featuring limited liability companies and individual entrepreneurs.

According to the Minister of Digital Transformation, all major bureaucratic "blockages" facing private drone manufacturers were resolved within six months through targeted legislative and regulatory changes (Reuters, 2024). Removing key legal and administrative barriers opened the sector to rapid expansion, allowing dozens of new manufacturers to enter the market.

Among the most impactful reforms were the elimination of taxes and import duties on UAV components, the simplification of drone certification and operation procedures, including the removal of unnecessary oversight bodies such as export controls and the Security Service of Ukraine (SBU) approvals (Bilousova et al., 2024), enabling of specialist exemptions from conscription (e.g., reserving professionals), and establishment of dedicated pilot training and testing facilities.

Adopted in March 2023, Resolution No. 256⁴ significantly reformed the procurement process for unmanned systems by lifting the state monopoly on specific categories of armaments and, for the first time, enabling private companies to competitively supply the Armed Forces through streamlined contracting procedures. The government also raised the allowable profit margin for drone producers from 1% to 25%, significantly improving commercial viability.

Furthermore, in 2022, the Ukrainian government launched the Diia.City program. It offers resident companies a preferential legal and tax framework, including reduced income tax rates, flexible "gig" employment contracts, and enhanced protections for intellectual property (Diia.City, n.d.). As of 2024, over 200 defense-tech companies, including drone manufacturers, have joined Diia.City to leverage benefits and scale production to support national security (Communications Department of the Secretariat of the CMU, 2024). However, a key limitation of the program is its inaccessibility to individual entrepreneurs, who constitute a large portion of Ukraine's IT and engineering workforce. Only incorporated legal entities can become Diia.City residents, excluding solo entrepreneurs from direct participation in its advantages, though they may still engage indirectly through contracts with resident companies.

Amid the ongoing war, the Ukrainian government has assumed a dual role as both a strategic procurer and a venture catalyst for domestic UAV development. On the procurement side, the Ministry of Defense has significantly scaled investments, allocating over \$2.5 billion to Ukrainian drone manufacturers between 2024 and 2025. Beyond procurement, the Ukrainian government actively fosters innovation through institutional platforms, such as Brave1, a national defense-tech cluster designed to bridge startups, engineers, and military end-users, in effect creating a combination of a marketplace and support for drone production. Brave1 not

⁴ <https://www.kmu.gov.ua/en/news/udoskonaleno-protseduru-zakupivli-bezpylotnykh-system-vitchyznianoho-vyrobnystva>

only coordinates operational testing and legal assistance but also serves as a grant administrator and accelerator for early-stage technologies. By September 2024, approximately 22% of Brave1's awarded grants had been allocated to UAV startups, underscoring the strategic priority placed on aerial systems. In parallel, over 25% of all R&D project applications submitted to Brave1 involved UAV technologies (Bilousova et al., 2024).

This state-backed venture infrastructure is complemented by the Army of Drones, a procurement and crowdfunding mechanism operating under the UNITED24 platform⁵, which matches public donations with government funds to purchase and distribute thousands of drones to the military. These dual channels of public investment (a hybrid procurement model) have not only seeded early-stage UAV and electronic warfare ventures but also helped transition the industry from its volunteer roots in 2022 to a more structured and competitive defense-tech market by 2025.

To ensure the military can absorb all these drones, the state has funded large-scale training. By November 2024, approximately 50,000 Ukrainian servicemen had been trained in drone operations, reflecting a substantial increase from the 20,000 operators trained in 2023. This surge in trained personnel was facilitated by the certification of over 30 drone operator schools by the Ministry of Defense, enhancing the nation's capacity to produce skilled UAV operators. Complementing these training efforts, Ukraine formally established the Unmanned Systems Forces (USF) on June 11, 2024, marking the creation of the world's first dedicated military branch for drone warfare.⁶ As of February 2025, the USF comprised approximately 5,000 personnel, organized into one regiment and six battalions, with an additional battalion in formation. These steps ensure a pipeline of skilled operators and signal institutional support for UAVs at every level.

4.2 National Bank of Ukraine financial limits

To the best of our knowledge, the impact of National Bank capital controls has not been thoroughly investigated in previous analyses of the Ukrainian policy responses to the Russian invasion. Wartime financial restrictions imposed by the National Bank of Ukraine (NBU) have indirectly encouraged domestic investment, including into the UAV sector. In response to the

⁵ https://u24.gov.ua/uk?utm_source=website&utm_medium=media&utm_campaign=main_page

⁶ <https://www.president.gov.ua/en/news/pidpisav-ukaz-yakij-rozpochinaye-stvorennnya-okremogo-rodu-si-88817>

invasion, the NBU introduced strict controls on currency and capital flows to prevent outflows of funds.⁷ These measures, while aimed at stabilizing the economy and national currency, had the side effect of keeping money inside Ukrainian borders, money that often found its way into local businesses and defense initiatives.

Starting in early 2022, the NBU banned or severely restricted most cross-border capital transfers. Thus, from April 2022, individuals were only allowed to purchase foreign currency up to a monthly limit of \$ 10,000 for certain approved defense-related imports. Essentially, Ukrainians could no longer freely send money abroad or invest in foreign assets. This applied to companies as well, dividend repatriation and foreign investment by Ukrainian firms were halted. The policy trapped substantial private capital inside the country. Many Ukrainian investors and businesses, who under peaceful conditions might have parked funds overseas, were left with little choice but to reinvest their money domestically. During wartime, a significant proportion of capital flowed into war-critical sectors, such as UAV production (as a patriotic investment or simply one of the few viable opportunities). With few other obvious outlets (real estate and consumer markets are depressed during war), investing in defense production or buying government bonds becomes one of the rational choices for business and citizens. In essence, money stays in Ukraine and works for Ukraine.

With tight limits on capital flow, any profits earned by Ukrainian defense companies tend to be reinvested at home. UAV manufacturers cannot easily move their earnings to foreign accounts or assets, so they are more likely to plow them back into expanding production capacity or R&D activities. Moreover, as noted earlier, the government capped profit margins on military contracts at 25%. Therefore, this limits excess profits, ensuring that companies focus on volume and improvements. Before the war, many Ukrainian drone companies relied on exporting to foreign markets for higher margins. But wartime export bans mean the state is basically the only one buyer, and manufacturers must take the best of the situation by reinvesting in better products for the domestic military. This policy cannot be sustainable in the future, yet paradoxically, the restrictions force a single-minded concentration on serving Ukraine's war needs, ensuring that all talent and capital remain directed at the battlefield.

⁷ <https://bank.gov.ua/en/news/all/natsionalniy-bank-y-nadali-vjivaye-zahodiv-dlya-pidvischennya-investitsiyoyi-privablivosti-ta-pidtrimannya-oboronozdatsnosti-ukrayini#:~:text=As%20a%20reminder%2C%20starting%20from,purchase%20the%20respective%20goods%20abroad>

The imposed financial restrictions³ created a market incentive to build drones locally. Rather than navigating bureaucratic hurdles to import a foreign UAV, both military and volunteer groups found it easier to fund domestic drone manufacturers in their national currency. As a result, capital controls served as a form of import substitution policy, nudging demand toward Ukrainian-produced drones and keeping payments within the Ukrainian economy. One example is the NBU's allowance for volunteers to spend the national currency (the hryvnia) on UAV components abroad without any limits.

5. Foreign partnership and knowledge transfer

Strategic partnerships, joint ventures, and foreign aid programs have provided both technology transfer and resources to the Ukrainian drone industry. Ukraine began acquiring Bayraktar TB2 drones in 2019, making its first significant entry into armed drone operations. In 2022, Baykar signed an agreement to establish a TB2/TB3 production facility in Ukraine, which would include a training and maintenance center. Construction continues despite wartime conditions, with completion planned for August 2025. This joint venture not only brings foreign investments but also transfers manufacturing know-how. Notably, Baykar's high-end UAVs already use Ukrainian-made engines from Ivchenko-Progress and Motor Sich⁸, reflecting a two-way exchange of technology.

The international "Drone Coalition" was launched in early 2024, co-led by the United Kingdom and Latvia. It represents a multilateral initiative to support Ukraine's defense through extensive UAV provision and capacity building.⁹ Comprising over ten partner nations, including Estonia, Denmark, Sweden, the Netherlands, Australia, Canada, the United Kingdom, Germany, New Zealand, Poland, and Latvia, the coalition has pledged significant financial resources.¹⁰ By early 2025, the coalition facilitated the delivery of over 30,000 drones, including reconnaissance and FPV systems (manned First Person View drones), via a joint procurement mechanism designed to streamline logistics and ensure rapid deployment.¹¹ Beyond immediate

⁸ <https://www.euractiv.com/section/defence/news/turkeys-baykar-to-complete-drone-plant-in-ukraine-in-two-years/>

⁹ <https://www.minister.defence.gov.au/statements/2024-07-11/joint-statement-drone-coalitions-ministers-defence>

¹⁰ <https://united24media.com/latest-news/international-drone-coalition-raises-over-eur500-million-for-ukraine-147>

¹¹ <https://www.gov.uk/government/news/30000-new-drones-for-ukraine-in-boost-to-european-security>

military aid, the initiative also emphasizes strengthening Ukraine's domestic drone production by integrating local manufacturers and fostering innovation, thus aiming to create a sustainable and scalable defense technology ecosystem within the country, which also serve to facilitate future dual use applications.

6. Volunteer engineering and civilian involvement: A “shadow” industry

Perhaps the most unique driver of Ukraine's drone expansion is the bottom-up surge of private entrepreneurship and volunteer ingenuity, especially since the 2022 invasion. Ordinary civilians offered their skills, knowledge, money, or time to band together to build DIY drones for the front.

A significant proportion of Ukraine's drone output comes from ad-hoc volunteer engineering teams that exemplify a decentralized, rapid prototyping approach. They leverage readily available parts, such as commercial quadcopter frames, hobby motors, and open-source software, to create effective combat drones at a low cost. Front-line units and volunteer makers constantly collaborate to test and refine designs in an agile loop. Thus, FPV drones, which originated from cheap racing drones, have evolved into deadly loitering munitions. One of the most compelling examples of this grassroots innovation is Wild Hornets, a registered charitable foundation that designs and manufactures FPV drones for frontline use. Founded in 2023, Wild Hornets operates as a hybrid between a volunteer collective and a lean defense-tech manufacturer, relying on donor support and civilian expertise rather than institutional funding. Their decentralized engineering model enables rapid iteration and the integration of battlefield feedback, facilitating direct collaboration between developers and combat units. As of 2024, Wild Hornets drones had reportedly neutralized more than 1,700 targets, causing estimated material losses exceeding \$1.70 billion.¹² What began as improvised, small-scale activities (such as retrofitting hobby or commercial drones) has evolved into a full-fledged production. The volunteer engineer movement essentially jump-started an industry that is now formalized, maturing, and attracting significant investments, with clear dual-use potential.

Ukraine's civil society also contributed directly to financing the drone boom. Crowdfunding has played a pivotal role in financing drone initiatives. Numerous volunteer funds and NGOs have raised money to build or buy drones. Notably, in mid-2022, a campaign by Ukrainian

¹² <https://wildhornets.com/en/>

activist Serhiy Prytula raised around \$18 million in just 3 days to purchase Bayraktar TB2 drones. The Come Back Alive Foundation raised approximately \$8.8 million for 25 Shark drone systems. At the same time, NGOs in Ukraine are generally prohibited from purchasing military-grade drones equipped with explosive payloads. Consequently, they primarily acquire commercial or dual-use drones, which are later modified for military purposes. This aligns with international legal frameworks that restrict the transfer of military equipment to non-state actors. At the same time, NGOs actively finance R&D, test and pilot unconventional technical solutions without bureaucratic delays, logistics, engineering work, or air defense integration – i.e., all aspects of military innovations except the actual deployment or transfer of lethal weapons, which remains under the exclusive authority of the state.

While rare, there are instances where NGOs or volunteers can purchase military-grade drones, provided they meet specific legal and procedural requirements. These exceptions are tightly controlled, significantly limiting the operational flexibility of NGOs. When NGOs supply drones to military units, these drones are often integrated into combat unit operations without formal quality assurance checks. This informal integration underscores the importance of community trust and the adaptability of volunteer networks in supporting military operations. As such, a defense manufacturer's partnership with reputable NGOs may also serve as an informal yet credible signal of technological competence and operational reliability, which are factors increasingly relevant for public procurement assessments in wartime settings.

Ukraine's wartime innovation economy is powered not only by capital, but also by the silent donation of time. In home labs and classrooms, civilian engineers, students, and coders have effectively formed a shadow defense industry. Ukrainian civilians have actively participated in drone development, often assembling drones in their homes to support the Ukrainian Armed Forces. Volunteers participate in various campaigns, such as People's Drone (People's FPV), SocialDrone UA, and Army of Drones, among others, to assist with hands-on work, including assembling drones, 3D printing spare parts, and training soldiers and civilians on drone use. Civilian developers contribute thousands of GitHub commits and open-source designs, including, but not limited to, AI targeting systems and PID controllers.

7. Conclusion

In this study we seek to analyze and identify the main causes behind the rapid emergence of Ukraine's domestic UAV industry, framed as a paradigmatic case of reluctant innovation. The

findings highlight how a convergence of structural preconditions, namely a robust STEM-oriented human capital base, and emergent wartime dynamics facilitated the swift reconfiguration of Ukraine's defense-industrial landscape. The transformation was not the result of centralized state planning, but rather a combination of bold and innovative policy initiatives that led to distributed agency. Simultaneously, the spontaneous involvement of other actors, such as volunteer technologists, civil society organizations, industrial initiatives, and targeted state interventions, occurred and was facilitated by procurement reforms, capital controls, financial restrictions, and foreign partnerships.

The Ukrainian case demonstrates that under conditions of existential threat, innovation systems could evolve rapidly outside conventional industrial models. These findings underscore the importance of institutional flexibility, civilian-military cooperation, and the integration of non-traditional actors in national defense ecosystems.

Future research could further investigate how temporary, improvisational structures adapt to the demands of long-term industrial planning, regulatory formalization, and integration into national defense strategies. Particular attention should be paid to the tensions between speed-driven, decentralized innovation and the bureaucratic logic of peacetime governance.

Overall, the Ukrainian process has been characterized by speed, scale, and urgency, which mirrors the determination to address an extreme crisis situation. Leadership and flexibility have been decisive in this process. It shares several features with Schumpeterian processes that underlie dynamic economic transformations and are based on experimentation, iteration, selection, and competition. Our upcoming analysis will revisit these similarities.

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