A Case Study on DARPA: An Exemplar for Government Strategic Structuring to Foster Innovation?

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Abstract Advocates for a mission economy contend that government bureaucracy can be transformed through a strategic structuring that would improve upon the dynamic capabilities necessary to pursue and direct innovation. The Defense Advanced Research Projects Agency (DARPA) is touted as a model organization of strategic structuring for inducing public sector innovation of emerging technologies. Applying economic theory and employing empirical analysis, I objectively examine key factors that are attributed to DARPA's success, such as the organization's autonomy, small size, and limited tenure of its program managers, in order to assess the worthiness of the agency's exemplar status of empowering a mission-oriented approach to innovation. I find that while DARPA undoubtedly provides value for national defense and has distinct advantages over other government organizations, it falls short in representing a sustainable and scalable source of strategic structuring that would befit the entrepreneurial state.

Keywords Public goods · Entrepreneurship · Innovation · Political economy

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Introduction

Advocates for a mission-oriented directionality to innovation tout the Defense Advanced Research Projects Agency (DARPA) as one model improvement within the public sector that provides the agility and flexibility to pioneer revolutionary

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technology advancement (Mazzucato 2021). The purpose of this chapter is to execute a case study analysis of the DARPA organization, exploring its origins from 1958 and detailing changes in its focus and processes over time and how those changes track with its effectiveness at Schumpeterian entrepreneurship. The bulk of the case study describes and documents the institutional mechanisms that DARPA possesses to promote innovation. Much has been espoused regarding the success of the DARPA model in the form of various attributes (Gallo 2021 and DARPA 2016), which I categorize by the following three key factors:

1) Trust and autonomy.
2) Small size and the externalization of research.
3) Limited tenure and urgency.

   This research objectively analyzes each factor, applying economic theory to corroborate or counter the expected outcomes from DARPA's purported strengths and defending these assessments empirically where possible. I find that the organization's touted autonomy is unstable over time due to political transaction costs as evidenced by increased congressional oversight, shifting focus toward incremental technology advancement to fulfill short-term military priorities, and a transfer of expert power to established vendors. While DARPA has distinct advantages over other government organizations, it falls short in representing a sustainable and scalable source of strategic structuring.

DARPA's History and Construct

Following the Soviet Union's success in the space race with the launch of Sputnik, the Eisenhower administration established the Advanced Research Projects Agency (ARPA) in 1958, chartered with preventing "technological surprise" (Van Atta and Windham 2019a, pp. 3–4). The agency was initially focused on large missions such as missile defense and nuclear test detection with a brief foray in space-related technology development until that function was absorbed by the standup of the National Aeronautics and Space Administration (NASA). However, within a few years, ARPA assumed an additional role in pursuing a "set of smaller, technically focused programs" in areas such as materials science, information technology, and behavioral science (Van Atta and Windham 2019a, p. 4). These pursuits led to what is typically acclaimed the agency's two greatest contributions to innovation: the precursor to the Internet and the foundation of personal computing.

   In 1972, because of increased scrutiny on military spending for many reasons including the unpopularity of the Vietnam War, the agency encountered its most significant focus change when Congress limited research efforts to only those having direct military application. This not only resulted in the name change from ARPA to DARPA but also added increased process and oversight (Fong 2019). The effects of these process changes to DARPA's purported strengths are explored in subsequent sections.

DARPA continued to evolve and shift focus throughout the decades following its renaming, primarily aligning with changes in national security priorities, such as the Global War on Terror in the 2000s. Despite these shifts, the underlying organizational mission has remained basically the same: "to prevent and create technological surprise" (Gallo 2021, p. 5; DARPA 2016, p. 4). DARPA asserts a commitment to achieve transformative research and development (R&D) with a stress on higher risks and higher rewards over incremental advances. To accomplish its mission, DARPA adheres to a process that externalizes research through an annual budget of approximately USD 3.5 billion to fund performers primarily from industry (62 percent in 2020), and secondarily from universities (18 percent in 2020), federal laboratories and research centers (15 percent in 2020), other nonprofits (4 percent in 2020), and foreign entities (1 percent in 2020) (Gallo 2021, p. 10). DARPA's funding levels have stayed fairly constant over time. So too has the agency's manpower footprint, which is primarily composed of approximately 100 "empowered program managers coordinating high-risk high-reward external research" (Reinhardt 2020). This feature along with special hiring and contract authorities sets DARPA apart from other government agencies in terms of its independence, which advocates claim provides flexibility for both ideas generation and enhanced engagement opportunities with potential performers. These elements of the DARPA model frame my case study approach in analyzing the three key factors that purportedly promote innovation. The first factor is trust and autonomy.

Factor 1: Trust and Autonomy

DARPA's autonomy stems from its explicit separation from the larger Department of Defense (DoD) to include the military services, which allows for disruptive technology pushes beyond the constraints levied by specific military requirements and missions (Gallo 2021). This uncoupling represents a mitigation of the institutional constraints that drive median results in the government domain and obstruct Schumpeterian entrepreneurship (Schnellenbach 2007). Less checks and balances, especially the avoidance of excessive oversight from Congress, provides DARPA a level of opacity that promotes speed and flexibility in decision-making, garners independence in problem-solving, and incentivizes risk-taking (Miller 1992; Reinhardt 2020). Ter Bogt (2003, p. 151) connects the "autonomization" of a public organization to transaction cost economics (TCE); specifically, DARPA represents an "internally autonomized organization," which stakes a claim in the lowering of economic transaction costs by limiting political influence.

The trust and autonomy bequeathed by the DoD and Congress to DARPA also extends to within the organization from the agency director to the aforementioned empowered program managers, who can select and terminate projects through their ability to deploy money rapidly and independently (Gallo 2021; Reinhardt 2020). Thus, DARPA's organizational structure consists of a unique combination of centralized and distributed control mechanisms. Miller (1992) stresses that causes of

market failure such as information asymmetry and team production externalities lead to hierarchical solutions for social dilemmas. Moreover, disadvantages of democracy such as preference instability and indecisiveness and/or manipulation in decision-making lend favor toward centralizing power (cf. Arrow 1963). In DARPA's case, autonomy has been purposefully granted to the agency director, and other stake-holders like the military services and Congress are restrained in their decision-making authority as it pertains to DARPA's purview.

Nonetheless, a hierarchy contains its own set of issues. Central planning efforts suffer from Hayek's knowledge problem and what Tullock (2005 [1965], pp. 148–152) refers to as "whispering down the lane," where agile coordination is constrained by the multiple levels of superior-subordinate interactions that impede knowledge diffusion and discourage entrepreneurship alertness and discovery. Miller (1992, p. 80) argues that firms can address these issues by injecting an additional level of autonomy within the organization via delegation: ". . .a dictator who needs good information and good ideas must create the basis for independence inside the hierarchy." The DARPA equivalency is delegating real shares of decision-making authority to program managers, who are hired from industry and academia and serve as experts in their specific domains of research within the fields of science and engineering (Gallo 2021).

Provided the strengths of DARPA's unique form of independence through the combination of centralized and distributed control governance structures, theoretical counters exist to this organizational construct's stability in maintaining autonomy, which also calls into question the appropriateness of possessing high levels of opacity for inherently governmental entities. The first counterpoint considers the overall agency level and its relationship to its external stakeholders. Because DARPA classifies as an "internally autonomized organization," it is neither truly independent nor private; therefore, political influence can still erode efficiency, at least over time. In attempting to incorporate TCE into the public sector domain, Ter Bogt (2003) proffers a political transaction cost framework to account for the lack of emphasis placed on economic efficiency in government organizations. This frame-work analyzes each of the primary characteristics of TCE as promulgated by Williamson (1981)—asset specificity, frequency and scale, and uncertainty—in order to assess the political willingness to increase or decrease an organization's autonomy. According to Ter Bogt's analysis, the willingness to "autonomize" will increase for basic government functions such as the provision of student loans or road maintenance. DARPA's case is the opposite of basic functionality. Its product, innovation, involves high asset specificity in terms of uniqueness and importance and high uncertainty in terms of the frequency with which it can be produced and the ability to measure success.

Furthermore, Ter Bogt's (2003) framework considers additional political trans-action costs associated with maximizing electoral support, the influence of special interest groups, and political opportunism with a focus on increasing political efficiency for inherently governmental organizations. Applying these consider-ations, DARPA's independence as an organization could be jeopardized by two key sources. The first source consists of special interest groups working through the

larger DoD and military services, who might desire to control the shape and direction of DARPA-related technology development efforts. This source includes large public-private partnership companies that perform a huge proportion of defense-related R&D. The second source are the taxpayers, who typically demand the very checks and balances that have been removed through "autonomization" to ensure their money is being spent wisely and competently. The higher the level of opacity within an inherently governmental organization, the more difficult the challenge to safeguard against abuses. Given that DARPA explicitly regards each program manager as filling the role of a technical subject matter expert, this high level of opacity can result in what Koppl (2018, pp. 189–200) refers to as a "rule of experts" scenario, where a monopoly of experts increases the likelihood of unreliability, which can lead to bad decision-making.

Another critical counterpoint involves DARPA's autonomy internal to the organization residing with the individual program managers. Miller (1992, pp. 86–89) highlights the downside of distributed control governance as explained through the Sen paradox: ". . .any organization that delegates decision-making authority to more than one subset of individuals must suffer from either incoherent behavior or inefficiency for some combinations of individual preferences." The tradeoffs given the Sen paradox involve the individual self-interest of each DARPA program manager and the agency's best interest. Thus, distributed control can evolve into a threatening construct to both the dictator and external stakeholders. However, the DARPA model exhibits additional strengths purported to combat inefficiency in outcomes and intransitivity in preferences. The second and third key factors of my case study analysis elaborates further on these strengths.

Factor 2: Small Size and Externalization of Research

To avoid the Sen paradox, Miller (1992, pp. 94–95) contends that the hierarchy must "shape and mold individual preferences into patterns that are mutually consistent." One way DARPA mitigates the threat of incoherent behavior and inefficient coordination is through its small manpower footprint. DARPA's core staff size gravitates toward Dunbar's number (~150), which is the suggested limit at which social relationships flourish as each member can get to know every other person in the organization. Knowing everyone creates peer pressure through scrutiny, which provides a check against abusing opacity and fosters an adherence to a common set of goals (Dunbar 1992; Reinhardt 2020). Remaining small in size may also help counter external threats to DARPA's independence from special interest groups and the taxpayer. By staying below the radar, DARPA might avoid targeting for predation and regulation despite the higher political transactions costs associated with extremely uncertain and disruptive innovation efforts.

DARPA maintains its small footprint by externalizing research, which is promoted as another strength of its governance model. The agency avoids the high transaction costs involved in obtaining the unique knowledge and equipment

required in pursuing groundbreaking research. DARPA does not establish its own labs or the bureaucracy involved in managing them (Cummings 2018; Reinhardt 2020). Instead, it outsources these assets through discrete project funding that yields a lower overhead and streamlines accountability by ensuring each project is responsible to one person, the program manager (Reinhardt 2020).

Despite the perceived advantages of DARPA's small size and externalization of research, there may also exist associated drawbacks. Overcoming the Sen paradox by internally streamlining preferences might restrict a sense of competition among independent program managers and instead promote expert failure by enhancing synecological bias through motives that Koppl (2018) argues are inherent in maximizing expert utility. These motives include identification that is tied to a common mission as well as a sympathy for and a desire to please fellow experts.

Moreover, even though the organization's small footprint might help to ward off threats to predation, it increases the detrimental effects of politicization should the willingness to decrease autonomy dominate as predicted by Ter Bogt's political transaction framework. If all program managers are aligned tightly with DARPA's director, absent bureaucracy, politicization of the director could lead to a prioritization of goals and efforts entirely dictated by external forces rather than the organization's stated mission (Reinhardt 2020).

An intentional restriction in size also shapes broader ramifications for Mazzucato's vision of strategic structuring that calls for a replication of the DARPA model to induce the entrepreneurial state. Breznitz and Ornston (2013, p. 4) argue that bastions of successful public sector entrepreneurship will more likely "occur at the periphery of the public sector, in low-profile agencies with relatively few hard resources and limited political prestige." They cite DARPA as a peripheral organization that does not suffer from the political interference found with a larger and "centrally positioned" agency. These strengths pose a significant challenge in attempting to scale the DARPA model in order to achieve a vision of transformational value creation by the public sector.

Finally, there are disadvantages in externalizing research that involve tradeoffs in transaction costs. While DARPA avoids the high overhead costs associated with providing its own labs and equipment, it incurs the costs of finding and establishing relationships with appropriate and competent performers and ensuring that these performers produce value on time and on budget. These costs involve large undertakings, which typically require hierarchical control to monitor and prevent shirking (Reinhardt 2020). Koppl (2018) argues that synecological redundancy is a key tenant in mitigating expert failure. Instead, the DARPA model relies on a lone program manager tasked with multiple ventures, which exacerbates the risk of unreliability due to expert error to include making unintentional or "honest" errors given the limited cognition of an expert's bounded rationality. Therefore, by outsourcing its potentially transformative research efforts, DARPA might find it tempting or even necessary to outsource the centralized control mechanisms required to produce such results. Such requirements can limit research partnerships to larger, more mature companies and increase the likelihood of rent-seeking behavior. Nevertheless, the DARPA model provides a check against these alleged disadvantages

by motivating active program management, which involves the third key factor of my case study analysis.

Factor 3: Limited Tenure and Urgency

Congress grants DARPA special privileges in hiring and contracting authority. Specifically, DARPA can directly and expeditiously hire science and engineering experts from industry and academia for term appointments, typically 3 to 5 years. DARPA's special contracting authority lowers the transaction costs of the government acquisition process in not only bypassing burdensome procurement regulations to develop flexible agreements with R&D performers but also by empowering the program manager to reprioritize and reallocate funds based on performance (Gallo 2021; DARPA 2016). These authorities give DARPA distinct advantages through the motivation of active program management and ideas generation as well as in providing a counter to the Sen paradox.

Limited tenure encourages program managers to take risks in funding ideas for short-term durations but with a long-term view in mind, where both the need and value proposition are uncertain (Bonvillian et al. 2019; Gallo 2021). The hiring process sets expectations upfront that the program manager position is not career oriented. Excelling in the position will not result in a promotion within the organization, and funding unsuccessful long shot ideas will likely not adversely impact one's career (Reinhardt 2020).

To achieve long-term impact, program managers seek ambitious project ideas and tolerate associated failures as "the cost of supporting potentially transformative or revolutionary R&D" (Gallo 2021, p. 6). However, checks are inherent in the DARPA process that attenuate the effects of failure via the short-term funding of seedling projects, which allows the program manager to track progress and terminate and redeploy funding for those projects that underperform (Van Atta and Windham 2019a). In this manner, while DARPA externalizes research, it bears the risk for the performer, which advocates insist is a major advantage over private sector venture capitalism. Furthermore, DARPA can also bear the risks for other funding mechanisms by signaling technology validation, which encourages larger industry performers to front their own money or other government entities like the National Science Foundation to provide grants to continue development (Reinhardt 2020).

In addition to incentivizing risk taking via active program management, limited tenure creates constant turnover of personnel (~25 percent per year) that should ideally result in a continued infusion of ideas. Not only does this turnover model help with new idea generation but also allows a revisiting of old ideas that might have been tried previously and failed. Subtle tweaks to an old idea or simply the timing and environment in which the idea reemerges may result in improved outcomes that would not have otherwise materialized had the organization preserved the memory of past naysayers (Gallo 2021).

A final advantage of limited tenure is that along with the aforementioned small manpower footprint, DARPA's hiring flexibility provides a counter to the Sen paradox associated with distributed control governance mechanisms. The DARPA director can shape coherent behavior by hiring similarly minded and motivated subordinates with preferences that align to the DARPA mission of creating and preventing technological surprise.

As with the other key factors, there exist theoretical counterpoints to the purported benefits of DARPA's limited tenure and flexible hiring policies. An obvious drawback to excessive risk taking is that associated failures are a cost to the taxpayer and moreover, could result in destructive entrepreneurial outcomes. While logic supports the need to tolerate failure when pioneering disruptive technology advancement, understanding the returns to such efforts via cost-benefit analysis remains an appropriate consideration. This includes taking into account the costs in revisiting or duplicating old ideas that simply will not work despite the fact that program manager turnover reinvigorates their appeal (Gallo 2021). Furthermore, while limited tenure may motivate risk-taking, it cannot completely displace familiarity bias, which influences agents to invest in and with those they trust (Reinhardt 2020). In the case of the DARPA program manager, this bias might result in allocating funding to those researchers with sound and stable reputations over less mature, smaller enterprises, which runs counter to Schumpeterian entrepreneurship.

With regard to flexible hiring practices, the methods DARPA uses to streamline preferences and foster coherent behavior do not fully embrace the theoretical underpinnings required in overcoming the Sen paradox. As government employees, neither DARPA program managers nor the director are residual claimants, which is a striking difference between public sector entrepreneurs and venture capitalists. The standard solution to address the agency problem caused by decision managers not being residual claimants is via compensation that accurately reflects performance in the overall market for management (Fama 1980). Miller (1992, pp. 100–101) stresses that the streamlining of preferences via socialization is insufficient because adverse selection causes measurement error in determining the potential fit of a candidate for hire. Instead, the most effective means of "reconciling transitivity, efficiency, and delegation" is through the compensation system. While DARPA's unique status allows for the authorization of higher salaries than compared to other government agencies, a pay gap certainly exists between similarly skilled private sector counterparts in the science and engineering communities. Consequently, DARPA must depend on the aforementioned personal gain incentives.

A final concern exists with the overall concept of active program management, which has sparked debate over the benefits of DARPA's changes to process over time. In the days of ARPA (1958–1972), program managers exercised less control over the efforts of performers, while maintaining responsibility of overall vision and funding (Worrydream 2017; Kleinrock 2014). Tracking progress and performance via standard program management techniques can focus too much priority on near-term results and derail long-term vision (Cummings 2018). This focus is bureaucratic in nature, which ironically is what DARPA is chartered to avoid.

Empirical Analysis

The next step of my case study analysis explores quantitative and qualitative evidence that bolsters either the points or counterpoints described above regarding the three key factors of the DARPA model. First, regarding independence, ample evidence exists that DARPA has become less autonomous over time, which is an indication that political transaction costs have influenced the willingness of political actors to tolerate a high level of opacity. Starting with the transition of ARPA to DARPA in 1972, increased oversight has influenced how DARPA spends its money. Lump sum authorization of funding by Congress has shifted to demanding annual budgets for each program that include a description of the work to be performed. Despite DARPA's streamlined processes over other government institutions, grants for seedling projects must still go through an open and involved solicitation process. As a result of orienting DARPA's work more to the needs of the military to counter existing threats, DoD has shaped and dictated shorter-term areas of R&D efforts to support active conflicts such as the Vietnam War in the 1970s and Global War on Terror in the 2000s. Finally, and perhaps the biggest example of increased politicization, the appointment of DARPA directors is now aligned with presidential administrations (Reinhardt 2020).

Regarding the pros and cons of organizational size, DARPA has maintained a relatively small manpower footprint over time. In remaining small and flat, DARPA has successfully resisted Parkinson's Law, a crucial contributor to bureaucratic inefficiency where success is measured by the growth in the number of subordinates under a director's control (Tullock 2005 [1965]). However, evidence exists that DARPA's externalization of research suffers from the high transaction costs involved in searching for competent researchers and monitoring performance. In 2001, DARPA started awarding prime contracts almost exclusively to "established vendors," which relegated universities and start-up firms into a teaming concept that reports through the prime contractor (Fuchs 2010, p. 1138).

Sound reasons exist for the shift in awarding prime awards to established vendors. Fuchs (2010) cites the decline of corporate R&D labs over time as responsible for raising the transactions costs. An established vendor can better perform the systems management necessary to see technology advancement through to production and thereby avoid "the Valley of Death." Conversely, the relegation of start-ups to a supporting role in the DARPA process is concerning considering the view that newer entrepreneurial firms are the linchpin for breeding successful innovation because of ownership incentives and information advantages (Karlson et al. 2021). Furthermore, the dependence on larger, more mature companies to provide the hierarchal control mechanisms for the externalization of research increases DARPA's vulnerability to rent seeking by special interests, which directly stunts productive entrepreneurial opportunities.

In a sense, DARPA's arrangement with established vendors might represent a transfer of expert power from the program managers to the large industry R&D performers. Koppl (2018) proffers an information choice theory model of an

epistemic system utilizing a sender-receiver game construct. As applied to DARPA following the shift in awarding prime contracts to established vendors, the program manager now represents the receiver (or nonexpert) beholden to a monopoly of senders (or experts) as represented by the large defense contractors. The receiver grows more powerless as rivalry among senders is reduced. Not only does this lack of rivalry increase synecological bias, but the intentional relegation of start-up companies also restricts free entry, which Koppl cites as a key contributor to expert failure: "'Potential competition' is more important than the number of incumbent competitors" (Koppl 2018, p. 205; cf. Baumol 1982).

DARPA's adherence to active program management might offset the increased likelihood of expert failure and vulnerability to rent seeking caused by the shift in contracting strategy. Anecdotal evidence supports the view that DARPA program managers have a healthy tolerance for failure. Over DARPA's history, project losers ranging from research into paranormal activity to developing mechanical elephant transports to more recently, testing rapid space launch capabilities have showcased a willingness to try out challenging and quirky ideas (Gallo 2021). Of a more quantitative nature, Goldstein and Kearney (2017, 2020) conducted studies measuring past project selection and performance for ARPA-E, the Department of Energy's transformational R&D organization, which can serve as a proxy for DARPA. Goldstein and Kearney (2017) find that ARPA-E program managers exercise autonomy via their tendency to select projects for funding that receive less consensus from external peer reviews.

Furthermore, Goldstein and Kearney (2020) find that program managers do not shirk from playing an active role in the management of their portfolio by frequently redeploying money to increase funding for stronger performing projects and decreasing or terminating funds for those that perform weakly. In this manner, they are exercising real options similar to the way venture capitalists monitor their investments and unlike the hands-off approach that other public sector entrepreneurial mechanisms such as the Small Business Innovation Research (SBIR) program take via the provision of grants.

In terms of the effectiveness of DARPA's flexible hiring practices, compensation gaps between program managers' salaries and their private sector counterparts loom as a significant concern. Reinhardt (2020) estimates that experienced scientists and engineers at large tech companies receive at least twice as much compensation, whereas this gap was much less severe (~20 percent) in the 1960s during the days of ARPA. The commercial high-tech sector promises to be even more competitive going forward, which may not bode well for attracting top talent to a position that entails no promotion and requires relocation to Washington, DC.

In analyzing possible frictions between DARPA's dual roles in executing transformative R&D and responding to threat-based time-sensitive challenges for the military, a review of DARPA's history tells a tale of two different organizations. The first tale involves the ARPA years from 1958–1972, when Congress and DoD exercised much less oversight over the agency and the program managers exercised much less oversight over research performers. One of the earliest DARPA directors, Jack Ruina, "valued scientific and technical merit above immediate relevance to the

military" and delegated a high level of autonomy to his program managers (Fuchs 2010, p. 1137). The best example of this delegation involves one of the organization's greatest successes, the R&D that led to the advent of the Internet and personal computing. J. C. R. Licklider, the program manager for these efforts, advanced an ambitious vision that foresaw computers serving as "interactive intellectual amplifiers for all humans, pervasively networked worldwide" (Worrydream 2017, para 14; Kleinrock 2014). This vision was only loosely connected to solving command and control challenges for national defense, and it did not entail a specific set of goals nor a roadmap. Instead, Licklider leveraged the power of his vision to find and organize an impressive network of researchers and sustain investments in the underlying technologies to achieve success (Van Atta and Windham 2019b, pp. 39–40; Bonvillian 2019, pp. 94–98).

It is important to note that ARPA's considerable level of independence did not always result in productive entrepreneurial outcomes. Project AGILE supported combat operations in Vietnam and involved mismanaged efforts to improve weaponry, which included chemical agents. The project was an unmitigated disaster, which led to the conviction of the program manager, William Godel, for embezzlement. Yet, because of its covert nature, the project avoided scrutiny allowing it to survive for over a decade (Van Atta and Windham 2019a; Reinhardt 2020). This example of a destructive entrepreneurial outcome calls into question the sustainability of unfettered independence for inherently governmental organizations, which provides a convenient segue to the second tale of DARPA.

The shift from ARPA to DARPA in 1972 increased oversight and focused the organization's efforts more directly on military application. By 1975, DARPA's new director, George Heilmeier, instituted what became known as the "Heilmeier Catechism," which was the genesis of active program management. Heilmeier influenced more of a top-down and mission-oriented approach for the management of projects that involved setting intermediate and long-term goals, tracking progress, and estimating the costs and benefits of each research effort as it pertained to the customer (Van Atta and Windham 2019a, pp. 14–15; Fong 2019, pp. 193–194; Cheney and Van Atta 2019, pp. 233–234). Although active program management mitigates the risks of longer-term, highly uncertain technology advancement efforts and increases the success rate of technology transition, it also entails greater costs to autonomy and disincentives toward risk-taking over ARPA's more vision-oriented approach.

The ultimate empirical evidence in evaluating the effectiveness of DARPA over time would be to accurately measure return on investment in terms of innovative output. Attempts at measuring patents per award and funding per patent illustrate that DARPA performs considerably well compared to other government agencies; however, these cannot be considered apples-to-apples comparisons given the varied charters and missions of these agencies, nor do these assessments address the more important question as to how well DARPA performs compared to the private sector (Piore et al. 2019, pp. 49–52).

Reinhardt (2020) reviews the agency's own advertised accomplishment timeline and bins what he refers to as "outlier successes" into two categories: pre-1972

(ARPA) and post-1972 (DARPA). An outlier success can be considered synonymous with architectural innovation, which disrupts and creates markets while also outmoding existing competencies (Abernathy and Clark 1985). The results of Reinhardt's binning excursion reveal that the vast majority (over 70 percent) of DARPA's architectural innovation occurred during the ARPA years. The ramifications of this revelation do not detract from the value DARPA has provided and continues to provide to its single customer, the military; albeit this value is harder to appreciate given its specific military utility and narrow applicability.

Conclusion

This chapter analyzed the institutional mechanisms of DARPA as a model for strategic structuring that fosters Schumpeterian public sector entrepreneurship. In reviewing three key factors that expound the DARPA model, I explored theoretical points and counterpoints that make for a complex and inconclusive assessment as to the potentiality of DARPA's distinctive form of organizational governance in fulfilling the vision of an entrepreneurial state.

Through a unique combination of centralized and distributed control mechanisms, DARPA possesses a higher level of autonomy, at least compared to other government organizations; however, I find this autonomy to be unstable. Political transaction costs associated with state-guided innovation efforts decrease the willingness to autonomize, which erodes independence via three discrete sources. First, concerns from the taxpayer over abuses to opacity and expert failure have led to more congressional oversight over time. Second, vulnerability to rent seeking by special interests has increased, which is evidenced by a transfer of expert power to and a growing dependence on established vendors to provide the hierarchal control mechanisms for the externalization of research. Third, pressures from external stakeholders such as the military have influenced a greater focus on shorter-term military or administration priorities, which can incentivize technology transition over risk-taking. While DARPA is better equipped than others to ward off threats to its autonomy through such advantages as flexible hiring practices and special contract authorities, its model depends on employing highly competent and motivated program managers, and yet, subsequently cannot depend on compensation to overcome the residual claimant agency problem.

My research reveals that the vast majority of DARPA's architectural innovation occurred prior to the critical shift from ARPA to DARPA in 1972, which was a time characterized by much less external oversight and a much lower pay gap between government and private sector high-tech labor. It is important to note, however, that this correlation between ARPA's greater autonomy and innovation success should not imply causation. Another factor at play could be the characteristics of the post-World War II era, or perhaps more specifically, the height of the Cold War, which involved a level of crisis that dictated a demand for rapid and novel change and raised alertness to entrepreneurial opportunities. Indeed, DARPA's founding is

steeped in a collective mobilization across the public sector domain to counter the crisis of technological surprise. Since that time as the Cold War diminished, preparing for "system-level war" shifted toward a focus on responding to "shorter-term tactical missions." Ruttan (2006, pp. 183–184) contends that the absence of a major war, or at least the threat of one, diminishes the probability that our political system could generate the willpower and resources "required to initiate and sustain the development of major military and defense-related general-purpose commercial technologies of the past."

Another crucial concern in assessing DARPA as a model for Mazzucato's strategic structuring vision is its scalability. Even if DARPA can effectively sustain a resistance to political interference, this would be attributed to its small footprint and its existence as a peripheral organization. The fact that DARPA's disruptive technology efforts can threaten status quo defense acquisition processes, which can drive opposition within the military, does not support the claim that the high-risk, high reward approach inherent in Schumpeterian entrepreneurship could expand to transform large areas of the government. Even attempts at cloning DARPA for the sake of establishing other peripheral organizations dedicated to long-term revolutionary R&D have met with resistance and limited success. For example, despite consultation on adopting the strengths and processes of the DARPA model, ARPA-E suffers from greater hierarchical control both internally and externally. Within the organization, the program managers are outnumbered by support staff, which entails a higher level of process-driven activity. External to the organization, ARPA-E is directly funded by the Department of Energy instead of Congress, which threatens independence of basic functions such as program selection and idea generation (Fuchs 2009; Reinhardt 2020).

In conclusion, DARPA undoubtedly provides value to the defense of the United States and has generated productive public sector entrepreneurial outcomes. However, the agency falls short in representing a sustainable and scalable source of strategic structuring that would befit the entrepreneurial state.

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