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Beyond Public and Private:

Collective Provision Under Conditions of Supermodularity

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I. Introduction

There are many situations where it is cheaper to provide a benefit to many people all at once, rather than providing them to one person at a time. Examples range from shipping networks to public health to digital infrastructure to scientific research. As technological development accelerates, more and more goods fall into this category, incentivizing economic actors to provide goods in a massively "wholesale", rather than retail way. This points toward greater efficiency, but also deeper economic and social vulnerabilities. It results in more and more vital infrastructure that is open to private capture and monopoly. And AI accelerates these dynamics to an unprecedented degree.

Goods which are more easily provided at scale than on an individual basis might be called "supermodular" goods. This phrase underlines the way they tend to bind discrete units together into larger wholes. Supermodular goods encompass everything under the familiar umbrella of "public goods", but also include private or *excludable* systems that become more effective when provided to more people. Capitalism assumes a world of discrete agents with private property endowments that they can trade with each other. In such a world it excels at facilitating trade – in other words, it thrives in a submodular world. But it is not well-suited for supermodularity. This explains a variety of failures in the physical and digital spheres, from the proliferation of technological monopolies built on supermodular network effects to the breakdown of our shared information ecosystem.

On the other hand, the potential collective benefit to appropriately resourcing, incentivizing, and governing supermodularity is enormous. As technological progress expands our capacities, this will only become more true. We should develop better funding and decision mechanisms, paired with new institutional structures, to address this gap. In particular, there is an opportunity to make public provisioning systems more decentralized (addressing legitimate critiques of central, state-led provision) without sacrificing public benefits or shared ownership.

A welcome development in this space is the growing ecosystem of experimentation with quasi-public supermodular goods providers, centered around public goods and commons funding, within the web3 and adjacent communities. This ecosystem has been marked by the development of crypto-native public goods

funding mechanisms (notably quadratic funding, retroactive public goods funding, impact certificates, etc.). These experiments can serve to uncover insights that may underpin better collective infrastructure and technology provision more broadly, whether through local government matching funds (as piloted in Colorado), or through processes that can be exported to other communities.

Here, we argue that to bring real coherence to the space of collective provision, this ecosystem must not only transcend the binary between public and private provision, but also discard traditional framings of public goods and commons, which are under-inclusive for the purpose at hand. Instead, the goal should be to solve for collective provision and governance under conditions of supermodularity. In making this argument, we proceed as follows: 1) reframing rivalry and excludability as continuous, rather than discrete, 2) introducing supermodularity and anti-rivalry, 3) describing supermodular networks spanning excludable, rivalrous, and anti-rivalrous goods, and 4) providing examples of enabling supermodular network provision.

II. Expanding the 2x2: Beyond Public and Private

It is well established that strict characterizations of boundaries between public and private goods, and therefore public and private provision, are overdrawn. However, we will embark on a brief review to establish just how overdrawn these distinctions are, and how confused this has made our overall approach to supermodular provision.

Below is the classic 2x2 categorization of goods, pioneered by Paul Samuelson and expanded by Vincent and Elinor Ostrom[1]. The 2x2 is predicated on two categorizations: excludability (can individuals be prevented from consumption) and rivalry (does consumption by one individual diminish availability to others). These axes produce four categories: **private goods,** which are excludable and rivalrous and thus efficiently provided by the market, **public goods,** which are non-rivalrous and non-excludable and thus underprovided by the market, often necessitating state or philanthropic provisioning, and **club goods and commons**, which are non-rivalrous and excludable vs. rivalrous and non-excludable, respectively.

	Rival	Non-Rival
Excludable	Private	Club
Non-Excludable	Commons	Public

[1] Thanks to Scott Moore for helpful additions on commons governance and digital public goods.

Each type of good has an oft-associated mechanism for governing the question of 'what is good' in that category. In the case of the public goods, the state (democratically or not), decides 'what is good' and funds it. In club goods, an association typically decides how to invest in the shared good and how to exercise the power to exclude. In the case of the commons, self-organizing groups decide 'what is good' and try to sustain it. In the case of private goods, market entities use the price mechanism to determine 'what is good' and provide it at a cost to capture profit.

But the messiness of reality breaks down these artificial distinctions, with significant consequences for decision-making and provision. Most resources lie somewhere on the private-to-public spectrum. Even personal goods can be shared with or have small-scale positive externalities on family and friends (e.g., furniture in a shared home). Most public goods are semi-excludable, such as through geography and access (e.g., lighthouses, fire departments, and parks). These, along with most club goods, are also semi-rivalrous, through depletion, congestion and exhaustion (e.g., roads, trails, library books, golf courses).

A more realistic conception might imagine rivalry and excludability as continuous, rather than as discrete, measures.

	Rival	Semi-Rival	Non-Rival
Excludable	Private (Cup of Tea) II	(Museum) I	Club (Toll Road)
Semi-Excludable	(Office ~~Printer~~)	(College Campus Pool)	(~~Book~~ PDF)
Non-Excludable	Commons (Lake) III	(Hiking Trails) IV	Public (Environment)

The key with this perspective shift is not only that goods exist along a spectrum, but more importantly that they can be *moved* along that spectrum. Where a particular good sits in this matrix depends, in part, on how we govern and fund it.[2].

[2] Most political actors already know that categorization is a choice, and deal with it in different ways. Free-market advocates may try to make goods provision trend towards the top-left, in hopes that provision can be decided upon and provided by market mechanisms (and they've been largely succeeding, for ex. with public investment in the US as a share of GDP falling by more than forty percent since the 1960s). But an inability to handle negative externalities, tendency towards monopolization, and inbuilt short-termism makes the market an ineffective default option for all goods that are not purely private. This may imply that most goods should be publicly provided, and this is absolutely a necessary corrective for some categories that have been privatized, infrastructure provision first and foremost. However, existing state mechanisms are often not best-suited to decide 'what is good' or execute on it. This is due to a propensity for special-interest capture,

After all, hiking trails can be made fully excludable with barbed-wire fences, electronic access points, and guards. The origin of private property came with the often violent enclosure of the commons—demonstrating that it is possible to shift lakes and rivers into private categories. We may think the environment is a pure public good, but tell that to citizens of cities cloaked in air pollution, where those that can afford air filters are certainly able to exclude others from clean air. Even public goods like pandemic prevention are largely predicated on rival resources (like tests) and excludable privileges (like working from home). And on the flip side, goods like public parks can be made less excludable[3]. The New York subway system does this for Central Park by making access easier from the boroughs. Further, rivalry can result from certain uses and not others. For example, breathing clean air might be non-rivalrous, but polluting that same air is rivalrous; using a well-maintained OSS library is non-rivalrous, whereas executing a DDoS attack on the maintainer is rivalrous[4].

We can draw two conclusions from this. First, as is already well theorized, the categorization of goods is not as clean as we may have originally thought. Determining category is as much about use, choice, norms[5], and infrastructure as it is about intrinsic qualities.

Second, many so-called public goods, from pandemic prevention to technical infrastructure, are in fact *networks of goods*, each placed at different points on the axes of rivalry and excludability. Maximizing the collective benefit from these goods requires understanding the different modes of provision and governance involved in producing and maintaining them.

III. Supermodular Goods, Anti-Rivalry, and Avoiding Capture

misalignment with relevant polities (which state should provide the Internet? or nationalize Facebook?), and the fact that many goods require sub- or supra- state coordination. Thus, while greater public provision is necessary, this is best when adjudicated through hybrid mechanisms for determining what is needed and how to best provide it.

[3] For an expanded example of excludability as a choice, let's look at a digital mp3 file. There is nothing inherently 'excludable' about such a file; in fact, its properties tend towards non-excludability, as mp3s can be freely transferred, read, and shared. However, producers of such digital files have a vested interest in ensuring excludability to incentivize purchase. Thus, the costly process of Digital Rights Management (DRM) emerged in order to limit file usage despite inherent non-excludability. DRM has multiple costs associated with it—beyond administrative and technical costs, DRM-ing a file means producing a program to read the file rather than relying on third party players and readers, requiring the extra steps of user authentication and account creation, preventing transfer of ownership, and being unable to support file formats once the DRM server goes offline. This is a cost that producers accept, and thus can force the rest of the ecosystem to accept, in order to *make* this particular type of good excludable. It can be argued that this form of DRM-ing is necessary to enable innovation and protect intellectual property. However, even if this is the case, it seems highly unlikely that the producers of these files are those best-placed to adjudicate tradeoffs between incentivizing innovation and positive-sum effects from file-sharing. And yet, in this paradigm of exclusion, it is largely those with the power to exclude that make society-affecting decisions over when exclusion is the appropriate choice.

[4] Thanks to Evan Miyazono for these helpful examples.

[5] On norms, a hiking trail can be excludable in many countries if it is on private land, but in Nordic countries Allemansrätten rules often mean that it legally cannot be; thank you to Vitalik Buterin for this helpful example.

Pure public goods, as traditionally defined, are rare. First, non-rivalry is more elusive than generally acknowledged: information, even if copyable at zero cost, is often more valuable to whoever gets it first. Second, complete non-excludability is rare except where enforced by a greater power like a government. Information can be kept secret, fences can be built, and goods can be hoarded.

But supermodular goods, which are more efficiently provided at scale rather than individually, are ubiquitous. Focusing on funding and governing supermodularity therefore presents the clearest opportunity to deliver great collective benefit.

In supermodular contexts, pure private ownership is economically incoherent because of the collective nature of value creation. We will briefly lay this out below.

A Generalizable Account of Plural Provisioning for Supermodularity:

1. The fundamental principle of efficient pricing in a market is that people are paid in accordance with their marginal product.
2. This holds in submodular situations, where the decreasing value of marginal contributions theoretically enables both fair compensation for inputs and surplus, which is taken as profit.
3. In supermodular situations, by definition, the marginal contribution made by the addition of any component *exceeds* the total amount created.
4. In these cases, one cannot pay out the full value of marginal contributions.
    a. Take the limit case of perfect complementarity (zero value from individual contributions, value only achieved through full participation) — in this case, the marginal contribution of every component is the total value. Paying marginal contributions is impossible.
5. Thus, the very principle by which markets theoretically achieve efficiency leads to enormous losses in supermodular cases. The whole notion of profit that capitalism is built on only arises in submodular conditions, where the sum of marginal products is less than the whole.

Diverse and hybrid modes of provisioning that combine sub- and supermodular processes are necessary to unlock collective value from these goods. Supermodularity particularly characterizes ecosystems that develop and deploy transformative technology: open-source software, inventions, scientific research, protocols and standards, and organizational innovations. Here are a few features of supermodularity that demand consideration:

- **Supermodular goods are often anti-rival.** Anti-rival goods go beyond mere non-rivalry (where use by one does not take away from use by another): instead, use by one adds *positive value* that others can enjoy. The term was coined by Steven Weber at Berkeley to describe open-source software, but can be extended to categories far beyond it: from discoveries and inventions (ex. solar cells) to ideas, to systems of law (ex. liberal democracy) to protocols (ex. blockchain protocols) and standards (ex. TCP / IP), to institutions (ex. Creative Commons). Anti-rival goods enable increasing returns to the network. These

are sometimes directly referred to as 'network goods', although not all network goods are anti-rival given network constraints.

- **Supermodularity can apply differently to different aspects of the same good.** Olleros uses the example of a US $10 bill. The bill itself is submodular: it is alienable and cannot be replicated at zero marginal cost. But the use of the bill contributes to the supermodular American currency system, which benefits from greater collective use. This also emphasizes the *designed* nature of many anti-rival systems. Anti-rivalry of currency is managed and protected, often by force or some other mechanism; it is often not a purely natural occurrence but a choice, with complex pluses and minuses.
- **Supermodular systems benefit from innovation in inclusion rather than exclusion.** By their nature, supermodular goods benefit from being shared, often in rough proportion to the amount of sharing. This has deep consequences for the way that goods are managed. Instead of innovating ways to exclude at cost, benefit accrues from innovation in inclusion. Managers of supermodular goods think in terms of inductance, not in terms of resistance.

IV. Plural Collective Intelligence Mechanisms for Supermodular Goods

These properties make supermodular systems difficult to deal with under existing capitalist defaults.

- **Supermodular systems are prone to capture and underfunding due to misapplied notions of private property.** Private property is best suited to decreasing returns (sub-modular) contexts, and thus when incorrectly applied can erode beneficial supermodularity through rent-taking and capture. This is evident in the existence of data monopolies, hyperconcentrated foundation models, and massive web2 platforms, which operate on network effects, but hoard privately-owned power to the detriment of the larger ecosystem. Vaccine delivery is another example—the inherent supermodularity of pandemic prevention means that purely private innovation and delivery are unequal to the task. A combination of underfunding and rent extraction can lead to massively constrained societal outcomes, limiting network growth.
- **Supermodular systems tend toward monopoly.** In a system where monopolies are strictly private and incapable of democratizing, this is unacceptable. However, scale is beneficial when divorced from dominance. We recommend instead a collective intelligence approach that accounts for the interests of the groups that are disempowered by monopolies, replacing monopoly prevention with democratization.
- **Supermodular systems have submodular components, meaning that pure public provision is often misled, while pure private provision leads to under-provision or excessive value capture.** Beyond congestion pricing, carbon pricing, and the like, market mechanisms can be useful in dealing with the elements of supermodularity that are scarce. Expanded voucher systems, shared pools of credit, token-based collective financing, and more can all serve to bring in the information potential of markets without privatizing returns.

Thus, supermodularity requires hybrid prioritization and decision-making mechanisms (henceforth, collective intelligence mechanisms) that combine democratic, market, and community governance. It is here that the nascent public goods funding ecosystem of web3 can contribute. Take grants programs like Gitcoin's which are based on quadratic funding (QF): they utilize a democratic market mechanism (QF) to match philanthropic (private) funds with community needs. The collective intelligence imaginary of supermodular goods takes these examples and expands on them to envision a broad range of mixed decision-making mechanisms that can serve to both provide and govern supermodular goods, to ensure availability, but also protect against negative-sum transitions. Recent innovations in building 'Decentralized Society' expand the possibility-space of such mechanisms through rich layers of community attestation and verifiable social identity.

Expanded opportunities here are significant. Possibilities include:

- **Mixed funding models.** Imagine if democratic matching-fund mechanisms were available for for-profit as well as non-profit entities. A range of corporations may then receive at least some amount of matched funding, which could be accompanied by some form of governance rights. For-profit cooperatives might flourish, with partial philanthropic funding, community-managed enterprises might benefit, or even programs democratically determined to be supermodular within traditional corporate structures. These funds would no longer be targeted to pure public goods, meaning that they would be enabling greater excludability than other funding opportunities. However, in return, the range of impact would be greatly widened—one can see this as a form of trading-in complete non-excludability for greater applicability. Rather than calls for nationalization, or internal / employee-driven advocacy, this method can enable oversight aligned with the mandate of growth while incorporating democratic preferences.
- **Last-mile funding for positive-sum infrastructure.** Typically, if an outcome is collectively desirable but unprofitable (even slightly), it is difficult to achieve without direct public subsidy or direct philanthropy. Many innovative projects with increasing returns can languish in this "valley of stagnation", from research to experimentation to small businesses that would benefit many in a community. CI mechanisms used to enable supermodular networks could shore up small-scale unprofitability, enabling better network outcomes.
- **Public investment with decentralized input and shared returns.** This logic can be taken even further. Imagine for instance using collective intelligence mechanisms to direct public funding for industrial policy, rather than public subsidies (which face the typical 'choosing a winner' criticism). Matching funds could enable far better information aggregation and processing across various relevant stakeholders—expert-driven forecasting, worker input, information from overseas suppliers, and the desires of the public—combining the decentralized logic of the market with the accountability of democratic input.
- **Community currencies and expanded voucher systems.** The basic idea of vouchers is simple: governments distribute a 'currency' usable only for some particular set of goods, enabling some

market-like intelligence on the allocation side while enabling greater provision. The Singapore housing system is a prime example—housing is publicly owned, but allocated with a flexible voucher lottery, allowing for some choice and trade while ensuring a base level of provision. There are limitations to the traditional setup: they either adopt the problems of the normal market (if vouchers can be sold), or sidestep the point of having a market (if they cannot). However, one can incorporate market-driven features without undermining egalitarian goals. Individuals could earn interest on vouchers, for example, or exchange value into adjacent contexts. More broadly, vouchers can expand into full-fledged community currencies, enabling internal governance and monetary policy to provide community goods and services (ex. allowing for customizability in exchange terms, transfers, mutualist systems of credits and loans, etc.). A far more thorough treatment of this design can be seen in Prewitt and Weyl's Plural Money.

- **Deliberative value elicitation.** Allocation is not the only or even the core problem at play in supermodular systems. Deliberation over what should be prioritized, when, and at what cost are equally necessary to steward these systems in the public interest. In fact, it is the lack of a reliable informational feedback loop that makes pure public provision non-ideal in these fast-moving circumstances. CI mechanisms in the form of decentralized consensus-building platforms (such as pol.is and Loomio), scalable citizen juries (citizen's assemblies matched with liquid democracy), and other forms of information aggregation (such as prediction markets) could be far more granular inputs into what should be prioritized, not just how.

Ecosystem of Collective Intelligence:

Mechanisms	Technologies	Systems
prediction markets, pricing, deliberation, voting, representation / liquid democracy, sortition, bureaucracy, hierarchy, community currencies	deliberation / voting / prediction platforms, DiDs and SBTs, blockchains, mesh networks, federated data architectures, impact certificates	Wikipedia, OSS, digital rails, AI governance, corporate structure, Gitcoin, nation-state democracy, public vouchers, industrial policy

Investment in net-new collective intelligence mechanisms to determine the shape of supermodular provision is just beginning. For them to succeed, we can and must make collective intelligence systems much better. Several inputs can be worked on:

- *Expanding the purview of collective input:* investing in large-scale digital democratic experiments and coordination technologies, developing value adjudication tools through augmented intelligence, and building federated networks of public and cooperative entities.
- *Enabling shared ownership*: building primitives that can lock in ownership for individuals and communities, as well as new modes of joint and fractional ownership.
- *Leveraging market mechanisms for information*: nudging prediction markets towards truthful mechanisms, and leveraging market dynamics and pricing for more democratic and subjective input, as

with cryptoeconomic experiments.

- *Improving institutional capacity*: building fluid, semi-permanent institutions that can both implement collective intelligence mechanisms and successfully build and execute on collective decisions.

V. Applications

A supermodular approach to transformative technology development and governance could address some of the most pernicious problems of the current system.

- **Artificial intelligence:** The existing funding ecosystem for AI is deeply implicated in challenges around both deployment and governance. Race dynamics that emerge from a desire for single-shot value capture (by both corporations and nation-states) disregard that both AI safety and AI progress are supermodular in nature. A supermodular approach would involve distributed value capture (via democratic alternatives to proposed windfall taxes), paired with consortium-based auditing (potentially tied to smart contracts or other autonomous auditing frameworks) to act as a check on privately-deployed funding. Data, which has both supermodular and submodular properties, would form a crucial institutional input via accountable intermediaries like data coalitions, allowing for different forms of rivalry and excludability to emerge aligned with, rather than opposed to, governance rights. This way, the massive upsides of AI could be better socialized; and a broader cross-section of society would be engaged in the project of mitigating its collective downsides.
- **Internet governance:** The early internet was designed as an open network of networks, funded and championed by the public sector, supported by academic institutions and the private sector, and governed by multi-stakeholder standards-setting processes. Existing internet protocols (HTTP, SMTP, TCP / IP) are still governed by multi-stakeholder bodies, and new protocols are added and debated regularly. However, the top layers of the stack are now largely captured by entities that privately provide the foundational digital rails that the original founders of the Internet imagined would also be open and interoperable. By 2017, Google and Facebook had control of 70% of Internet traffic. Taking a supermodular approach would mean moving away from corporate capture without insisting on nationalization. This would involve the development of further open protocols for basic digital affordances—identity, payments, data sharing, communications—with value capture at the application layer still open for corporations, but rent-seeking at the infrastructure layer governed by transparent, public-private coalitions.
- **Carbon markets.** There is a growing market for carbon offsets as corporations adopt net zero commitments; however, minimal auditing and impact monitoring has led to a proliferation of ineffective offset products. Instead of purchasing direct offsets, one can imagine a world in which corporations could instead support green energy infrastructure (ex. nuclear plants) or climate-resistant infrastructure (ex. updating the ailing electricity grid), and receive similar offsets. Investing in infrastructure is riskier than commodified carbon offsets, but orders of magnitude more effective. This is a prime case where pooled mechanisms are necessary, combining standardized measurement (of offset

potential), with clear risk calculations (carried out by experts), with public input (on positive-sum infrastructure projects), and private benefit (via low-cost adhering to regulation via innovation, rather than bounties).

While digital technology has expanded the range of supermodularity, they are by no means purely digital—transportation networks, art, cities, traditional commons, and universities can all be thought of as variously supermodular, with anti-rival characteristics that are vulnerable to capture (which is partly why many of these are subsidized by governments). One relevant illustration is in the ecosystem of local journalism, which is currently massively underfunded in the United States, to the detriment of the social fabric of countless communities. While the physical products of journalism are rival and potentially excludable, digital reporting can be made non-excludable and non-rival. Access to high-quality information is anti-rival with appropriate funding mechanisms in place. However, the current mix of goods has given rise to monopoly capture (today, half of all daily newspapers in the US are controlled by financial firms), with predictable impacts on reporting, accuracy, and longevity. A vibrant shared information ecosystem is crucial to the functioning of democracy. Still, no single actor can step in and guarantee it—a supermodular network that spans public, private, and community actors is necessary.

VI. Conclusion

Existing economic incentives treat private goods as the default. Other modes of provision are turned to when necessary and corrected—through innovation in excludability mechanisms such as DRM or subscription pricing—whenever possible. In a world of accelerating supermodularity, this leaves significant collective value on the table.

Instead, we would encourage a general expansion of supermodular funding mechanisms. This requires greater overlap between funding models. Corporations should get some public funding in return for governance rights and commitments, and public organizations should engage in submodular rationing to reduce inefficiencies.

One could imagine a future involving:

1. Funding models for transformative tech that incorporate supermodularity (ex. capped returns with public goods distribution mechanisms for surplus)
2. Internal public goods mechanisms at corporations (ex. QF for money set aside for carbon offsets within corporations, including longer-term infrastructure offsets; cross-cutting internal infrastructure as internal public goods)
3. Introducing submodularity into public goods provision (ex. community currencies, voucher systems)
4. Partial funding of private corporations by supermodular mechanisms in return for stakeholder governance (ex. liquid democracy-style representations, Soulbound Token issuance to employees)

Expanding the scope to supermodular networks across public and private mechanisms can enable more democratic input over all categories of provision, lead to collective intelligence innovation, and enable better coordination of goods provision across scales.