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When Military Interventions Decrease Military Power. Evidence from the French Case

Josselin Droff[a], Julien Malizard[a] and Olivier Schmitt[b]

[a]Chair of Defense Economics, IHEDN, Paris, France; [b]University of Southern Denmark, Odense, Denmark

ABSTRACT

Military interventions create dilemmas for military organizations which must balance security-related tasks (such as peacekeeping or crisis management operations) and defense-related tasks involving deterrence and the preparation for high-intensity operations. This article specifically examines the trade-off between security and defense tasks through an original analysis of the impact of the intensification of the French armed forces' operational tempo on the overall availability of military equipment. We argue that the intensification of military interventions generates gaps in a country's military capabilities. More precisely, an excessive operational tempo, understood as an unsustainable level of deployment given regeneration capabilities, can reduce the ability of military organizations to generate operationally effective forces. Through an original methodological approach, using a multilevel econometric model that estimates a specific dimension of military power applied to the French case, this article contributes to the literature on the strategic utility of military interventions by examining their structural impact on the armed forces.

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Introduction

Military power is fundamentally about the use, or threat of use, of military force to achieve security objectives. This requires the building of military institutions designed to achieve diverse tasks. In fact, the production of military power can be considered an input – output process involving four main steps: budgets, forces, capabilities and force employment strategies, amounting to the achievement of security objectives (Smith 2009). The availability of military equipment is critical because it conditions the effectiveness of armed forces and more broadly, defense outputs (Hartley 2012). However, the diversity of tasks that military institutions may have to fulfill could lead to trade-offs in the generation of military power because of declining availability. For instance, there is tension between security-related tasks such as the military interventions that Western states have conducted since the end of the Cold War and defense-related tasks such as deterrence and preparation for high-intensity operations.

This article specifically examines the trade-off generated by the multiplicity of ways armed forces can be employed, through an original analysis of the impact of the intensification of the French armed forces' operational tempo on the overall availability of military equipment. Operational tempo can be defined as the rate of military actions or missions (Castro and Adler 1999). Hence, the intensification of military interventions is a key component of an increasing operational tempo. Following the recent literature, we define military interventions as "instances of international conflict or potential conflict outside of normal peacetime activities in which the purposeful threat, display, or

CONTACT Josselin Droff Josselin.Droff@fdd-ihedn.fr Chair of Defense Economics, IHEDN, Ecole militaire 1 place Joffre, Paris 75700

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use of military force by official government channels is explicitly directed toward the government, official representatives, official forces, property, or territory of another state actor (Kushi and Toft 2023, 755). Assessing the overall effect of the intensification of the operational tempo on availability is relevant because reduced availability in the long run generates potential gaps in a country's military capabilities (Droff, Malizard, and Menuet 2023). More precisely, an excessive operational tempo, understood as an unsustainable level of deployment given regeneration capabilities, can reduce the ability of armed forces to conduct critical force generation activities and thereby the desired output: operationally effective forces able to field relevant military capabilities. This article argues that such a gap in terms of military capabilities should be considered a strategic cost for the country, that is, costs that would likely affect the provision of defense services in the long run, in the context of evolving missions for the armed forces and a pivot towards high-intensity operations.

This article contributes to the literature on the strategic utility of military interventions by examining their structural impact on the armed forces and the trade-offs they generate: it is thus at the intersection between security studies and defense economics. Specifically, it makes three contributions: two substantial and one methodological. First, it contributes to the security studies literature by identifying and measuring a hidden cost of military interventions, thus contributing to the broader debate about their strategic utility. Second, this article contributes to the defense economics literature by demonstrating a causal link between the availability issues of military equipment and operational tempo (Keating and Dixon 2004; Lavin, McNab, and Sullivan 2017; Sokri 2011). Our third contribution is methodological, since we use a multilevel econometric model that estimates a specific dimension of military power, the availability of military equipment, which is often overlooked in the security studies literature trying to measure military power (Beckley 2018; Lindasy and Gartzke 2022). We discuss these three contributions in turn.

When it comes to the strategic utility of military interventions, several authors question the effectiveness and rationale of altering the social fabric of foreign countries (Jahn 2007; Williams and Masters 2011). Yet another strand of the literature attempts to evaluate the costs of these interventions to assess their relative utility. Most authors estimate direct costs by comparing real output or synthetic output based on situations without conflict (Abadie and Gardeazabal 2003; Collier 1999); and direct costs seem to be inferior to indirect costs (e.g. sending troops, rebuilding a country after war, treating war-wounded soldiers, financial costs, opportunity cost of the conflict) (Blomberg, Hess, and Orphanides 2004). For example, the famous work of Bilmes and Stiglitz estimates that the total military cost of the invasion and the occupation of Iraq and Afghanistan have exceeded USD 3,000 billion (Bilmes and Stiglitz 2008). Our article's contribution is to underline that the increasing operational tempo caused by military interventions in the long run results in a large 'halo of costs,' with the latter including potential operational consequences on military capabilities (i.e. a non-monetary measure of consequences of excessive military engagements). We demonstrate the existence of a trade-off between the force structures and skills designed for stability and counter-insurgency operations on the one hand, and the force structure and skills designed for high-intensity warfare on the other. Thus, we illustrate the consequences of military interventions: while they can seem politically appealing in the short term, they have a long-term strategic impact by eroding the 'military capital' of the armed forces.

Thus, the article empirically demonstrates an effect that was intuitively observed in policy debates but lacked substantiated evidence. In the U.S.A., the services have reported persistently low availability levels that have been attributed to emerging and continued demands on military forces, reduced force structure, and increased frequency and length of deployments (GAO 2016). In the UK, during the first decade of the 21st century, the armed forces were operating abroad at a level that exceeded the defense planning assumptions on which they were configured (Dorman 2017). According to the British National Accounting Office (NAO), 'The impact of high activity levels is pervasive and results in additional strains on processes, people and equipment across the Department and inevitably impacts on the ability of the armed forces to reconfigure for new tasks. For example, reduced levels of collective training within the army could, if continued, detract from its ability to conduct certain types of operations in the future. These strains and stresses are not something that can be easily quantified in financial terms' (NAO 2005). These arguments confirm the theoretical framework developed by Droff et al. showing that a trade-off arises in the long run between military capabilities and military interventions (Droff, Malizard, and Menuet 2023). As such, our article contributes to the debates about the effectiveness of military interventions and the nature of military power.

Second, the existing literature on the availability issues of military equipment has focused mostly on the relationship between aging military equipment and operational availability and cost. For example, Keating and Dixon demonstrate that the KC-135 R fully mission capable rate declines by approximately 4.0% per year as the system ages, and annual maintenance increases at the rate of 6.64% per year (Keating and Dixon 2004). In their study, Keating et al. found the availability of F-18 aircraft fighter declines at roughly 2.3% per annum (Keating et al. 2014). Lavine et al. empirically examine whether the aging of the US Coast Guard ships affected operational availability and operating cost (Lavin, McNab, and Sullivan 2017). Their estimation suggests that the operational availability of ships decreased at a rate between 0.83% and 1.8% per year, and the cost increased at a rate between 0.33% and 7.81% per year. We provide original insights into the literature in several ways. First, contrary to other studies such as Sokri (2011), this article does not focus only on aging and the equipment replacement problem. Although this article focuses on availability issues, it uses a different research perspective by connecting availability issues to defense output and security as a whole for a country, thus providing a strategic perspective often lacking in the defense economics literature. Moreover, the literature on availability issues has often adopted a microeconomic (or sectoral) perspective. Although most of the research has generally focused on aircraft with theoretical and empirical models – except for Lavin et al. (2017), who focused on ships – we extend this literature to focus on all armed forces with a multiplatform perspective (i.e. aircraft, helicopters, armored vehicles, ships, and submarines).

Our third contribution is methodological because our modelling technique has two distinct advantages. First multilevel models offer a natural way to assess contextuality, i.e. in our context that equipment belonging to the same group are more likely to behave in the same manner. Statistically, individuals within a group are not considered independent of each other. Second, multilevel models allow to take into account unobserved heterogeneity by including random effects. This type of model is well suited to our dataset and, more specifically, to a multi-equipment perspective, namely, an estimation with high heterogeneity in terms of equipment characteristics (see Section 2). To the best of our knowledge, this article is the first to use such a modeling technique to investigate this issue. Thus, we develop a new formal model that can be replicated and used by international security scholars when analyzing military power, particularly the consequences of force employment.

Overall, we aim to formally estimate, measure, and question the relation between the intensification of military interventions on the one hand and a degradation of the availability of military equipment on the other, in order to discuss its consequences on the overall capabilities of the French Armed Forces. As discussed in more details below, the French armed forces are an interesting example because France explicitly aim at developing capabilities for the entire spectrum of conflict, has been engaged in a multiplicity of military interventions since the end of the Cold War and, as a medium-sized power, is thus more illustrative of a trade-off that many countries may encounter in generating military power. The topic has recently been put on the national agenda (Zajec 2018), especially during the mandate of General Pierre De Villiers's former chief of staff of the French Armed Forces (De Villiers 2017). As stated by the French NAO, 'The ability to provide and renew the resources for military interventions depends on the possibility of regenerating at a sufficient rate both the major equipment and operational capacity of military personnel with an adequate training. This is not currently ensured at the sufficient level' (Cour des Comptes 2016, 113). Thus, we explore the extent to which a country can reach a critical threshold in terms of engagement in conflicts, given the resources allocated to defense and the renewal capabilities of its armed forces.[1] We used an original database to assess the extent to which military interventions affect the evolution of the domestic equipment availability rate. In our empirical estimation, we use two proxies to measure the intensification of military interventions: (i) the number of squared kilometers where France deployed troops and (ii) the real budgets allocated to military interventions. We consider other relevant factors identified – or suggested – in the literature (age, size of fleets). The data cover the 1997-2017 period and 75 different types of military equipment. Our results show that military interventions negatively affect availability rates, the effect being particularly pronounced in the case of helicopters, fixed-wings aircrafts and main battle tanks, three categories of equipment which would be required for high-intensity operations.

The remainder of this paper is organized as follows. Section 1 discusses the rise of military interventions in the post-Cold War era and the related trade-offs in the generation of military power. Section 2 analyzes the deep changes in the nature of French military interventions over 20 years (1997-2017) in light of this broader context. Section 3 presents the empirical model and the data used to estimate the relationship between an increasing operational tempo and the availability of major French military equipment in 1997-2017. Section 4 presents and discusses the results, while the conclusion discusses areas for future research.

Military Interventions and the Trade-Offs in Generating Military Power

In Robert Art's classic taxonomy, military power has four functions: defense, deterrence, compellence and 'swaggering' (Art 1980). Defense refers to the deployment of military power with the aim of warding off an attack or minimizing damage if attacked; deterrence is the use of military power to prevent an adversary from acting in an undesirable way; compellence is the use of military power to force an adversary and change its behavior, and swaggering is the use of military power to increase the state's international status. The end of the Cold War has ushered an 'intervention era' during which states (in particular but not exclusively Western states) have been much more willing to use force abroad through military interventions. For example, while the United States had been engaged in forty-six military interventions between 1948 and 1991, that number was increased five-fold to 232 military interventions between 1992 and 2021 (Congressional Research Service 2021). Most importantly, the nature of those military interventions has evolved. While military interventions designed to increase deterrence dominated the US military interventions during the Cold War, most US military interventions post-1991 focused on humanitarian assistance, stability operations or counterinsurgency (Kavanagh et al. 2019). It thus seems that the 'deterrence' function of military power has been superseded by the 'compellence' and 'swaggering' functions, through the rise of military operations abroad.

This raises the question of the factors driving the rise of interventions. Based on an extensive literature review, a report from the RAND corporation identified ten factors which, in isolation or combination, can lead states to initiate military interventions (Kavanagh et al. 2021). These ten factors are external threats to sovereignty, concerns for the regional balance of power, alliance commitments, national status and prestige, domestic politics and legitimacy, co-identity group populations in the target country, economic interests, the personality and beliefs of senior leadership, ideology, and, finally, military capabilities required for intervention. Beyond these generic factors, the 'intervention era' led by the Global North and that followed the end of the Cold War was clearly anchored in a broader intellectual project of liberal internationalism (Ikenberry 2018; Paris 1997), and a shift in security cultures emphasizing risk management (instead of threat reduction), thus fostering an attitude of permanent worldwide policing through military means (Heng 2018; Schmitt 2020).

Specifically, military interventions from the Global North went through three main phases since 1991 (Clausen and Albrecht 2021). The first phase, immediately following the end of the Cold War, was characterized by an understanding of conflicts as being the product of political instability, ethnic grievances, and poverty (Lacina 2004). The identified solution was then to assist allegedly fragile/failed states and support them in transforming into Western-style polities. The 9/11 attacks triggered a second era of intervention, explicitly designed to counter the threat of transnational jihadist groups. This led to comparatively large-scale military interventions involving combat operations, particularly in Iraq and Afghanistan, and a refocus of the security/governance nexus around 'counter-insurgency' activities (Smith and Jones 2015). Finally, faced with the limited strategic effectiveness of large-scale deployments, Western states have pivoted towards a third stage of interventions. This third period, from the early 2010s onwards, is characterized by a combination of reliance on local partners (sometimes branded as 'local ownership') in order to facilitate risk-shifting and deniability (Krieg and Rickli 2019), and by the gradual distancing from the battlefield, leading to debates about an emerging 'remote warfare' (Jeangène-Vilmer 2023; Rauta 2021). Thus, it is clear that military organizations have been employed in a multiplicity of different types of interventions over the past 30 years.

Observers have raised doubts about the strategic effectiveness of such military interventions, especially in the wake of the Iraq and Afghanistan interventions. Critics have noted that military interventions alter the political fabric of the local communities with unexpected results (Downes and Monten 2013; Peksen 2012), create dilemmas between security and governance that are almost impossible to solve (Lake 2016; Paris and Sisk 2009) and foster an 'interventionist industry' that becomes insensitive to local needs (Autesserre 2014). The problems can be magnified in extreme cases of interventions, such as foreign-imposed regime change (Downes 2021).

However, despite their apparently limited strategic relevance, it is clear that Western policymakers have used military interventions as an important foreign-policy tool, which has shaped the transformation of Western armed forces in the post-Cold War era towards expeditionary forces (Farrell et al. 2013). For example, European armed forces have developed dedicated brigade-level units and operational headquarters with the explicit goal of being able to conduct military operations abroad (King 2011), although the pace of transformation was not the same within NATO, creating fears of a 'transatlantic gap' in terms of resources and deployed technologies (Teriff, Osinga and Farrell 2010 2007). Similarly, special forces units and quick reaction forces have been privileged in terms of resource allocation, another sign of the onus being placed on expeditionary capabilities since the end of the Cold War.

Yet, the emphasis on military interventions highlights trade-offs between the creation of military power and military effectiveness. Military effectiveness can be defined as 'the degree to which militaries can accomplish at acceptable costs the goals assigned to them by political leaders' (Reiter 2017a). Trade-offs in military effectiveness can relate to political support, security threats, and war-fighting. Examples of such trade-offs related to war fighting include stoking up nationalist sentiments in the troops versus dehumanization of the opponent's civilian and soldiers (with the risks of facilitating war atrocities); eliminating legitimate targets versus risking civilians' lives (thus fueling sympathy for insurgent groups); emphasizing force protection at the expense of mobility and intelligence collection, etc (Reiter 2017b). We argue that military interventions introduce another type of trade-off: between the force structures and skills (and the associated procurement and training programs) designed for stability and counter-insurgency operations on the one hand, and the force structure and skills designed for high-intensity warfare on the other. Therefore, conducting military interventions decreases one's ability to conduct high-intensity warfare.

Stability and counter-insurgency operations require specific military skills and force structures to be more effective. Because they put an emphasis on restraint in using military force, at least in the recent Western experiences (Ucko 2016), these operations mostly rely on light infantry and special operations forces with support from armored, artillery and air forces. They also require peculiar military skills, including small unit leadership, decentralized control, restraint and a dedicated doctrine fit for purpose (Felter 2017; Friesendorf 2018). In fact, adapting military organizations for acquiring those skills has historically been difficult, whether in Vietnam or in the conflicts of the past two decades (Farrell, Osinga, and Russel 2013; Fitzgerald 2013; Ucko 2009). On the other hand, high-intensity operations rely on a different force structure: armored troops, artillery, and air forces carry the heavy weight of the operations with support from the other arms. These operations also require a specific doctrine for combined-arms maneuver and jointness (the integration of the different services in a collective action), and specific skills for which soldiers need to be trained. In other words, we argue that it is extremely difficult (and probably impossible) to create an all-purpose force that would be equally effective on the entire spectrum of conflict since the requirements of stability and counterinsurgency operations are at odds with those of high-intensity warfare.

Because they had to adapt to stability and counterinsurgency operations in the context of reducing formats, Western armed forces developed a certain set of skills and acquired certain capabilities that should make adjusting back to the requirements of high-intensity warfare more difficult. In that regard, the role of recent military interventions is important since these interventions exhaust resources (especially capabilities used in all conflict types, such as helicopters) and drive transformation towards a specific format for the armed forces. To explore the role of military interventions in creating a trade-off between stability-focused or high-intensity focused armed forces, we analyze the case of the French armed forces since 1991.

France is an interesting case for at least two reasons. First, French defense officials always claim that the French armed forces can participate in operations on the entire spectrum of conflict, meaning military activities ranging from peacekeeping to high-intensity warfare (Pezard, Shurkin, and Ochmanek 2021). In terms of defense procurement, this is translated into two major modernization programs for the army. The first one, nicknamed 'SCORPION', has been in the works since 2005 and was officially launched in 2014. It consists of a broad modernization of the so-called 'median segment' of the army, introducing new infantry equipment, Armored Personal Carriers (APCs) and Infantry Fighting Vehicles (IFVs), developing a new combat management system and modernizing the Main Battle Tank (MBT) 'Leclerc'. Most of the program should be completed by 2025. At the same time, the army initiated preliminary works for the program 'TITAN,' which designates the modernization of the 'heavy segment' of the army. This includes the development of a new MBT, new long-range artillery capabilities, air-defense systems, and a new attack helicopter. The air force has adopted the multi-role 'Rafale' fighter, which has been used in many operations (including Afghanistan and Libya) since the early 2000s, but also has high-intensity combat capabilities. Since the late 2010s, the Air Force has also started developing a new air combat system, which should be introduced by 2040. Finally, the navy is developing a new aircraft carrier, and modernizing its frigates while updating its two classes of submarines (SSBNs and SSNs). All these programs signal the French's ambition to cover the full spectrum of operations without, in principle, suffering from the trade-off identified earlier (Rynning and Schmitt 2018).

Second, France has been an interventionist country for the past thirty years, which makes it an ideal case to test the impact of interventions on the generation of military power. Since 1962, France has been conducting about 160 military interventions, the vast majority of those being initiated after the end of the Cold War, and 44% of which taking place in sub-Saharan Africa (Pannier and Schmitt 2021). There are three main reasons explaining the French proclivity to use force: 'the institutional mechanisms facilitating the use of military power; elite perceptions of and narratives about France's role in the world; and experiences of deployments of military power, which shape mental maps and preferences relating to the use of force' (Pannier and Schmitt 2019, 898). Therefore, the French example plays the role of a 'crucial case' in exploring whether a trade-off between military stability-focused or high-intensity focused armed forces exists, and how it operates: it is a country that has maintained a high level of military ambitions and explicitly claims to be able to operate at all levels of conflict, while at the same time having participated in many military interventions in different settings. Considering its relative size, France is more likely to be impacted by a potential trade-off than a superpower such as the United States, but is also more illustrative of the dilemmas that middle and major powers will face when building their armed forces.

The Changing Nature of French Military Interventions

Since 1995, France has conducted approximately 106 operations outside of its national territory. Figure 1 shows the evolution of French military interventions credits in volume, from 1977 to 2017. The two peaks of 1993 and 2011 respectively correspond to the operations in the Balkans and Libya. Notably, the engagement in two other operations – the Gulf War (1991) and the Serval operation in Mali (2013) – cost up to EUR 1 billion. The annual cost of military interventions is currently up to EUR 1.2 billion (approximately 3.75 % of the total defense budget of the country).

From the end of the 1970s to 2017, several periods are identified. The first period covers the early 1980s to the mid-1990s, with an increase in military interventions spending. The second period comprises 1994 to the beginning of the 2000s and corresponds to a decline in French military interventions. Finally, in the period from the early 2000s to 2017, military interventions costs increase rapidly (multiplied by 2 in volume between 2000 and 2017). This period starts with the intervention in Afghanistan and includes subsequent operations in Libya (*Harmattan*), Mali (*Serval*), the Central African Republic (*Sangaris*), the Sahel (*Barkhane*), or Syria and Iraq (*Chammal*). This increase in budget was a consequence of the growing involvement of the French Armed Forces in military operations, especially in the fight against terrorist groups abroad. Geographically, military interventions are concentrated in a few places. In 2015, according to the French *Cour des Comptes* (French NAO), 70% of military interventions costs were concentrated in Iraq/Syria (Operation *Chammal*), and the Sahelo-Saharan strip (Operation *Barkhane*) (Cour des Comptes 2019).

Consequently, the increase in military interventions cost per soldier is caused by increasing non-personal costs. Following Hébert (2008), the pre-2008 period can be considered 'labor intensive' because most military interventions costs are personnel costs. By contrast, in the post-2008 period, military interventions can be considered more 'capital intensive,' that is, less intensive in manpower cost, with increasing maintenance, ammunition, and infrastructure costs (Malizard and Droff 2018). Military interventions have changed for almost 10 years and become more expensive, with fewer military personnel and more 'capital-intensive' operations over larger territories under harsher climatic conditions. To this trend, we add other qualitative transformations of military interventions that can be summarized by two features: time and space.

Regarding time, the average duration of a military operation is close to 15 years. Longer military interventions can nevertheless easily be identified. For example, the intervention of the armed forces in Chad started in 1965, and French troops still operate in and from the country (with some variation in the number of soldiers). A similar assessment can be made about the military intervention in the Central African Republic (CAR), which began in 1965, or in Congo, which began in 1967 (Goya 2022; Powell 2017). Other examples can be found in the Middle East (e.g. Lebanon) or the Balkans. Only two military operations were engaged in a multinational coalition based on a resolution of the UN Security Council with a significant volume of means and lasted a few months: the First Gulf War (7 months) and the intervention in Libya (5 months). Notably, because of the digitalization of conflicts, increasing speed of the spread of information, and increasing role of intelligence, the response time has continually decreased in order to ensure strategic superiority. Digitalization also contributes to increasing what the literature calls 'operational tempo' (Rynning, Schmitt, and Theussen 2021).

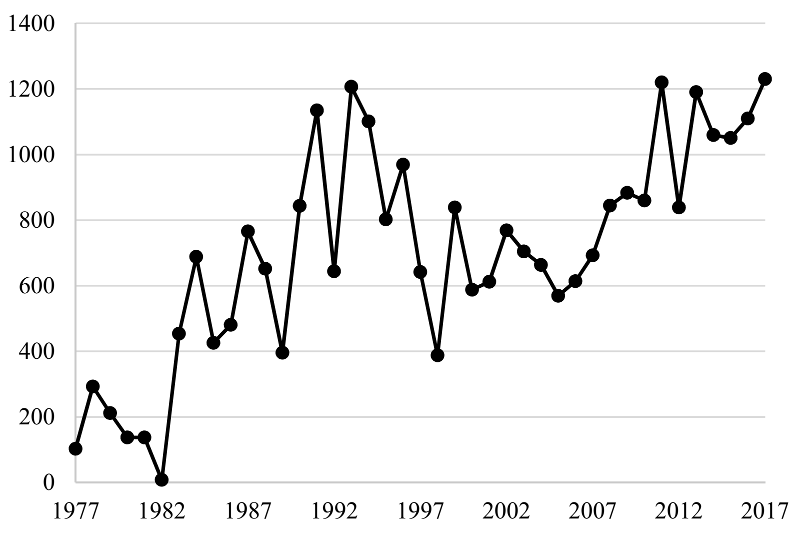

Figure 1. Cost of French military interventions 1977-2017 in volume, EUR millions. Source: authors, data from Hébert (2008) and the French Ministry of Defense (EUR [2010])

The evolution of a military interventions also has a spatial dimension. The French Armed Forces must control and engage in increasingly larger spaces. To prepositioned military bases (e.g. in former colonies such as the Ivory Coast, Senegal, or CAR, or diplomatic partnerships such as a military base in the United Arab Emirates), we must add the recent conditions of engagements located in larger zones such as Afghanistan, the Sahel-Saharan strip, or Iraq-Syria. It is also necessary to consider the increasing importance of new missions, such as fighting against maritime piracy or illegal fisheries, that contribute to enlarging the geographical perimeter for potential military operations, especially for the French Navy.

Figure 2 illustrates this trend and shows that the number of squared kilometers by deployed soldier has been multiplied by 8 from 1990 to 2017. The area of the *Barkhane* Operation in the Sahel (Mauritania, Mali, Burkina Faso, Niger, and Chad) is as vast as Europe. Such an extension of the geographical perimeter has consequences for the logistical footprint, wear of equipment, and maintenance and operating costs.

In addition to such a 'size effect,' we must consider zones with tough climatic conditions. According to the literature, environmental operating conditions is a major factor potentially affecting the exhaustion of equipment – especially for wheeled and tracked vehicles and rotary-wings aircraft (DoD 2007) – and hence, their availability in the long term. In the case of France, this phenomenon has been documented in many public reports (Cour de Comptes 2016).

Overall, this operational tempo leads to the overuse of military systems, which degrade faster than they would under nominal conditions (e.g. training missions and routine exercises). This effect has also been reported in other countries. In the U.S.A., the Congressional Budget Office (CBO) showed that trucks from the US Marine Corps and US Army have covered approximately 10 times more miles per year in Iraq or Afghanistan than during peacetime (CBO 2005). In 2007, a US study conducted by the Office of the Under Secretary of Defense (OUSD) found that high-tempo operational usage accelerated the rate of wear on nine selected systems from 19% (C-17 transport aircraft) to 344% (Abrams tanks M1A2), with an average potential acceleration factor of 80% for the whole sample (DoD 2007).

France is no exception to the rule. For example, the VAB (small light armored vehicles used by French land forces) is wearing 6.7 times faster in military interventions than in nominal use conditions on domestic soil (Cour des Comptes 2015). This overuse of equipment is combined with the increasing cost of equipment owing to aging. For example, some helicopters (e.g. Gazelle), light armored vehicles (e.g. VAB), or scouting and anti-submarine warfare aircraft (e.g. Atlantic 2) are aging worryingly. In military operations, because of emergency and operational

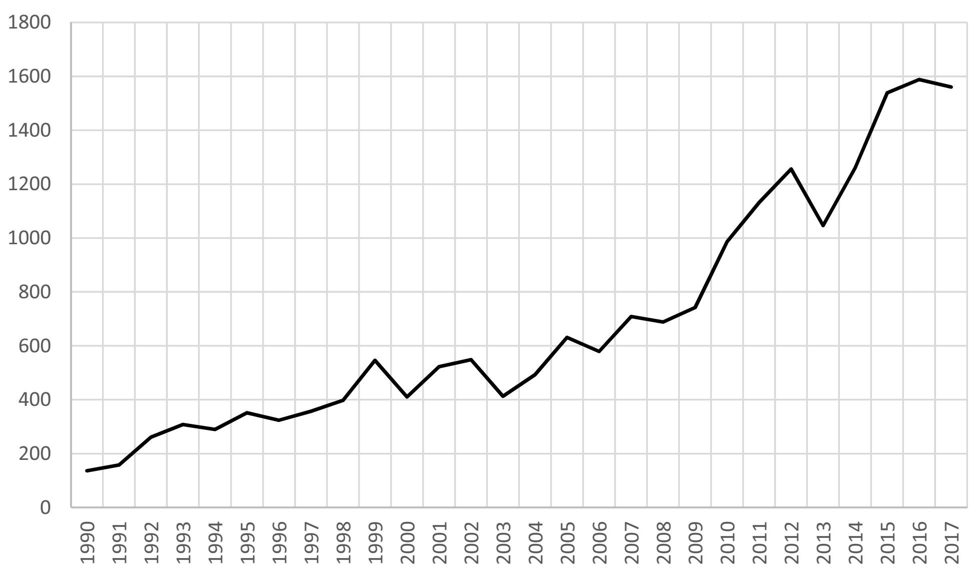

Figure 2. Number of squared kilometers where France has deployed troops, by deployed soldier (1990-2017). Source: authors, data from IISS, Military Balance

need, the availability of equipment can be considered 'high,' that is, with 80% or even 90% rates. Given the limited budget and resources allocated to the armed forces, the domestic availability is difficult to keep constant (or even tends to decline) because the operations tempo remains high.

Empirical Model and Data

Dependent Variable

The analysis is based on the idea that the availability rate of equipment on the national territory (i.e. domestic rates we collected) is closely related to the availability rates in military interventions. A high rate of availability in military interventions generates industrial and economic pressures on the maintenance repair and overhaul supply chain and this situation affects the availability of platforms in the national territory, the training of armed forces, and the future intervention capabilities of the country such as other military interventions or high intensity warfare (Droff 2013). The availability of platforms in military interventions, therefore, conditions the availability of platforms in the national territory because of the favored allocation of budgets to military interventions that leads to the rationing of resources in France. The immobilization of equipment is observed because of the postponement of repairs (due to lack of manpower or postponement of spare parts orders) and this has a direct impact on the domestic availability rates of equipment in France. This has a direct impact on the domestic availability of equipment in France. Finally, a knock-on effect on the training and education of troops and therefore on the operational potential of the armed forces is likely to be observed.

To support this idea, Table 1 compares the availability rates in military interventions with the domestic availability rates for a sample of 17 selected military platforms (aircraft) with available data for both availability rates from 2008 to 2016. The average availability rates in military interventions is 81.5%, whereas the average domestic availability rate is 37 point of percentage (pp) less.

Table 1. Average availability in military interventions and on national soil (2008-2016).

	Availability in military interventions	Domestic Availability	Difference
Average	81.5%	44.1%	37.4pp
Air force			
Rafale Air	92.6%	50.0%	42.6pp
Mirage 2000D	93.3%	38.8%	54.6pp
Mirage F1 CR	91.2%	40.1%	51.1pp
C160	74.0%	46.9%	27.2pp
C130	65.7%	43.7%	22.0pp
CASA	88.6%	60.9%	27.8pp
Fennec Air	86.0%	54.1%	31.8pp
Caracal Air	84.5%	45.7%	38.8pp
Naval Aviation			
SEM	87.4%	38.0%	49.4pp
Rafale M	88.6%	50.1%	38.4pp
Hawkeye	82.7%	45.7%	37.0pp
ATL2	83.4%	38.0%	45.4pp
Army			
Gazelle	79.2%	53.0%	26.1pp
Puma T	72.7%	41.4%	31.2pp
Cougar T	74.3%	30.2%	44.0pp
Caracal T	70.1%	40.6%	29.5pp
Tiger	71.9%	32.4%	39.5pp

Source: author's calculations, sample based on public parliamentary data (144 observations of availability rates in MOA and 147 observations of domestic availability rates).

We thus argue that the domestic availability rate is the best proxy for measuring the ability of a country to prepare for a full spectrum of military operations (including military interventions and high intensity warfare). First, a low domestic availability rate (for instance due to military interventions) has an opportunity cost in terms of training for soldiers (Malizard and Droff 2018): in a context of many military interventions, lack of military and budgetary resources implies that soldiers are likely to be undertrained compared to NATO targets (Cigolotti and Gréaume 2020). Second, a trade-off may arise in case of simultaneous operations because the same equipment is used both for military interventions and other missions such as high-intensity warfare. Third, both capital and labor are complementary. However, as France has a 'capital intensive' armed force (high level of equipment by soldier), investigating the equipment side is a satisfactory proxy for military capabilities, and explains why we treat domestic availability rates as our dependent variable.

Model

We aim to disentangle the effect of an increasing operational tempo from the potential effect caused by the 'normal' aging and fleet size. In addition, if all equipment is probably affected by the intensification of military interventions, such an effect can also be a different variable from one piece of equipment to another or from one group to another, depending on the intensity with which these assets are used in military interventions. We use multilevel analysis, a set of statistical techniques for examining data with sources of variability nested within one another (Snijders and Bosker 1999).

In our case, because the observations are organized into non-overlapping groups, linear multilevel models can be applied (Figure 3). Our panel dataset enables a three-level estimation because observations collected by equipment by years (level 1; yearly measurements) are nested in 75 pieces of equipment (level-2; individuals; e.g. Rafale aircraft, Gazelle helicopter, Tiger helicopter), which are nested in 22 more-general groups (level-3; groups; e.g. aircraft fighters, light helicopters; see appendix 1 for a list of the 22 groups). Finally, these 22 groups are nested within the 4th level with only four groups (armored vehicles, helicopters, ships, and aircraft). This fourth level is not formally used in the multilevel analysis.

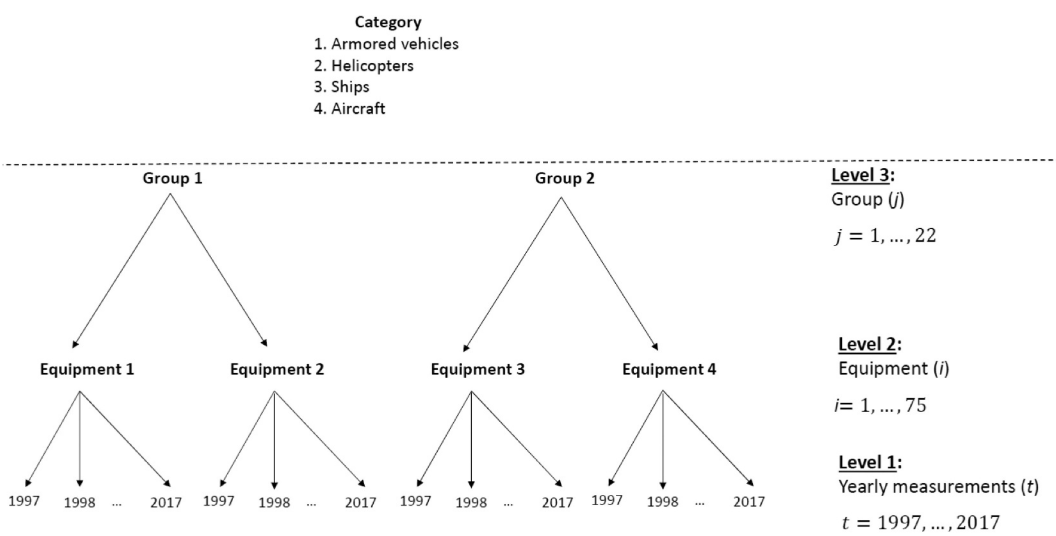

Figure 3. Hierarchical structure of the data. Source: authors

In a multilevel dataset, observations in the same group are supposed to be correlated because they share common group-level random effects. In other words, individuals within a group are generally not independent of one another. Two reasons can justify this modeling choice so that unobserved group characteristics are of interest. First, strategic and tactical factors are not considered in our empirical analysis because of the absence of available data, but readers may posit that these factors are not independent of each other (i.e. why Rafale aircraft are not chosen compared with the Mirage aircraft for a certain type of mission). Second, industrial factors are crucial to availability rates. We observe that it is impossible to measure them properly because maintenance contracts are not public information.

Regressions in mixed models allow two types of effects: 'fixed effects, meaning intercepts and slopes meant to describe the population as a whole, just as in ordinary regression; and also random effects, meaning intercepts and slopes that can vary across subgroups of the sample' (Hamilton 2013, 187). The idea is to obtain trends in availability rates, which are a combination of the overall trend (fixed effects) and variations on that trend (random effects) for each group. The structure of mixed models enables us to consider the role of the particular context in which each piece of equipment is evolving. The specificity of such models particularly makes sense in our case because the situation will probably differ by, for example, the heterogeneity of military equipment (e.g. technology), their doctrinal use in military operations, and the conditions where they are maintained.

We can write the following panel data regression model:

$$r_{ijt} = x'_{ijt}\beta + y'_t\gamma + u_{ijt},\ i = 1,\ldots M,\ j = 1,\ldots,N_i,\ t = 1,\ldots,T_i \quad (1)$$

where the dependent variable r_{ijt} is the domestic availability rate of the ith equipment for the jth group for the tth period. x_{ijt} denotes a vector of k explanatory variables related to equipment and y'_t refers to variables related to the operational tempo. Note that there is no variation 'between' for the proxy of operational tempo, because no precise information is available at this level (e.g. the exact number of Rafale deployed in operation in a precise zone in a given country is not public information for security reasons). However, the *Military Balance* provides yearly systematic information on the areas (countries, seas, regions) where countries deployed military troops. This also justifies the use of a mixed model to capture some effects that would not be modelled by idiosyncratic variables such as age of equipment or the size of fleets. In equation (1), $x'_{ijt}\beta + y'_t\gamma$ denotes the 'fixed part' of the model as its effect is unchanging across categories and equipment. To consider random effect at individual or group levels, we include random intercepts. The disturbance of equation (1) is then given by

$$u_{ijt} = \mu_j + v_{ij} + \varepsilon_{ijt},\ i = 1,\ldots M,\ j = 1,\ldots,N_i,\ t = 1,\ldots,T \quad (2)$$

Where μ_j and v_{ij} are the random part of the model, where 'random' simply means here 'allowed to vary'. Hence, μ_j denotes the jth group unobserved group-specific effect, assumed to be i.i.d. $(0, \sigma^2_\mu)$; v_{ij} denotes the nested effect of the ith equipment in the jth group, assumed to be i.i.d. $(0, \sigma^2_v)$. ε_{ijt} denotes the remainder disturbance, also assumed to be i.i.d. $(0, \sigma^2_\varepsilon)$. The μ_i's, v_{ij}'s, and ε_{ijt}'s are assumed to be independent of each other and among themselves. Notably, this model allows for an unequal amount of equipment in each group and a different number of observed periods across groups (Baltagi, Song, and Jung 2001).

Given our data, the specifications of the general model take the two following forms

$$r_{tij} = \beta_{0ij} + \beta_1 \ln\mathrm{AREA}_{ijt} + \beta_2 \ln\mathrm{AGE}_{ijt} + \beta_3 \left(\ln AGE_{ijt}\right)^2 + \beta_4 \ln QUANT_{ijt} + \beta_5 \left(\ln QUANT_{ijt}\right)^2 + u_{ijt} \quad (3)$$

$$r_{tij} = \beta_{0ij} + \beta_1 \ln\mathrm{BUD}_{ijt} + \beta_2 \ln\mathrm{AGE}_{ijt} + \beta_3 \left(\ln AGE_{ijt}\right)^2 + \beta_4 \ln QUANT_{ijt} + \beta_5 \left(\ln QUANT_{ijt}\right)^2 + u_{ijt} \quad (4)$$

$\ln AREA_{ijt}$ is the log of the total surface – maritime and land surfaces – where the French Armed Forces are supposed to be deployed. We use it as a proxy to assess the size of the territory in which the armed forces are supposed to officially operate. $\ln AREA_{ijt}$ is calculated per year and takes the same value for each piece of equipment each year. $\ln BUD_{ijt}$ is the log of the cost of military interventions in volume. This variable is available only per year and has the same value for each piece of equipment each year. These variables are proxies for operational tempo, $\ln AREA_{ijt}$ is more related to the operational activity, whereas $\ln BUD_{ijt}$ to monetary costs.

Because operating an older fleet will probably be an underlying cause for a decrease in availability, we include the age of fleets in the model. $\ln AGE_{ijt}$ is the log of a calculated proxy of the age of a given piece of equipment *i* in group *j* at time *t*; a quadratic term is also included to account for any 'bathtub-curve effect.' $\ln QUANT_{ijt}$ is the log of the quantity of a piece of given equipment *i* in service in group *j* at time *t*. The question of a scale effect is investigated because of a quadratic term.

β_0 is the constant of the fixed effect part of the model. β_1, β_2, β_3, β_4, and β_5 are the coefficients to be estimated, and u_{ijt} is the error term defined in equation 2.

To generalize the effect of military interventions on the availability of equipment (measured either by a geographical or a financial proxy), a negative sign of the coefficient β_1 is expected as a response of the availability rate to the increasing operational tempo (measured by the total size of the territory, i.e., *AREA* or by budgets, i.e., *BUD*).

Based on the literature, β_2 is expected to be positive, whereas β_3 is expected to be negative to show some quadratic effects. The sign and significance of these coefficients can suggest an inversed so-called 'bathtub curve,' widely used in industrial economics and maintenance literature.[2] We expect no a priori sign for β_4 and β_5, and readers can question, for example, the existence of the scale effect. Thus, we test different specifications with both terms for the variable *QUANT* (linear and squared terms).

To justify for equipment unobserved specific effect or group unobserved specific effect, μ_i and v_{ij} are respectively expected to be significant.

Finally, to estimate the model, we use the mixed command implemented in the Stata software. The econometric method of estimation is the maximum likelihood estimation (MLE).

Data

Our original dataset covers three different areas of information – equipment (e.g. domestic availability rates, age, size of fleets), military interventions expenditures, and areas of deployment – collected from various sources.

In this analysis, availability is the technical availability rate of equipment in the national territory. Data on technical availability rates of equipment are available from 1997 to 2017 ($t = 1997, \ldots, 2017$). The source is public with several parliamentary reports released since the beginning of the 2000s (National Assembly, Senate, and French NAO reports). The data cover 75 major types of military equipment (aircraft, helicopters, ships and attack submarines, light armored vehicles, and tanks; $i = 1, \ldots, 75$).

This original database is built by referring to released parliamentary reports. Not all the equipment has 21 observations, which is due to several reasons. First, because of the strategic characteristics of the availability of equipment, some data are sometimes missing because they have become 'classified' at a given period, namely, when equipment is related to nuclear deterrence activities (e.g. SSN class submarines or Mirage 2000 nuclear aircraft fighters). Second, some weapons systems only entered into service at the end of the period, and reciprocally, other equipment were withdrawn from service during the considered period. Equipment is nested in groups ($j = 1, \ldots, 22$). The general trend for this variable from 1997 to 2017 is shown in Figure 4.

The solid line shows a decreasing trend in availability over the period. A strong decrease from 1997 to 2002, followed by a short increase and a sort of plateau. From 2010 until today, the decrease started again and the global level of availability in 2017 is, on average, 20 points lower than at the end of the 1990s. In addition, the pattern of individuals' rates suggests a higher dispersion of data at the end of the period and a form of heterogeneity, depending on a piece of a type of equipment or categories of equipment.

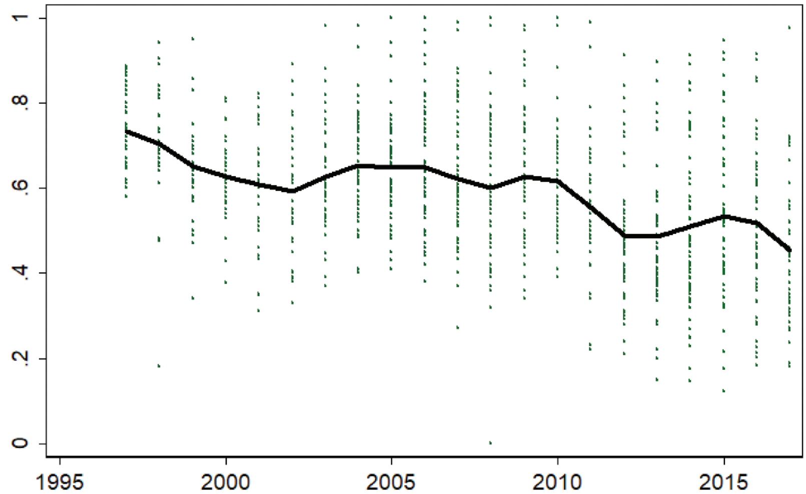

Figure 4. Availability rate of fleets, 1997-2017 (all equipment). Source: authors, from parliamentary reports; dots are yearly observations, the solid black line is the yearly average of availability rates

The exact average age of equipment is not public information. Thus, we calculate a proxy of the age of each platform with the following rule: the considered year less the year of entry into service of the equipment. For example, the Tiger helicopter that entered active service in 2005 is assumed to be 12 years old in 2017.

Data on the size of fleets, namely, the number of systems in service in the armed forces, are from the Military Balance (MB) released by the International Institute for Strategic Studies (IISS) between 1997 and 2017.

The main source of information on deployment (troops and locations) is from the MB released by the IISS between 1997 and 2017. We aim to measure the total surface of the territories where France deployed troops. For each year, all the countries where France deployed troops are noted because of the category 'Deployment" in the MB.[3] The total surface area where France has been deployed during the period is estimated by summing the total number of squared kilometers by year. When the MB wrote a country or a zone where France deployed military troops we count the total surface of the zone. For example, in 2015 France deployed troops in Mali, so the total area of the country[4] is counted in our variable *AREA* for this year. For each year, we can sum the total area in terms of squared kilometers. Note that, based on the construction of the variable, there is no variation between individuals.[5]

Unfortunately, there is no complete information on the number of platforms deployed in military interventions.

Data on military interventions expenditure are expressed in volume (constant EUR [2010]). Data can be found in the reference article by Hébert (2008) and in the OED (*Observatoire Economique de la Défense*) Website, in its statistical yearbook (for the recent period). In the analysis, the data are considered a proxy for operational tempo and our main explanatory variable. Again, based on the construction variable, there was no variation between the individuals.

Results and Discussion

We first present and discuss the results of what we call the general model based on equation (3), namely, the model for all equipment (armored vehicles, helicopters, ships, and aircraft), and alternative specifications based on equation (4). A test of random effect (RE) against fixed effect (FE) doesn't lead to reject the null hypothesis that RE provides consistent estimates (Cameron and Trivedi 2010).[6] In addition to the nature and structure of dataset (nested data), this is another element in favor of a multilevel analysis.

Results

First, the likelihood-ratio test confirms that the mixed model, with both fixed effects and random intercept, offers a significant improvement over a linear regression model with fixed effects only (Table 2). Second, in the random part of the model, both estimated variances of the constant per group and per equipment are significant. This finding shows that the random effect is beneficial. Considering the log likelihood criterion, a small improvement is found between model 1 (M1) and the general model 2 (M2), with squared terms on both age and quantity. Thus next, we comment on M2.[7]

Table 2. Results of the general mixed model estimation.

Variable	M1	M2
Intercept	3.999***	4.025***
	(0.375)	(0.373)
ln(AGE)	0.088***	0.099***
	(0.028)	(0.028)
ln(QUANT)	0.005	−0.054***
	(0.008)	(0.028)
ln(AREA)	−0.202***	−0.200***
	(0.022)	(0.022)
ln(AGE)^2	−0.031***	−0.032***
	(0.006)	(0.006)
ln(QUANT)^2		0.009***
		(0.003)
var(GROUP)	0.011***	0.009***
	(0.005)	(0.004)
var(EQUIP)	0.006***	0.006***
	(0.001)	(0.002)
var(RESID)	0.011***	0.011***
	(0.001)	(0.001)
Obs.	1065	1065
AIC	−1555.393	−1564.196
BIC	−1515.627	−1519.459
LL	785.696	791.098

Standard errors in parentheses, *p<0.1, **p<0.05, ***p<0.01.
AIC, Akaike information criteria; BIC, Bayesian information criteria; and LL, log likelihood

The estimation shows significant results consistent with our initial intuition. After adjusting for the nested-level error structure, we find that the effect of military interventions is negative and significant ($\beta_1 = -0, 2$). When the number of squared kilometers where French troops are deployed increases by 10%, the domestic availability rate of equipment decreases by 2pp. All other things being equal, the negative effect of military interventions is higher than the effect of all the covariates. Operational tempo, measured by area, is then a critical factor in determining availability rates. In other words, we can empirically demonstrate that an increased number of military interventions decreases the availability of military equipment, thus posing a dilemma to defense planners.

Considering age, at this global level and all other things being equal, our results show a concave relationship between availability and age ($\beta_2 = 0.099$ and $\beta_3 = -0.032$). The availability rate is lower for equipment in its infancy and then increases to reach a plateau because of learning effects and the increasing reliability of the systems. This result is in accordance with the 'bathtub-curve' effect but is shown here only in its two first parts (part 1, systems in an infancy period with a high probability of failure, and part 2, maturity of systems with a plateau).

Regarding the size of fleets, our results show that smaller fleets have higher rates on average with however a decreasing rate (concave relationship) as expressed in M2 (linear approach – M1—does not have a significant effect). This finding favors a higher importance given to some small – but very strategic – fleets such as aircraft carriers, nuclear attack submarines, and more generally, ships. When the quantity increases, it becomes easier to increase a military effect with, however, a lower availability rate (e.g. large fleets of armored vehicles or some aircraft).

From the random part of the model, we observe that the residual between-group variance is estimated as 0.009 compared with a residual between-equipment variance estimated at 0.006 and an estimate of 0.011 for the residual within-equipment deviation. The intraclass correlation (ICC) is defined as the proportion of variance between clusters (Hox, Moerbeek, and Schoot 2018), namely, the proportion of variance that can be explained by the clustering or grouping structure .[8] For our level 'group,' the corresponding estimated residual is 0.34.[9] Thus, 34% of the variance in the availability rate that is not explained by the covariates is because of unobserved group-specific characteristics. The same calculation shows that 23% of the variance not explained by the covariates is due to unobserved equipment-specific characteristics. Finally, 57% of the variance not explained by the covariates was due to unobserved invariant equipment-specific characteristics nested in groups. These relative high values of ICC in our results show the degree of dependence of our observations.

In Table 3, Models 3 and 4 are estimated with the budget in military interventions (*BUD*) as the main explanatory variable (see the specification in equation 4). The same comments that were made regarding the results with the specification in equation (3) still apply. In addition to the hierarchical structure of our data, we check the possible effect of time on our results that are based on a longitudinal dataset. We run the same general models and add a time trend (M5 and M6); this does not change the main results.

Table 3. Alternative specifications of the general mixed model estimation.

Variable	M3	M4	M5	M6
Intercept	1.456***	1.497***	15.586***	14.356***
	(0.115)	(0.115)	(2.485)	(2.432)
ln(AGE)	0.095***	0.106***	0.077***	0.078***
	(0.029)	(0.029)	(0.028)	(0.028)
ln(QUANT)	0.006	−0.053	−0.054***	−0.055***
	(0.008)	(0.020)	(0.019)	(0.019)
ln(BUD)	−0.124***	−0.122***	−0.053***	
	(0.016)	(0.016)	(0.021)	
$\ln(AGE)^2$	−0.035***	−0.036***	−0.021***	−0.022***
	(0.006)	(0.006)	(0.007)	(0.007)
$\ln(QUANT)^2$		0.008***	0.007***	0.008***
		(0.003)	(0.003)	(0.003)
Time trend			−0.007***	−0.006***
			(0.001)	(0.001)
ln(AREA)				−0.110***
				(0.031)
var(GROUP)	0.011***	0.009***	0.008***	0.008***
	(0.005)	(0.004)	(0.004)	(0.004)
var(EQUIP)	0.007***	0.007***	0.005***	0.005***
	(0.002)	(0.002)	(0.001)	(0.001)
var(RESID)	0.011***	0.011***	0.011***	0.011***
	(0.001)	(0.001)	(0.000)	(0.000)
Obs.	1065	1065	1065	1065
AIC	−1537.455	−1545.351	−1573.974	−1580.056
BIC	−1497.69	−1500.614	−1524.267	−1530.349
LL	776.728	781.678	796.987	800.028

Standard errors in parentheses, *p<0.1, **p<0.05, ***p<0.01.
AIC, Akaike information criteria; BIC, Bayesian information criteria; and LL, log likelihood.

Finally, we also estimate our models by using restricted maximum likelihood (REML) in place of maximum likelihood (ML). This method is justified because ML estimates can be downwardly biased when the number of level-2 units is small (Snijders and Bosker 1999). Depending on authors, the number of level-2 units can be considered as small in our case (i.e. up to 30 but less than 100; see Mc Coach (2010) for a discussion on sample size). Our main results remain unchanged with a REML procedure, in terms of signs and magnitude of coefficients.

Next, to plot the sum of the level-2 and level-3 residuals, we use the so-called best linear unbiased predictors (BLUPS). In Figure 5, the average random intercept presented is the sum of the random intercept of equipment and random intercept of a group (general model, specification M2).

The BLUPs graph highlights the relevance of a multilevel model because, all other things being equal, groups have different availability rates, and the model is supposed to consider some unobserved group-specific characteristics (random effect) given the estimation of the fixed effect part (see subsection above). The graph reveals that, for example, at any given level of independent variables, the availability rate of attack, heavy, and medium helicopters is lower than that of the middle-of-the-road light helicopter or training aircraft groups. A similar comment can be made for the availability of equipment well above the middle-of-the-road groups. This case is, for example, of a passenger's transport aircraft. Notably, such aircraft are atypical because they are leased to the manufacturer with performance-based contracts and, hence, have very high availability rates (approximately 95%–98%). The data also show that except for aircraft carriers and submarines, the major equipment of the French Navy (frigates, patrol ships, transport ships, and oil tanker ships) has higher availability rates.

This result is consistent with the major role played by the helicopters in military operations – with higher logistic footprints – and also with a recent parliamentary report that highlighted the importance of climatic condition in the availability of helicopters, especially since 2010 (Dominique De Legge 2018). This result is also consistent with the major role played by fixed-wing aircraft in recent conflicts, particularly regarding bombing, scouting, and intelligence missions.

Finally, these results confirm the specific characteristics of ships. First, this different behavior of ships is consistent with the NAO mentioning that in the case of the Navy, mission of crews are, by definition, always far from their base, that is, abroad (Cour des Comptes 2016). Although this situation is normal for crew members, it can be seen as a type of 'permanent engagement' for the Navy in military interventions in our framework, explaining the somewhat atypical results of ships. Second, the French Navy has smaller fleets on average (e.g. a unique aircraft carrier) than other equipment such as wheeled armored vehicles. The production of some military effect needs to

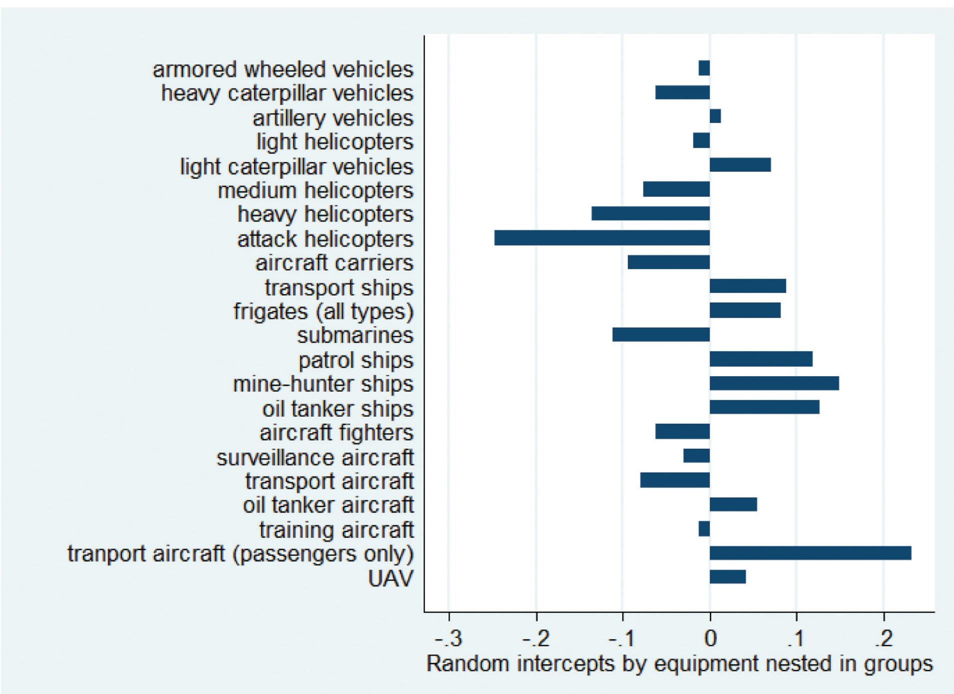

Figure 5. Best linear unbiased predictors (BLUPs) by equipment nested in group (general model). Source: authors' calculation

structurally maintain higher availability rates on average which can be responsible for outliers (e.g. the availability of the unique nuclear aircraft carrier was equal to zero in 2010 because of a major maintenance planned operation). Such structurally higher availability rates may also be explained by the better maintenance performance. For example, the French Navy has introduced performance-based contracts for maintenance since the beginning of the 2000s, which increased the availability rate of vessels (e.g. attack submarines). Finally, in the event of a high-intensity conflict – or preparation for such a conflict – these results also suggest that the naval component of the French armed forces (with the exception of the submarines and the aircraft carrier) would probably have less difficulties to be up to standard, compared to the aircraft or armored vehicles for example.

Interpretation

This multilevel analysis demonstrates the structural trend in the degradation of the availability of major equipment of the French Armed Forces caused by military interventions, all other things being equal and despite significant differences between categories of platforms. Thus, we wonder what the consequences of such a trend are. In the long run, the degradation of availability will probably affect operational activity and, more specifically, training and the preparation of troops. In short, military interventions create a major dilemma, since they structurally degrade the capabilities required for other, more intensive, military operations.

To support this idea, an interesting comparison is the objective of the country in terms of planned and actual military activity. These data were collected from an official document that describes the goals for air, land, and naval forces, which cover the 2006-2019 period. In general, the goal is defined in Military Planning Law and is in line with the North Atlantic Treaty Organization requirements (i.e. aircraft fighter pilots must fly 180 hours per year) to meaningfully contribute to collective defense. Such a standard may not be reached for many reasons, but one major reason is the unavailability of platforms, especially in the training component of the overall activity of the military. Figure 6 plots the relative distance between the goals of the armed forces in terms of activity and actual activity.

A measure close to zero means that the objective is reached; the further from zero, the less the objective is reached. The parabolic shape of the curve is notable because two periods are observed. The first period is from 2004 to 2011, with an improvement of the situation, and a second period from 2011 until today, with a degradation of the situation. A possible explanation for this pattern is the structural degradation of the availability of the major equipment that severely constrained the

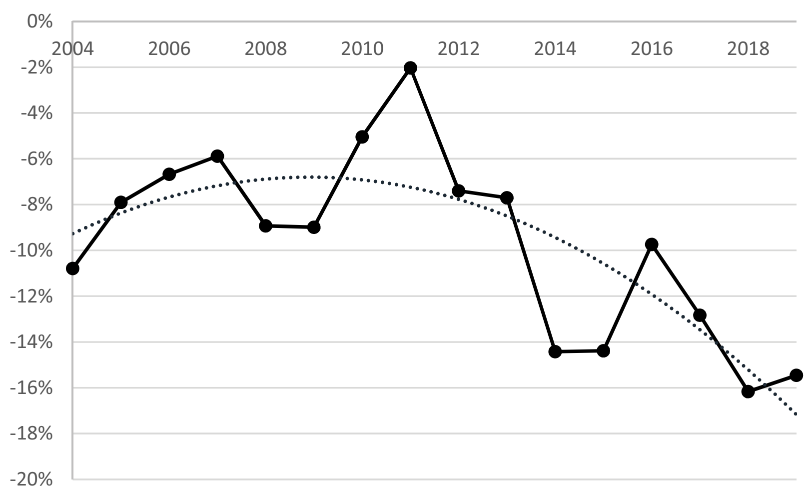

Figure 6. Distance to the target (%). Source: authors, data from the French Ministry of Defense

possible activity of the armed forces (Malizard and Droff 2018). In short, owing to their operational activities, the French armed forces cannot train and develop the skills required for high-intensity operations.

Although it is difficult to precisely assess this effect, some illustrations are useful. Some capability gaps have been identified, most notably in airlift transport and helicopters. In the French Air Force, a loss of know-how in some very specific expert fields is observed, and a marked slowdown in the training of young recruits (Pozzo di Borgo and Demessine 2016). By the end of the 2010s, parliamentary reports mentioned that approximately 20% of fighter pilots and 40% of tactical aviation pilots could not train across the full spectrum of their mission because of a too low rate of the aircraft caused by the effort directed toward military interventions. This is an excellent illustration of the trade-off in skills that military interventions introduce: as explained by a French *Rafale* pilot: 'providing close-air support to the army in operation Barkhane "counts" as flying hours, but it is of course far from preparing us for high-intensity operations' (Marilossian 2018, 21).

In naval aviation, the increasing operational tempo combined with the aging of the fleet put the replacement of old platforms under pressure, and capability gaps are feared by naval authorities. Some original solutions such as leasing helicopters to the private sector have been adopted. Regarding the special forces of the French Navy, the current activity exceeds their capabilities by 15%, with negative consequences on equipment and the training of troops (Marilossian 2018).

Conclusion

Engaging a country in several military operations abroad requires fine tuning between the military effort and the resources allocated to sustain the military effort. This article has shown that military interventions and, more specifically, the increased operational tempo caused by military interventions negatively affect the availability of equipment in the long run. We argue that such an effect represents a type of operational cost first borne by the armed forces and then by the country. This strategic cost that goes beyond a budget and monetary resources might be added to what we can call the 'halo of costs' identified in the literature on the estimation of conflict costs (Smith 2014).

This finding calls for further research into the sources of military power and military effectiveness. Generating military power is fraught with a number of trade-offs between various policy areas ('guns versus butter'), but also between different designs for the armed forces themselves: armed forces geared towards expeditionary warfare may be structurally unsustainable if they are regularly used in military interventions. Therefore, countries must carefully take into consideration the degradation caused by military interventions when building up military power and include these hidden costs in their defense and security planning. For the trade-off analysis to be meaningful, it should balance out the expected diplomatic benefits of joining a military intervention, the expected strategic output, and the costs in terms of public finances, international reputation, and public cohesion. We argue that the balance sheet should also include the degradation of military capabilities induced by participation in military interventions. Moreover, regarding military effectiveness, there is a trade-off between engaging in military interventions and maintaining adequate training and readiness levels for high-intensity operations.

In order to alleviate this trade-off effect and make military interventions sustainable, three options seem possible. The first option is an increase in budgets: military interventions and maintenance budgets have been increasing for more than 15 years, and the current economic context is still in favor of a major increase in defense budgets, especially maintenance budget. The latest statements of the Ministry of the French Armed Forces point towards this direction. Another option is increasing the productivity of production factors, to raise the 'military effect' of military equipment and soldiers or even the productivity of the maintenance sector. In the specific case of the maintenance sector, reforms are ongoing in the French armed forces. A third option can be to reduce – or even abandon – strategic ambitions or a decrease in involvement in conflicts and thereby reduce France's ambitions in the international scene, for example through different modes of intervention (Inbar and Shamir 2016). In all cases, difficult political choices must be made.

Further research may attempt to replicate this model with data coming from the United States or the United Kingdom in order to quantify the effect of military interventions on their military capabilities or, data permitting, use the same approach with Russia's intervention in Syria: the prospect that the Russian military effort abroad may have undermined Moscow's ability to wage high-intensity warfare (as demonstrated in Ukraine), deserves further exploration.

Notes

1. Notably, this analysis does not consider the costs associated with internal operations such as Sentinelle (since 2015) or Vigipirate. We argue that the cost of such operation is relatively smaller than that of military interventions : in 2015, the Sentinelle operation cost approximately EUR 170 million (and approximatively the same amount in 2016). In addition, such operations mainly imply land forces and their specific training. Before that, these operations cost less than EUR 10 million.
2. In such a curve, divided into three parts, the first part is a decreasing failure rate (infant mortality with low availability rate of equipment); the second part is a constant failure rate (availability rates of equipment reaches a plateau); and the third part is an increasing failure rate (wear-out failures with again, low availability rates).
3. Notably, this includes all the military personnel deployed outside domestic soil, including the military deployed in permanent foreign bases (e.g. Pacific bases in the US case or foreign bases for France, including bases in foreign former colonies). Contrary to other studies that focused only on combat operations, we consider that prepositioned forces can be considered a form of deployment, notably because in the French case, they very often serve as support, supply and logistic nodes for combat operations. Moreover, they also serve as first responders in case of unforeseen geopolitical crises, as illustrated by the role of the French base in Djibouti to conduct emergency evacuation operations in Chad in 2023 (*Opération Sagittaire*), and maintain a high level of readiness, with substantial means allocated. These bases can thus be conceptualized as rear bases in the broader context of an intervention (even though they are usually located in a different country than the one in which combat operations take place, they are still part of the intervention itself).
4. The World Bank publishes data of the surface area of countries. It would obviously be interesting to know the exact share of the territory where France deploys troops each year, or better yet, the territory covered by each type of system. However, such information is not publicly available. Our *AREA* variable is therefore a compromise variable that we assume is sufficient for statistical analysis.
5. Refer to appendix 2 for descriptive statistics of the variables used in the estimations. See appendix 3 for the correlation matrix of the variables.
6. The test has been done with the sigmamore option with Stata, which specifies that both covariance matrices are based on the same estimated disturbance variance from the efficient estimator.
7. For descriptive statistics on the number of observations in groups at the different levels, see appendix 4.
8. In other words, ICC is the expected correlation between any two randomly chosen measurements belonging to the same group.
9. 0.009/ ;(0.009 + 0.006 + 0.011) = 0.34.

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ORCID

Julien Malizard http://orcid.org/0000-0002-6774-4106
Olivier Schmitt http://orcid.org/0000-0003-1366-6621

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Appendices

Appendix 1: Twenty-two groups of equipment and examples of equipment

(1) Armored wheeled vehicles (e.g. VAB transport troops vehicle, VBCI)
(2) Heavy caterpillar vehicles (e.g. Leclerc and AMX30 main battle tanks)
(3) Artillery (e.g. Caesar, AUF1)
(4) Light helicopters (e.g. Gazelle, Fennec)
(5) Light caterpillar vehicles (e.g. VHM)
(6) Medium helicopters (e.g. Puma)
(7) Heavy helicopters (e.g. Caracal, Super Frelon, NH90)
(8) Attack helicopter (Tiger)
(9) Aircraft carriers (e.g. Jeanne d'Arc, Foch, Charles de Gaulle)
(10) Transport ships (e.g. Mistral class)
(11) Frigates (e.g. FREMM, Horizon)
(12) Submarines (e.g. Rubis class – SSN)
(13) Patrol ships
(14) Mines hunter ships (e.g. Eridan Class)
(15) Oil tankers ships
(16) Aircraft fighters (e.g. Rafale, Mirage 2000, Super Etendard modernisé)
(17) Surveillance aircraft (e.g. Falcon, Hawkeye)
(18) Transport Aircraft (e.g. A400M, C130, C160, Casa)
(19) Oil Tanker aircraft (e.g. KC 135)
(20) Training aircraft (e.g. Alpha jet)
(21) Transport aircraft (for passengers only) (e.g. A310, A320)
(22) UAV – Unmanned Aircraft Vehicles

Appendix 2: Descriptive statistics of the variables used in econometric analysis

Variable		Mean	Standard Deviation	Minimum	Maximum	Observations
r	overall	0.591	0.165	0.000	1.000	*N* = 1073
	between		0.129	0.297	0.952	n = 75
	within		0.117	−0.066	0.952	T-bar = 14.30
AGE	overall	20.246	11.516	0.000	55.000	*N* = 1343
	between		10.949	1.500	45.000	n = 75
	within		5.597	10.246	30.246	T-bar = 17.90
QUANT	overall	131.831	514.518	0.000	4413.000	*N* = 1299
	between		466.308	1.000	3826.952	n = 75
	within		88.259	−1070.122	717.878	T-bar = 17,32
AREA	overall	19,600,000	4,364,953	14,600,000	28,300,000	*N* = 1575
	between		0.000	19,600,000	19,600,000	n = 75
	within		4,364,953	14,600,000	28,300,000	*T* = 21
BUD	overall	826.995	233.433	387.654	1230.266	*N* = 1575
	between		0.000	826.995	826.995	n = 75
	within		233.433	387.654	1230.266	*T* = 21

Appendix 3: correlation matrix of the variables

	availability	age	quant	area	budget
r	1.0000				
AGE	−0.2120	1.0000			
QUANT	0.0600	0.1412	1.0000		
AREA	−0.3474	0.1653	−0.0227	1.0000	
BUD	−0.3454	0.1779	−0.0232	0.7699	1.0000

Appendix 4: Descriptive statistics on the number of observations by level

General model

		Number of observations		
Level	Number	Minimum	Average	Maximum
Group	22	6	48.4	184
Equipment	75	3	14,2	21