

Private Pigou Goes to War: The Environmental Costs of Warmaking

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Abstract: Following Arthur Pigou, economists have long recognized the environmental costs of private economic activity. The environmental costs of state warmaking, however, are neglected by economists, who discuss national defense as a public good. The standard public good framing includes two tacit pre-suppositions about state actors. One is that they have the necessary economic knowledge to move society closer to the optimal provision of the good, such that social welfare is increased. Another is that they have the incentive to act on that knowledge. This paper critically considers both assumptions in the context of the neglected environmental costs of state warmaking. We argue that policymakers are typically not in a position to know the full environmental costs of their military activities and that they lack the incentive to take the full environmental costs of their policies into account, as they are largely incurred by others in the present and future.

Keywords: Arthur Pigou, environment, environmental costs, externality, military, national defense, Pigouvian tax, war, warmaking

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1. RECRUITMENT

What are the environmental costs and consequences of state warmaking? This question is important because warmaking activities affect the physical environment in dramatic, and often irreparable, ways. The environmental consequences of warmaking have expanded through time with advances in modern military technologies. As one scholar noted, “Human technological innovations from one war to the next have not only increased in terms of the level of harm inflicted upon the enemy, but also upon the environment as well” (Hupy 2008, p. 407).

Following Arthur Pigou (1920), economists have long recognized the environmental costs of private economic activity. The environmental costs of state warmaking, however, are neglected by economists, who focus on discussing national defense as a public good. In the standard view, the market underprovides public goods when compared to the theoretically optimal amount due to pricing issues and the free-rider problem. As a result, the state must step in to fill the gap (Samuelson 1954, 1955). This framing includes two tacit presuppositions about state actors. One is that they have the necessary economic knowledge to move society closer to the optimal provision of the good, such that social welfare is increased. Another is that they have the incentive to act on that knowledge.

This paper critically considers these assumptions in the context of the environmental costs of state warmaking. By “warmaking” we mean the broad set of state activities that fall under the purview of “national security,” “national defense,” and “the military.” This includes investments in training and other preparations for war, engaging in war-related activities, and the consequences of these activities.

Our argument is twofold. First, policymakers are not able to know the full environmental costs of their military activities. Government actors are epistemically limited in accurately assessing the environmental costs of warmaking. Some of these costs are known in a broad sense, but difficult to meaningfully quantify; others are unknowable. Even when warmakers intend to cause environmental damage as part of their strategy, they cannot know the full downstream effects. Second, policymakers lack the incentive to take the full environmental costs of their actions into account since those costs are largely incurred by others. It follows that, even if it were possible to accurately quantify war-related environmental costs, policymakers have a weak incentive to take these costs into account due to cost shifting.

Our analysis is grounded in Buchanan’s (1949) treatment of alternative framings of public finance. One view, what he called the “organismic view,” treats the state as a “fiscal brain” that effortlessly computes and implements the socially optimal policy. An alternative framing—what Buchanan calls the “individualistic view”—conceptualizes the state as being composed of goal-oriented people embedded in specific organizational and institutional environments. These environments influence the types of knowledge generated and the incentive to act upon that knowledge.

Recent scholarship has extended Buchanan’s framing to the topic of state warmaking, highlighting the epistemic and incentive constraints on policymakers considering the traditional public good justification for state action (Coyne 2015, 2022; Coyne and Goodman 2020). This serves as an entry point for our economic treatment of the negative environmental effects of warmaking. We seek to understand how warmaking policymakers produce environmental costs and face an incentive to ignore the full consequences of their actions. In doing so, we highlight a category of warmaking costs neglected by economists.

We contribute to two strands of scholarship. First, we contribute to the literature on public choice, beginning with Buchanan (1949). The field of public choice has long focused on the nuances and challenges of the state provision of public goods, which cannot be assumed (Buchanan 1968; Ostrom and Ostrom 1977). Nonetheless, the government provision of national defense remains front and center of what are deemed to be the necessary activities of a well-functioning state. This presumes that the state will do in practice what its proponents want it to do in terms of providing public goods. We question this assumption by highlighting a tension in state public good provision—the production of bads (negative environmental effects) resulting from activities justified on the grounds of solving a market failure (national defense).

Second, we contribute to scholarship tracing the relationship among warmaking and environmental consequences and costs (e.g., Lanier-Graham 1993; Austin and Bruch 2000; Machlis et al. 2011; Lawrence et al. 2015; Kireitseva et al. 2023). To date, this literature is largely written by non-economists with rare exceptions (see Brauer 2009). We explore how economics can contribute to understanding the important issues related to warmaking and the environment.

Now that we have completed our opening recruitment pitch we move on to subsequent sections, which follow Private Pigou, the namesake of Arthur Pigou, through basic training, deployment, and debriefing. The next section, basic training, considers the theoretical issues and tensions in the traditional model of public good provision with a focus on epistemic and incentive issues facing policymakers as they pertain to the environmental costs of warmaking. Section 3, deployment, discusses several categories of environmental costs of state warmaking. Section 4 concludes our mission with a debriefing of the main implications.

2. BASIC TRAINING: THE STATE PROVISION OF GOODS AND BADS

Phase One: Foundations

Writing in the 1920s, Arthur Pigou set the theoretical stage for government interventions to address market failures. He noted that private producers will pursue their private marginal benefits and costs, which may diverge from social marginal benefits and costs. A negative externality will result when the private marginal benefits of an action are greater than the social marginal benefits (and the private marginal costs are less than the social marginal costs). Negative externalities will be overproduced since the private producer does not incur the full costs of their actions. A positive externality, in contrast, occurs where the private marginal benefits are less than the social marginal benefits of an action (and the private marginal costs are greater than the social marginal costs). Positive externalities will be undersupplied compared to a situation where all costs and benefits are internalized. This reasoning set the stage for market failure theory and the possibility of government intervention as a remedy.

The concept of public goods was introduced and formalized in the work of Richard Musgrave (1939, 1941) and Paul Samuelson (1954, 1955). Theoretically, they showed that goods that are both non-rivalrous (i.e., where one person's consumption of a good does not inhibit another person's consumption of the same good) and non-excludable (i.e., where no individual can be prevented from consuming a good) will be under-produced when private actors are left to their own devices. This creates space for Pareto improvements, with the state acting as the conductor orchestrating improvements in social welfare. National defense was one example provided by Samuelson (1955, p. 350), and it has since become economists' textbook example of public goods.

Complications arise when the blackboard model of public goods provision is operationalized through existing political institutions. Buchanan (1949) pointed out the disconnect between the identification of a theoretical market failure and the practical design of policy to address it. In his view, the assumption of a benevolent social planner who maximizes a known social welfare function left an unopened "black box" containing the particulars of the policymaking process. A resulting research program drawing on the fields of public choice and new institutional economics sought to open this box by extending the tools of economics to the study of the policymaking process itself.

What Buchanan (1949) called the "individualistic view" focused on the constraints facing decision-makers embedded in specific institutional environments. Subsequent scholarship focused on the epistemic limitations and incentives facing policymakers, as illustrated by Coase's (1959, pp. 894-5) analysis of the Federal Trade Commission, which noted that,

Quite apart from the malallocations which are the result of political pressures, an administrative agency which attempts to perform the function normally carried out by the pricing mechanism operates under two handicaps. First of all, it lacks the precise monetary measure of benefit and cost provided by the market. Second, it cannot, by the nature of things, be in possession of all the relevant information possessed by the managers of every business which uses or might use radio frequencies, to say nothing of the preferences of consumers for the various goods and services in the production which radio frequencies could be used.

Given the importance of this "Coasian problem," let us consider these epistemic and incentive issues in more detail.

Phase Two: Epistemic institutionalism

Epistemic institutionalism emphasizes the distinct nature of economic knowledge generated in different institutional settings (Boettke 2018). This focus can be traced back to the socialist calculation debate, during which Mises (1920, 1922, 1949) and Hayek (1948) emphasized that the economic knowledge produced by the entrepreneurial market process cannot exist absent that process. Economic knowledge regarding the best use of scarce resources is the result of ongoing rivalry between private economic actors who compete over scarce resources; this process is guided by the knowledge and feedback provided by monetary prices and profit and loss (Lavoie 1985a,b, 1986; Kirzner 1992). The political allocation of resources replaces the market process with the political process, generating an entirely different type of knowledge regarding how resources should be used (Buchanan 1954; Wagner 2016). In the political process, the valuations of policymakers replace those of private consumers, and top-down control of resource allocations replaces the decentralized and emergent allocations that occur in private markets.

As noted by Lavoie (1985b), the limitations of the state planning of resource allocations extend beyond comprehensive economic planning and also apply to non-comprehensive government planning. While the former refers to government efforts to plan all economic activity outside of markets, the latter refers to government efforts to plan parts of economic activity absent markets. The difference between the two is one of degree and not kind, as planning in both settings suffers from the inability of government planners to rely on economic calculation to determine the best use of scarce resources amongst an array of technologically feasible alternatives. This matters because many government functions, including warring, reflect non-comprehensive forms of planning (Coyne and Hall 2019).

This poses three epistemic challenges for the government provision of public goods. The first is that it is assumed that policymakers know *what* good should be produced. There is a difference between general categories of goods and the specifics of the goods demanded by consumers. For example, “security” is a broad category that includes an enormous range of potential goods and services of different types, qualities, and quantities. Individual choosers will value various aspects of security differently, just like their valuations of clothes, food, and housing vary greatly.

Policymakers lack access to the utility functions of consumers in a manner allowing for the determination of specific consumer wants and the aggregation of those wants into any single scale of values that can be enacted through policy. As Buchanan (1959, p. 126) noted:

Individual preferences, in so far as they enter the [social welfare] construction must be those which appear to the observer rather than those revealed by the behavior of the individuals themselves. In other words, even if the value judgments expressed in the function say that individual preferences are to count, these preferences must be those presumed by the observer rather than those revealed in behavior.

This means that at some point the analyst will need to impose their own valuations regarding the specifics of what constitutes security.

A second challenge is the assumption that policymakers know how to produce public goods in an economically efficient manner to maximize social welfare. If economic efficiency is the goal, it is not enough to know what is to be produced, but also how to produce it to maximize the value of scarce resources. The challenge is that the best use of scarce resources in production is an emergent feature of the market process rather than a pre-determined recipe (Hayek 1948, pp. 92-106; 1978, pp. 179-190; Lavoie 1986; Kirzner 1992).

As Hayek (1948) noted, “the solution to the economic problem is in this respect always a voyage of exploration into the unknown, an attempt to discover new ways of doing things better than they have been done before. This must always remain so as long as there are any economic problems to be solved at all, because all economic problems are created by unforeseen changes which require adaptation” (p. 101). The

state provision of public goods necessarily entails shifting at least part of economic decision-making from the market process to the political process, limiting the ability of market competition to serve as a discovery procedure of the best use of scarce resources (Lavoie 1985b).

This matters because public goods theory demands that government, as producer, determine the efficient means of producing a desired output. This calculation includes comparing trade-offs across numerous margins, including the environmental consequences of production. Different technologically feasible production methods will have different environmental consequences. The challenge is that policy-makers need to make these judgments absent the market process and the economic knowledge generated through that process.

A third challenge is the assumption that policymakers know that their production of public goods generates benefits net of any associated bads. Assume that national defense is a public good and that government provision of the good generates air pollution. As per the standard textbook example, this pollution would be a negative externality tied to the action of the producer who does not internalize the full costs of their actions. The difference with the textbook case is that in the case of national defense pollution is not a market failure, but rather a government failure. To provide a public good that increases social welfare, policymakers would either have to know how to avoid the negative externality in the first place, or to produce enough net social benefits to outweigh the cost of the bad (pollution).

To understand the epistemic challenge facing policymakers, consider the difficulties with implementing the standard solution to privately produced negative externalities—a Pigouvian tax equal to the size of the externality. As Nye (2008, p. 34) notes, “Absent detailed information about both regulatory distortions and private Coasian transfers, knowing the size of the PEX [Pigou Externality] gives us no clue as to the size of the optimal Pigou tax”. One reason is that an accurate accounting of the appropriate Pigouvian tax requires adjusting for other government interventions (regulations and taxes) that contribute to the externality.¹ Another is that even in a world with efficient transfers it is possible, and likely, that externalities would still exist. Finally, even with positive transaction costs, private parties may engage in some Coasian bargains to limit the harmful effects of the externality. If these possibilities are not considered, a Pigouvian tax will be overstated because it will assume the harmful effects of the externality are greater than they actually are (Nye 2008, pp. 32, 34).

Things become more complicated when we move from the realm of privately created negative externalities to government created negative externalities since the state is the ultimate regulator and tax-collecting entity; the state is not going to impose a Pigouvian tax on itself. An alternative to taxation is self-imposed regulations (the state regulating its own behaviors) to limit the negative externality. But regulation does not avoid the same epistemic issues of having to know the optimal regulation that adjusts for all other behaviors (known and unknown).

Phase three: Incentive institutionalism

While epistemic institutionalism focuses on the economic knowledge generated in different institutional settings, incentive institutionalism focuses on the incentives facing choosers in different settings. A large public choice literature explores the incentives facing participants in democratic politics (Rowley and Schneider 2004; Reksulak, Razzolini and Shughart 2014; Congleton, Grofman, and Voigt 2019a,b). This work highlights that there is often a wedge between the preferences of voters and the actions of elected officials and bureaucrats who represent citizens. To understand the foundations of this wedge, consider the challenges with the voting booth serving as an effective mechanism for communicating voter preferences to policymakers and for serving as a disciplinary device for elected officials.

One issue is voter knowledge. Voters tend to be rationally ignorant of policy details because they face a weak incentive to collect available information; the reason is that their single vote has a relatively small impact on electoral outcomes (see Downs 1957; Bohanon and Van Cott 2002; Heckelman 2003; Gelman, Silver and Edlin 2012; Somin 2013; Brennan 2016). This means that voters will tend to lack the incentive to

gather information on warmaking policies, including their costs. This weak incentive applies to the initial election of policymakers and to monitoring politicians once in office. The incentive to be informed will be even weaker where the costs of policies do not fall directly on voters, which is also the case with warmaking. For instance, warmaking activities that destroy land or generate pollution in a foreign location impose little direct cost on domestic voters, but significant costs on those living in the target area.

Another limit on voter knowledge is that the effects of policies are long and variable. A policy passed today may generate long and variable costs that only become apparent well into the future. Even if a citizen-voter was interested in gathering relevant information on these costs today, they may be unable to do so since they are not yet observable. Consider the environmental costs of warmaking. Some costs are readily observable—e.g., the destruction of infrastructure due to bombing—but others may only become obvious in the future—e.g., long-term effects of military explosives on ecosystems—if ever. This means that even the most informed voter will only possess part of the relevant information regarding the production of goods and bads associated with warmaking.

A second issue is that the information available to voters is partially endogenous to the political organizations that generate it. Because political organizations produce information about their activities, they have some discretion to strategically frame, filter, and conceal information as it benefits them. This is especially problematic in cases where information production is highly centralized and insulated from oversight and contestation, such as in the case of the national security sector where a classification system allows for the legal concealment of certain national security information (Coyne, Goodman and Hall 2019; Coyne and Hall 2021). This limits the ability of voters, watchdog groups, and others, to be informed about what their government is doing as it pertains to warmaking and the associated environmental costs.

The third issue is the fact that each qualified voter receives one vote limiting their ability to communicate the intensity of their preferences (Tullock 1959). Each vote counts the same whether a voter has a very strong preference for a certain policy or whether they are entirely indifferent and randomly select an option. One citizen may have a strong preference against the environmental costs of warmaking, while another may not care at all; the vote of each citizen counts the same such that the recipient of the vote cannot gauge the relative intensities of the voters' preferences.

The fourth issue is the time gap between elections limits the voters' opportunity to provide feedback. Citizens cast a vote for an elected official based on their perception of conditions at the time of the election. Post-election conditions will change, however, and voters will need to wait for the next election to cast their ballot. Consider that U.S. voters elected George W. Bush president in November 2000. The September 11, 2001, attacks and subsequent "war on terror" began during the first year of his presidency. Most voters did not anticipate these events at the time they cast their vote and would need to wait three years to cast their next vote. In general, voters often need to wait for long time periods to express their concerns that emerged after the prior election, limiting the ballot box as a means of feedback to policymakers.

Finally, citizen voting is limited as a source of feedback due to difficulties with identifying the parties responsible for the environmental costs to taxpayers. State warmaking consists of a massive complex of elected officials, bureaucrats, and private actors (Priest and Arkin 2011). Even if the environmental consequences of warmaking can be determined, and even if the voter cares about these issues, it will often be unclear if a candidate on the ballot is directly responsible. This makes it difficult for even the most interested voter to determine who to vote for or against.

Even under the most well-functioning real-world democracies, the combination of these five factors limits the ability of voters to both communicate their preferences to elected officials and to discipline those officials as it pertains to the environmental costs of warmaking. And keep in mind that these issues pertain to domestic voting. Since state warmaking is often international in nature, related policies will tend to affect both domestic citizens and foreigners, with the latter having even less say in the policies adopted—the foreign targets of a state's warmaking do not get a vote as to whether they should be targeted. This matters for the incentives facing policymakers.

In general, the various frictions in politics mean that there is no clear Coasian solution (Coase 1960; Acemoglu 2003) to the Coasian problem (Coase 1959) of epistemic and incentive limitations facing policymakers. The reason is that the wedge between voters and government actors creates space for narrow opportunism—policies that serve the interests of government actors and special interests. In addition, the imperfections in democratic systems also create commitment problems whereby policymakers today cannot credibly commit to future behaviors because of ineffective enforcement mechanisms (Acemoglu 2003).

The imperfections in domestic politics, combined with the international effects of warmaking, means that policymakers do not incur the full costs of their actions. Return to the case of the polluting factory. The factory operator can shift costs, with part of the cost of production falling on those who do not benefit. This cost shifting means that the operator will produce more bads than they otherwise would when compared to a situation where they internalize the full costs of their actions. The same is the case of state warmaking.

Policymakers incur some direct costs from their decisions (either immediate costs or anticipated costs in the future), but many of the costs of warmaking fall on other people. This means that policymakers will engage in an overproduction of cost-generating warmaking activities as compared to a situation where they fully internalized the full costs of their actions. In other words, state actions to produce a public good justified on the grounds of resolving a market failure will produce an over-supply of bads. This reasoning comports with the findings of Lawrence et al.'s (2015) review of the literature, which finds “little evidence that military strategists consider environmental consequences of military activities when planning or executing military actions related to conflict” (p. 454). Absent the incentive to care about environmental consequences, people will tend to care less and produce more harms compared to a situation where they incur the full costs of their decisions.

Phase four: Graduation

Please join us in congratulating Private Pigou who has successfully completed basic training and is ready to be deployed to the battlefield. The main takeaway of his training is that even in the most effective real-world democratic systems, policymakers face epistemic constraints for knowing what goods to produce and how to produce them efficiently. They also lack full knowledge of the bads, both in terms of the range of costs associated with their policies, their magnitudes, and their distribution. Moreover, political incentives are such that policymakers will overproduce bads since they face weak feedback and discipline, while being able to shift costs onto others, both domestically and abroad. These lessons apply to the production of a wide range of potential bads (see Coyne 2022), including a range of environmental costs.

3. DEPLOYMENT: THE ENVIRONMENTAL COSTS OF WARMAKING

Both preparing Private Pigou for war (e.g., training exercises and the production of military equipment) and sending him to war generate a range of environmental costs. These costs are reflected in the following general categories which are based on the past and present environmental consequences of warmaking. Our discussion of each category appreciates the possibility of three types of intentionality—the first active and intentional and the latter two passive and unintentional (see Lanier-Graham 1993, pp. 11-12).

One possibility is that Private Pigou engages in intentional and direct environmental harm, such as the purposeful destruction of forests or farmland, to weaken the enemy. In this scenario, Private Pigou does not suffer from any knowledge problems regarding the immediate costs of their actions since they deliberately intend to cause environmental harm. When these types of activities are part of the warmaker's toolkit, they will have a strong incentive to use them both because they are viewed as acceptable and because the related costs largely fall on others.

A second possibility is that Private Pigou produces unintended and direct environmental harms caused by the presence of troops and equipment. In this scenario, Private Pigou does not intend to create

environmental harms as in the first scenario, but does so as a byproduct of his presence and activities. To varying degrees he may, or may not, have knowledge of the indirect environmental costs of his actions. Either way, he does not internalize the full costs of his actions and will tend to overproduce harms that fall into this category.

Finally, Private Pigou's warmaking activities might generate indirect and unintentional harms. These refer to long and variable environmental costs associated with warmaking activities. The long-term effects of the testing, use, and storage of nuclear or chemical weapons would be an illustration of this last category. As in the previous cases, Private Pigou lacks the incentive to fully consider these costs.

These three possibilities can also be related. For instance, intentional direct (possibility one) environmental destruction may lead to unintended environmental degradation (possibilities two and three) through time. The relevance of each type of intentionality, and the consequences, depends on the context and the warmaking activities undertaken.

Air contamination

Air emissions include substances emitted into the atmosphere by human activities. The maintenance and operation of a military, even if not directly engaged in war, generates significant air emissions. For instance, the United Kingdom's Ministry of Defense accounts for 50% of the UK's central government emissions, and aviation accounts for two-thirds of the Ministry of Defense's fuel consumption (Ministry of Defense 2021). The U.S. Department of Defense is the largest single consumer of energy domestically, among the largest internationally, and is the largest institutional generator of greenhouse gases in the world (Crawford 2019, p. 2).

Empirical analyses suggest that higher expenditures on military activity lead to higher per capita emissions of pollution and greenhouse gases, even after controlling for other factors (Bildirici 2017; Bradford and Stoner 2017; Sana and Neila 2016; Erdogan et al. 2022; Wu et al. 2025; Cutcu et al. 2025; Ngounou et al. 2025). Clark, Jorgenson, and Kentor (2010) find that military expenditure per soldier increases the scale of energy consumption, and that overall energy consumption is positively correlated with the number of military personnel relative to the overall size of the domestic population. Together, these studies suggest that human-made air pollution is an indirect effect, with both immediate and longer-term consequences, of maintaining and operating a large-scale military sector.

Some evidence suggests that war reduces the overall amount of carbon dioxide (CO₂) emissions (Reuveny, Mihalache-O'Keef, and Li 2010; Marrouch and Sayour 2024). One suggested reason is that vehicles and industrial plants that generate pollution are often destroyed during war. Another is that economic activity (e.g., production and transportation of goods) often decreases as people and resources are pulled into the war effort, contributing to an overall reduction in CO₂ emissions (Westing 1980; Tucker 2004). Note, however, that although overall CO₂ emissions may fall, empirical evidence shows that the "intensity" (the amount of CO₂ emissions per unit of economic activity) of CO₂ emissions increases during war. This may be the result of production processes that are less environmentally friendly due to increased war production and an easing of environmental restrictions (Marrouch and Sayour 2024).

Further, even if overall emissions fall during war, warmaking often increases air contamination in specific localities. For example, the operation of heavy military equipment, which tends to rely on petroleum-based fuels, may contribute to increased air pollution in areas where warmaking activities take place. The use of various weapons (chemical, explosive, etc.) may also produce intense local air contamination. Consider the use of herbicides (Agent Orange and Agent Blue) by the U.S. Air Force in South Vietnam as part of Operation Ranch Hand (1962-1971) for the purposes of deforestation (see Buckingham Jr. 1982; Brauer 2009). This affected the health of a significant number of people in targeted areas who either inhaled the toxic substance of Agent Orange (TCDD), or who interacted with the herbicide through skin contact (Young 2009).

Finally, the disposal of war-related waste can lead to localized pollution and immediate bodily harm. During the occupation of Afghanistan and Iraq, for instance, the U.S. Army used open burn pits to dispose of human waste, plastics, electronics, and chemicals. The resulting carcinogens polluted the air while causing health issues for many U.S. soldiers (Woskie et al. 2023). In each of these scenarios, air contamination is an indirect effect of warmaking with both short- and longer-term environmental consequences.

Water contamination

Water contamination refers to the pollution of water bodies due to human activity. Water contamination can be direct and intentional as illustrated by the Gulf War oil spill of 1991. In one of the largest oil spills in human history, Iraqi military forces intentionally dumped an estimated eleven million barrels of crude oil into the Persian Gulf to try to prevent U.S. marines from landing on the coast (Michael 2011). Beyond the immediate effects the spill had long-term effects, well beyond those known or considered by the perpetrators, on the water and environment, adversely affecting both marine and land environments (Mostafawi 2001; Michael 2011; Issa and Vempatti 2018).

Water contamination can unintentionally contribute to a chain of consequences adversely affecting human health. Consider warmaking preparations, which include a variety of military exercises in anticipation of future warmaking. One study of U.S. bombing exercises in Puerto Rico found significant neonatal health effects: “The military exercises have significant negative consequences for early life outcomes—particularly for congenital anomalies. The sudden end of bombing practices is associated with a 5.6–7.9 per thousand (56–79%) decrease in the incidence of congenital anomalies as the main driver for improvements in neonatal health outcomes” (Bobonis, Stabile and Tovar 2020, p. 2). The main channel identified for these adverse health outcomes was water contamination in the impacted area resulting from the bombing exercises. This illustrates how water contamination can occur indirectly and unintentionally, in this case through land-based military activities, as a government engages in domestic warmaking preparations.

The same goes for long-term water contamination caused by warmaking activities. Herbicidal warfare in Vietnam led to long-term water contamination decades later. One recent study found that five decades after the use of herbicides, “Some Air Force bases in Thailand and Vietnam continue to be dioxin contaminated soil and sediment hotspots. As a result of water and wind action, runoff, soil erosion, transport and deposition, these hotspots are spreading beyond airbase perimeter fences and into adjacent lakes, rivers and ponds” (Olson and Morton 2019, p. 4).

Another major source of water contamination is the dumping of weapons and munitions in bodies of water (Hutchinson 2017; Mitchell 2020). Both the Allied and Soviet forces, for instance, dumped chemical munitions and warfare agents in the Baltic Sea after World War II (Glasby 1997). “The largest amount of weapons was dumped in the Baltic Sea and Skagerrak Strait on the order of the British, Soviet and American military administrations in Germany. At least 150,000 tonnes of chemical weapons were dumped into Skagerrak, and about 50,000 chemical munitions containing around 13,000 tonnes of CWA [Chemical Warfare Agents] are known to have been dumped in the Baltic Sea” (Szarejko and Namieśnik 2009, p. 13). These chemicals continue to pose a health risk for the Baltic Sea ecosystem and the surrounding human communities (Beldowski et al. 2016; Briggs et al. 2016; Vanninen et al. 2020).

Soil disturbances

Warmaking affects the properties of soil. Most warmaking activities do not target soil directly, meaning that the harmful effects tend to be indirect and unintentional. The main effects fall into two general categories of disturbances—physical and chemical—with potential second-order effects (Certini, Scalenghe and Woods 2013).

An example of physical disturbances to soil would be the clearing of land with heavy machinery. This can lead to soil compaction, affecting the quality of soil and its ability to support vegetation and animals.

Another example would be the construction of military installments, which involves soil sealing. Soil sealing refers to the covering of soil with construction materials which limit the flow of water (e.g., a concrete foundation). This can adversely affect water infiltration (the ability of soil to absorb water), which can affect vegetation and animals, while contributing to water runoff which may adversely affect surrounding areas. Another example would be the relocation of large numbers of people due to war, since sudden and significant concentrations of people in a single geographic space can lead to land degradation (Certini, Scalenghe, and Woods 2013).

While ground-level effects of warfare (e.g., destruction of vegetation) are readily observable, it is also important to appreciate the unobservable and deeper effects of warmaking on the earth and environment. Hupy and Schaetzl (2006) introduce the concept of “bombturbation” (“turbation” refers to the mixing of soil) to emphasize the unique impact of military explosives on the earth’s surface, which differ from other types of disturbances due to the force of explosives and the way they mix with the soil. Bombturbation refers to “the cratering of the soil surface and mixing of the soil by explosive munitions, usually in warfare and other military related activities” (Hupy and Schaetzl 2006, pp. 825-6). The use of war-related explosives produces craters in the earth’s surface, potentially disrupting numerous soil layers (humus, top soil, sub soil, weathered rock, and bedrock) in ways that impact the surrounding physical environment and ecosystem (Hupy and Schaetzl 2006). Understanding the full range of consequences is only possible long after the initial deployment of explosives.

The second category is chemical, which refers to human-created interactions between soil and pollutants. An example is the use of Agent Orange by the United States in Vietnam to destroy vegetation to expose the Viet Cong. Agent Orange contains the dioxin TCDD, a highly toxic chemical which can lead to soil contamination with (literal) downstream effects. TCDD “can adhere to leaf surfaces, fine soil particles, organic materials and sediments that can be carried by runoff into downstream waters and deposited in ponds, wetlands and lakes. In this way, TCDD bioaccumulates in aquatic species and can become biomagnified throughout the food chain via mollusks, fish and fowl eaten by other animals and humans” (Olson and Morton 2019, p. 15).

The effects of the chemical pollutants on soil can last for decades after initial contamination. For instance, in 2016 the United States Agency for International Development (USAID) identified 500,000 cubic meters of dioxin contaminated soil at Bien Hoa Air Base in Vietnam (USAID 2023). This base served as a central hub for Agent Orange storage during the Vietnam War.

This reasoning extends beyond Vietnam. In general, military explosives “release chemicals that after eventually causing an immediate acute detrimental effect for living organisms can reside in soil to induce subtler, more enduring effects” (Certini, Scalenghe and Woods 2013, p. 11). These enduring effects will tend to be neglected by policymakers because of a lack of knowledge about their specifics at the time of choice, and because of a lack of incentive to take them into account since the costs are external to the decisionmakers.

Unexploded ordnances

Unexploded ordnance refers to weapons and munitions that have not been detonated. Examples of such weapons include bombs, rockets, landmines, grenades, mortars, and cluster munitions. The intentionality and temporal effects of the warmaking actions resulting in unexploded ordnances vary.

Consider a case where one army places landmines in a geographic space with the intention of preventing other people from entering the area. In this scenario the presence of unexploded ordnances, which purposefully render the land unusable, is direct and intentional. Intentional actions can result in long-term effects, which may be unintended, such as unexploded ordnances remaining for decades after hostilities have ended.

One example of this is the “Zone Rouge,” or “Red Zone,” in northeastern France. This area was closed off by the French government in the wake of World War I because of a significant number of unexploded

ordnances covering the land. Though the war ended more than a century ago, the threat of unexploded ordnance remains today. As McLachlan (2023) notes, “It’s likely *Zone Rouge* will never be fully cleared. It’s been projected that it will take at least 300 years of work to completely clear the battlefields of their dangerous remnants.” Another example is that a large number of unexploded ordnances were intentionally dumped in oceans following the two world wars and continue to pose a significant environmental threat to this day (see Maser and Strehse 2020). In general, “Land mines and other explosive devices left behind in war (such as cluster bombs) present perhaps the worst ongoing environmental threat, as they make using natural resources (such as farm fields) a deadly activity in affected areas” (Clark 2008, p. 4).

The presence of unexploded ordnances can also be the result of purely unintended and indirect effects of warmaking. An example would be unexploded ordnances left behind on military installments once foreign military troops exit (Massarino 2024). This same scenario can occur within the borders of the war-making country once a military installment is no longer in use. This is illustrated by the challenges posed by unexploded ordnances when the government attempts to close domestic military bases within the United States (see MacDonald et al. 2004).

Unexploded ordnances affect both human beings and ecosystems. Well after wars have ended, innocent people are maimed, killed, and psychologically damaged through unintentional interactions with unexploded ordnances (see Frost et al. 2017). The same is the case for ecosystems (Westing 1996; Dudley et al. 2002; Certini, Scalenghe and Woods 2013).

Unexploded ordnances can adversely affect soil and water quality due to the toxic substances in munitions, which affect flora and fauna. Like humans, animals may accidentally detonate unexploded ordnances. They may also be adversely affected by changes in the availability of food and water due to contamination or harm to the environment. These effects are long, variable, and not evident in their scale and scope prior to, and during, warmaking.

Deforestation

Deforestation, which refers to the clearing of trees from land, is one of the most cited environmental consequences of warmaking (see Meaza et al. 2024).² The large-scale removal of trees can have a variety of environmental effects including contributing to climate change (due to the loss of tree capacity to absorb carbon dioxide), soil erosion and flooding (due to reductions in rainfall absorption), and harm to animals and plants that rely on the ecosystem that emerged around trees (Harris 2006; Brauer 2009).

In some cases, deforestation is an intentional act of war with the aim of preventing enemies from having access to timber or coverage for concealment. During the Vietnam War the United States Army used “Rome Plows” (named after the Rome Plow Company), modified plows with sharp blades, to remove trees and foliage that could be used by the enemy for concealment (Brauer 2009, p. 48; Starry 2002, pp. 147-8). They also used defoliants, such as Agent Orange and Agent Blue, with the aim of intentionally destroying forest cover to root out the enemy. As noted earlier, these chemical herbicides had widespread and long-lasting ecological and health effects (Westing 1971a, b, 1974, 1976; Yamashita and Trinh 2002; Brauer 2009, pp. 49-58).

In other cases, deforestation is an unintended result of other warmaking activities. One example would be the destruction of trees due to the movement of heavy military equipment or for purposes of establishing military installments. In this scenario the primary intention is not to destroy the trees, as under the prior scenarios, but rather a secondary effect of the primary intention of military movement.

Whether intentional or unintentional, there are immediate and long-term environmental consequences of warmaking on forested land: “This impact occurs for various and varied reasons from simple over-exploitation of the resources for fuel, construction, or other uses, or because in times of conflict the usual processes governing the uses of forest resources break down” (Rotherham 2024, p. 1). The full extent of these costs cannot be known by warmaking policymakers at the moment of choice and largely fall on other people.

Harm to animals

The harm to animals associated with warmaking can be significant. To provide one example, it is estimated that eight million horses, mules, and donkeys used to transport soldiers and war materials died during World War I (McIntyre 2017). Directly and intentionally attacking animals has been part of past military strategies to weaken the enemy. For instance, during the Vietnam War the U.S. military targeted elephants because they were used to transport military supplies (Dudley et al. 2002).

In many cases the harm to animals is indirect and not the primary intention of warmakers. For instance, deforestation, air pollution, water contamination, and soil disturbances related to warmaking activities can all harm animals absent the intention of doing so (Westing 1996; Brauer 2009). The U.S. military's use of herbicides during the Vietnam War to reduce forest cover had immediate effects on animals and long-lasting, unintended, effects on the types of species that could sustain and thrive (Brauer 2009, pp. 58-62). A final example is the use of sonar by the U.S. Navy, which harms cetaceans who rely on sound waves for major life functions. The sonar pings created by U.S. military ships can affect feeding and mating patterns affecting marine animals in the immediate term and their populations through time (Parsons et al. 2008; Goldbogen et al. 2013).

In addition to the direct harm caused to animals, there can also be second order effects on human welfare as illustrated by the effects of nuclear testing on animals and, hence, on the animal products consumed by humans. Nuclear fallout can contaminate soil and the vegetation consumed by animals. In addition to the contaminated vegetation harming animals directly, it can also harm humans who consume meat and milk (Brauer 2009, p. 8). None of these perverse harms on animals and humans are the intended consequence of nuclear testing.

Regarding the general impact of war on animals, one empirical study focused on Africa found that violent conflict is the most consistent indicator of declines in the population of animal species (Daskin and Pringle 2018). This is due to a variety of factors, such as targeting animals as a military strategy, the neglect of animals during war, the increased consumption of animal meat, poaching, and the destruction of conservation infrastructure. A survey reviewing case studies on war and animal conservation notes that beyond the immediate connections between warmaking and animal conservation, there are also indirect effects on animals due to institutional and socioeconomic changes resulting from war (Gaynor et al. 2016).

Examples of institutional factors include changes in domestic government and conservation capabilities, and the potential withdrawal of international support. Socioeconomic changes include things like the increased consumption of animals and natural resources due to displacement and economic hardship and decreases in ecotourism. The specifics of these changes and their impact on animals vary depending on the context, but they highlight the numerous indirect channels through which warmaking can harm animals.

4. DEBRIEFING

Private Pigou has successfully concluded his mission; let us debrief on the main lessons learned. The first is a broad lesson and applies to the general notion of public goods and their provision. The justification for the state provision of public goods is that social welfare will be increased. This assumes that policymakers know what is to be produced and how to produce it, not from a purely technical perspective, but from an economic perspective that incorporates the opportunity cost of scarce resources. There are fundamental epistemic issues with determining the optimal government provision of a good outside of the market context.

Further complicating welfare-enhancing provision is the need to account for the various bads generated by government interventions to produce a potential good. Interventions into complex systems can never do just one thing, making it important to consider these other factors when making claims about increases in social welfare as per standard public goods theory. Efforts to address one supposed market failure—e.g., the provision of public goods—can result in government failures on other margins—e.g., negative exter-

nalities. Some of these bads, which span various geographic spaces and populations, are immediate while others will appear in the future.

A second lesson applies specifically to one category of bads—the environmental costs of warmaking. The environmental costs of war will be understated for two reasons. One is that policymakers will lack full knowledge of these costs at the time of choice. The second is that policymakers face a weak incentive to appreciate these costs and their limited knowledge regarding their extent and magnitude. The reason is that policymakers incur, at best, a small portion of the environmental costs of their decisions. This allows them to shift costs to other people, both domestically and abroad. Just as private actors overproduce negative externalities, so will warmaking policymakers.

What can be done? Shifting our focus from privately created negative externalities to government-created ones poses the challenge that the state is the ultimate tax-collecting entity. The result is a “Paradox of Pigou” in cases of government created negative externalities—who will tax the Pigouvian taxman?

An alternative is self-imposed regulations to limit the negative externality. For instance, the United States Department of Defense (DoD) is subject to environmental laws at the federal, state, and local levels. One issue with this solution is the aforementioned knowledge problem—determining the optimal level of pollution outside of the market. Another issue is that there are typically exemptions that weaken the effectiveness of regulations as they pertain to warmaking.

In some instances, this entails the DoD seeking exemptions on a case-by-case basis (see Bearden 2006). In other cases, exemptions are part of the law. For instance, in 2021 President Biden signed an executive order (Executive Order 14057) instructing government to “achieve a carbon pollution-free electricity sector by 2035 and net-zero emissions economy-wide by no later than 2050” (Biden 2021, p. 70935). However, the order contains exemptions for matters of national security, military training, intelligence, and combat.

Given the current structure of the warmaking system, the legacy of Private Pigou remains intact—a legacy of government overproducing war-related environmental costs in the name of producing a public good. There are many benefits and costs to warmaking spanning numerous margins. Our analysis has emphasized some of these costs, and there are many more related to our focus. For instance, we have not discussed the environmental consequences of the loss of human life due to war. As Julian Simon (1989, 1998) argued, people are part of their natural environment and cannot be separated from it. The human propensity for creativity, Simon argued, is crucial for innovating to resolve critical environmental problems. The loss of human life associated with warmaking, therefore, reduces the number of people who might contribute to environmental improvement and the end of wars associated with environmental pressures (Simon 1989). To the extent that people care about and prioritize the associated environmental costs, however, the only solution may be to take steps to limit the root cause—warmaking.³

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NOTES

- Existing scholarship identifies instances where government actions result in negative environmental externalities. For instance, studies show that government-granted subsidies encourage overproduction and overconsumption of fossil fuels, increasing greenhouse gas emissions and air pollution (Arzaghi and Squalli 2023). Agriculture subsidies, like those for the monocropping of corn in the Midwest, often lead to overuse of chemical fertilizers, pesticides, and water resources, leading to soil degradation and water pollution (Williams 2020).
- For a historical overview of the role of forests in warfare, see Rotherham 2024.
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