

Planning progress: Incorporating innovation and structural change into models of economic planning

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Abstract

This paper addresses the challenge of incorporating innovation and structural change in models of economic planning. Previous approaches to economic planning have mostly considered the static problem of the allocation of goods and services, leaving a secondary role (if at all) for the dynamic problem of innovation and change. However, Morozov (2021) argues that the key challenge for any alternative economic system, including planning, is to incorporate a model for progress that can rival the perceived innovative and dynamic nature of capitalism. Finding previous approaches to change in planned economies to be insufficient as central elements of planning technological progress, this paper introduces two new and complementary approaches to planning innovation: Democratic accelerated missions and screening and scaling technologies. Democratic accelerated missions act on the demand side of innovation, translating democratically formulated needs for new capabilities into research and development projects to fulfill these needs. Screening and scaling technologies act on the supply side, selecting promising new technologies based on democratically decided priorities and developing them towards finished products. Both approaches draw extensively on quantitative and qualitative evidence from different strands of literature on innovation to build an empirically grounded model, with a particular focus on (1) democratic decision-making in planning innovation, and (2) incorporating insights from technology prediction and the economics of innovation to steer technological progress. The proposed model demonstrates the feasibility of planning and directing technological progress, and is a first step towards designing institutional and algorithmic structures to this end.

Keywords

Economic planning, innovation, technological change, technology prediction

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Introduction

The idea of economic planning has recently experienced a resurgence in interest, with renewed discussion that advances in digital and other technologies now make the idea feasible [Groos \(2021\)](#). Modern computing and communication tools would allow for a decentralized and distributed way of planning, adapting to the needs of consumers and citizens, rather than being imposed through a top-down general plan as was the case in the Soviet Union. The first wave of discussion, often called the socialist calculation debate, which originated in the 1920s and 1930s, was effectively ended with the article by [Hayek \(1945\)](#) on “The Use of Knowledge in Society.” In it, he argues that only a decentralized, market-based economic system can incorporate all the local and tacit knowledge necessary for efficient production, which would never be possible in centralized planning, ensuring the superiority of the market over the plan. In a follow-up to this article, [Hayek \(1968\)](#) refines this argument and argues that it is the process of competition, embedded in the market, that brings forth the efficient use of knowledge and production possibilities, thus describing competition as a “discovery procedure.” This view, seeing a competitive market-based system as superior because it can incorporate dispersed knowledge, eventually became the dominant paradigm in economic thought. A second wave of discussion arose around the fall of the Soviet Union, which was (among other problems) widely seen as a failure of its central planning. Several models were put forward how planning could be improved¹: [Cockshott and Cottrell \(1993\)](#) put forward that new computational methods could improve efficiency in production and allocation. [Albert and Hahnel \(1991\)](#) with the Participatory Economics model as well as [Devine \(1988\)](#) with Negotiated Coordination emphasize a distributed, decentralized, and democratic, form of planning, instead of the centralized top-down planning in the Soviet Union. The recent third wave of discussion on economic planning makes several contributions to this literature. First, as mentioned above, further improvements in digital technologies make planning plausible again, since the large-scale data availability and computing power should help to solve the problem of dispersed knowledge outlined above ([Groos, 2021](#)). Further, recent technological developments that are emphasized are advances in logistics ([Phillips and Rozworski, 2019](#)), and the interface between the production and consumption side of the economy akin to large online retailers ([Saros, 2014](#); [Morozov, 2019](#)). Second, the nature of work and its voluntariness have been given more consideration ([Benanav, 2020](#)). Third, discussions on ecological questions with regards to economic planning have sparked great interest ([Akbulut and Adaman, 2020](#) and citations therein).

What is common to these proposals, in all three waves, is that they understand the problem of planning mostly as a problem of producing and allocating a set of goods. This is evident, for example, in the ParEcon model by [Albert and Hahnel \(1991\)](#), which is in essence a general equilibrium type setup with a different allocation mechanism than prices, but showing that these can still lead to pareto efficient outcomes (a typical optimality condition for allocations in neoclassical economics). This focus on allocation of fixed goods is even more evident in the model by [Saros \(2014\)](#) where allocation happens through a “general catalogue” from which consumers and producers can pick and pre-order goods and inputs. Similarly, [Morozov \(2019\)](#) mentions such a general catalogue as a possible solution to the Hayek critique. While both of these models mention an adjustment mechanism ([Saros \(2014\)](#) mentions “filling in the gaps” in the general catalogue; [Morozov \(2019\)](#) speaks of “seizing the means of feedback production” to adjust produced quantities and allocation), these fall far short of a formulation of dynamics and change in the models of a planned economy. With a focus on solving the static problem of planning in terms of production and allocation, there is surprisingly little concrete research about innovation and structural change in models of planning. In a lecture based on the upcoming book [Morozov \(2024\)](#), Evgeny Morozov

argues that solving the static problem of planning does not invalidate the main critique brought forward against planning:

"It still misses the legitimation of capitalism at a much higher meta level [...] where on the one hand it establishes itself as the only way to realize the promises of liberalism and modernization which is the constant never-ending production of the new, and I would call it the institutionalization of the creative and the institutionalization of creativity if you will, while also constantly pointing out that any alternative schemes of economic organization like for example socialist planning and to some extent also green post-Keynesianism and what are described as kind of greening up the entrepreneurial state, they would not be able to deliver on this radical institutionalized newness [...] which is what you can get only if you preach to the gods of competition and to the gods of capitalist markets." Morozov (2021)

Through a reexamination of the Hayek (1945) and especially the Hayek (1968) critique of central planning, he argues that competition, markets, and capitalism derive their perceived superiority not mainly from a more efficient allocation of goods, but from the constant introduction of new goods and services. He goes on to specify that

"the kind of broader intellectual and political objective of this alternative leftist progressive project should be to articulate a vision of how you would be able to generate and institutionalize the new [...] in a way that avoids some of the problems associated with socialist planning in part because for me (and this is where I buy into quite a lot of the arguments made for example by Austrian economists against socialist ones) socialist planning even if you can make it to work really well, it's essentially an instrument for effectively allocating resources, it's not necessarily an instrument for producing the new." Morozov (2021)

Thus, we are presented with a twin challenge: Finding a model of institutionalizing the new in a non-capitalist, progressive form, and doing so in the context of economic planning which Morozov argues is as a framework incompatible with this project. This requires a reformulation of the problem of planning itself, away from improving static allocations, and towards incorporating innovation and structural change to create a truly dynamic planning model.²

Morozov is not alone in posing this challenge and focusing the view on innovation in a non-capitalist economic system. A similar view was expressed in Srnicek and Williams (2016), who, in line with other accelerationist thinkers, argue that any post-capitalist system must be highly innovative and forward-looking to gain popular support. A recent historical contribution was made by Menon (2022), who discusses the origin and politics of the planning system in India after the end of colonial rule. The book stresses that the promise of improvement in living standards was central to establishing the credibility and popular support of the economic planning committee, which in turn stabilized the young democracy and the Indian state after independence. However, innovation can also be seen as an end in itself, besides a mere means of gathering support for overcoming capitalism: Technological progress, if redirected towards progressive ends, contributes to human flourishing and liberation from work, from sickness, and from oppression (this view was perhaps most recently expressed in Bastani (2019)). For all these reasons, a model for economic planning should at least feature, if not center, a dynamic formulation of innovation and change.

The goal of this paper is to outline a model for innovation and structural change in economic planning. The next section reviews three existing proposals of how innovation could be incorporated into models of planning. Testing them against (quantitative) evidence on how technological progress happens, as well as normative and political goals that a proposal for planning should fulfill,

these models are evaluated as to whether they can serve as the cornerstone of how planning can produce innovation. Section 3 outlines a model that is both firmly set in a planning framework, and can plausibly institutionalize the new in a way that challenges capitalism. The model is designed around two main components: Accelerated, democratic missions for the demand side of innovation, and selecting and screening technologies for the supply side of innovation. Section 4 discusses the main advantages and shortcomings of the model, Section 5 concludes.

Three approaches to innovation in planned economies

“Kickstarter”-type proposals

The “kickstarter”-type refers to proposals where innovative projects are proposed, and the allocation of resources to competing projects is done via direct voting procedures. For example, the proposal by [Cottrell and Cockshott \(2008\)](#) suggests that there could be direct democratic voting on how to allocate labor time to different projects for innovation, where the labor time and resources are drawn from a specific innovation budget set aside from the overall budget available to the planning authority (they suggest a fixed fraction could be set aside each year). Similarly, [Benanav \(2022\)](#) suggests a fixed budget to be set aside for purposes of innovation, sciences, art, culture, and other “undefined or underdefined needs.” Each person would be given a certain allocation of production tokens (the currency necessary to acquire resources), and could freely form associations to pursue these needs. Individuals can either use the tokens themselves or transfer them to an association of their choice. If all individuals receive a fixed amount of tokens, and they can be transferred to different purposes, this is akin to a fractional voting procedure or a public goods investment. While the article states that these associations could be formed and receive resources “without promising any particular social benefit in return,” the model also offers that they would “generate innovations that people might want to incorporate into the social provisioning process,” and explicitly states the aim of formulating a socialist investment function.

In similar spirit, [Laibman \(2001\)](#) puts forward a proposal for an “Entrepreneurial Fund.” Proposals to this fund are awarded by lottery (beyond minimal screening for viability), and further funding can be acquired through setting flexible prices. After a fixed period (the paper suggests 5 years), the enterprise either becomes part of the general plan or folds. The proposal explicitly includes the lottery as a selection mechanism to rule out the concentration of power in the hands of the selection committee.

With this in mind, one can now analyze whether this model of effectively voting on different proposals for projects is adequate as the centerpiece of technological innovation and structural change in a model of economic planning, and raise several criticisms. The first and foremost concern is the level of resources and time that it takes to research and develop new technologies, and whether these could be raised and sustained by such an investment process. There is good evidence that the average time to develop a scientific breakthrough into a useable technology is around 20 years ([Ahmadpoor and Jones, 2017](#); [Marx and Fuegi, 2020](#)). For highly novel breakthrough technologies, there is also the need to develop many complementary innovations and for the technology to diffuse throughout the economy, often taking several decades more ([David, 1990](#)). It is unclear at best how such a long-term commitment of such a significant amount of resources would be organized through a kickstarter-type process. If the proposal would only be voted on in the beginning, it would require the dedication of a large share of all producer tokens available in that period, something which makes it both more unlikely to get the amount of tokens necessary to fund the project, and would also limit the funding for other projects in this period. If the proposal included a plan on how many

tokens would be necessary over the next several plan periods and years, it is unclear from a democratic perspective whether such long-term commitment of funding should be bound in advance several decades ahead of when such tokens will be spent and resources bound which might otherwise be spent on other projects. Proposals and projects would need to be reassessed periodically, to decide whether adequate progress has been made and whether new funding should be made available. This would compound the problems outlined below, and furthermore contribute to funding uncertainty for the development teams, who would need to invest significant time and resources into attracting funding.

A second concern is the amount of resources required to develop technologies. For each new drug or pharmaceutical product, the cost of development to bring it to the market is about 1 billion USD (Wouters et al., 2020). The Apollo programme for the moon landing cost over 25 billion USD in the 1960s, which equals to about 165 billion USD in current terms. Corporate investments (excluding publicly funded research) in the development and application of artificial intelligence have been over 500 billion USD in just the last 10 years (Zhang et al., 2021). Other examples are scientific projects like CERN or ITER, decades-long multi-billion dollar collaborative endeavors for a specific research purpose (nuclear physics in this case). Furthermore, there is evidence that in any given domain of technology, investments have to increase to keep up the pace of technological development (Bloom et al., 2020). For example, investments in computer chips needed to keep up Moore's law have increased by a factor of 20 over the last 50 years. These numbers are an indication of the level of investment needed to develop a new technology into a product. A kickstarter-type model needs to explain how the resources necessary can be marshalled and sustained.

Together, the amount of resources and the amount of time needed to develop a technology to its full potential point to an important economic process neglected in the above voting models: Structural change. This process of going from an idea or a prototype to an industrial application allows for the benefits of the technology to be used widely, bringing down costs, improving quality, and developing new applications. Developing appropriate production processes and facilities is difficult and requires further resources, deep knowledge, and the potential for experimentation, as was recently discussed in the context of the mRNA vaccines against Covid-19. Structural change also entails the application of a technology as an input into other products. One example is the computer chip, which was useful to build computers, but also extremely useful as an input into other devices and products (Moser and Nicholas, 2004; Youtie et al., 2008). Scaling up technologies and structural change needs to be taken seriously as a challenge when discussing investment, neither of which are adequately captured by voting or kickstarter-type models.

The third potential issue is the mismatch between what might be interesting and what might be useful. If research projects and scientific associations are formed and receive funding based on the interest of its members, there is no *a priori* reason why this should align well with what is useful to society (this is made very explicit in Benanav (2022)). If a body is to be created that coordinates between the interests and the useful applications (such as the negotiated coordination body in Devine et al.), this is a key feature that needs to be understood and designed well.

Lastly, such a process requires an unrealistic amount of understanding of the voting population to understand the technological and societal implications of a large number of technologies of completely different type, such as medical innovations or advances in robotics for more efficient production processes. Weighing the technological benefits of one proposal over the other will sometimes be trivial, but will often require a certain depth of understanding of technological possibilities, potential pitfalls, and uncertainty in costs and benefits. This problem is exacerbated when the number of proposals is several orders of magnitudes.³

Together, these pieces of evidence make it doubtful that kickstarter-type models can serve as the central mechanism for innovation in planned economies. Furthermore, these models are so decentralized that it is hard to speak of planning at all in this context, since there is often no ex-ante coordination mechanism. For this reason, the next section presents the innovation process in the negotiated coordination model, as well as investment councils suggested for a Cockshott/Cottrell-type model.

Negotiated coordination and investment councils

An alternative model for innovation and structural change is put forward in the model of negotiated coordination developed by Devine and co-authors (Devine, 1988; Devine et al., 2002; Adaman and Devine, 2022). A key part in their planning model is the democratically organized production unit, whereas coordination between production units (and other interests) is managed by a negotiated coordination board. Apart from the allocation of goods (replacing what they call 'market exchange'), they regard the central problem of planning as forward-looking investment decisions (replacing "market forces"). Whenever production units want to make changes to their production process (e.g. through new technological developments or through building new production capacities), they submit these plans to the negotiated coordination board. This board, consisting of representatives of different stakeholders, reviews all the proposals of the different production units along with priorities set by the planning committee and the representative assembly, and decides how to optimally allocate investment to the different proposals (Devine, 1988). Through the involvement of different stakeholders and democratic decision-making, the investment is supposed to be aligned to societal priorities, while simultaneously allowing for an efficient use of (tacit) knowledge. Although investment decisions in this model do not follow the logic of capital accumulation as such, it nevertheless features a rate of return that all production units should aim for, and which guides investment decisions.

A related perspective is developed in the papers by Nieto and Mateo (2020) and Nieto (2021), which explain how entrepreneurship could be accommodated in a Cockshott/Cottrell-type planning model. The core part of their proposal are investment councils, representative and pluralist boards which distribute funding for innovation and development according to priorities set in the general plan. They further subdivide into investment funds, which are tasked with more specific projects or technologies. Complementary to the investment councils, the papers also mention innovation ecosystems containing, for example, company research departments and institutions carrying out strategic projects according to the general plan.

One problem that this model solves through planning and the negotiated coordination board is how to achieve coordination of investment decisions. In capitalist markets (and to some extent in the kickstarter model), each company makes its investment decision based on its local information about prospective demand, technological developments, and other "market forces." These investment decisions are only validated or falsified after the realization of those uncertain factors. Coordination failure, for example, through unrealized demand or non-availability of suitable technologies, is thus a constant occurrence in the capitalist process, leading to inefficient use of resources and the potential for miscoordination and crisis. Negotiated coordination aims to overcome this through ex-ante coordination, where prospective demand and technologies being developed are communicated and coordinated before investment decisions are taken.

An interesting proposal is made by Kotz et al. (2002), who suggest to separate the funding and incubator stage of innovation (the "Innovation Facilitation board") from the decision to absorb the developed product into the general plan (the "Innovation Approval board"). Together with the idea

to have demands for innovation formulated by the citizens, this proposal points in the direction of the core ideas of this paper developed in the next section.

While this proposal offers some prospects for how structural change could be planned and managed, it also faces some shortcomings. First of all, by leaving the decision to request funds to the production units, it is geared towards incremental changes to existing products or production processes. This brings two problems with it: First, radical invention of new products is not considered, which create new capabilities for society (Aghion and Howitt, 1992). Innovating altogether new products is one of the key perceived advantages of capitalism, which a planned economy model should plausibly explain how to replace. Second, it does not explain the development of new cross-cutting or general purpose technologies that significantly impacts all sectors and technologies. Such cross-cutting technologies have been found to be of key importance to improving productivity and to creating new opportunities for long-term development (Bresnahan, 2010).

This perspective on incremental, sectoral-based innovation model also neglects a different perspective on technological progress, progress by combinations of existing technologies (Arthur, 2009). There is good empirical evidence that the most novel and most useful technologies come from combining disparate existing technologies (Verhoeven et al. (2016); Fleming (2001)). About 60% of patents granted in the US make a new, never before observed combination of technological elements (Youn et al. (2015)). The most novel combinations also tend to produce the most impactful technologies (Kim et al. (2016)). Thus, radical innovation is most likely to happen when there are substantial cross-sectoral connections and cross-fertilizations of different technologies, which is at least doubtful in the sector-based innovation model envisioned by Devine et al.

While none of this in principle invalidates innovation processes described in coordinated negotiation or through innovation councils, they are currently mostly conceived as sector-based investment models. Those face shortcomings with respect to producing significant radical innovation, new products, and cross-cutting technologies. Building effective processes and allocating enough investment to radical innovation will require a substantially extended model, some elements of which are suggested below.

Mission-oriented innovation

A central feature of the current discourse on innovation in both progressive circles and also broader policy discourse is the mission-oriented innovation approach pioneered by Mazzucato (2013, 2018a). Broadly speaking, it centers innovation policy around grand challenges that will help to substantially improve people's lives and solve important societal problems (such as reducing the harm from cancer or greening the country's energy production). Once a grand challenge is decided, it is broken down and operationalized through specific missions with clear and measurable targets. All the relevant stakeholders and sectors are involved, such as different branches of government, relevant industries and services in the private sector, and civil society organizations. The mission is then further subdivided into a range of individual projects that will help solve the mission. Substantial resources (financial and non-financial) from the various stakeholders are mobilized, often organized and coordinated through the "Entrepreneurial State" (Mazzucato (2013)). Such missions are now part of innovation policy at various levels, from the EU Horizon programmes to the famous DARPA in the United States and state investment banks like KfW in Germany.

These institutions utilize a wide variety of financial tools to set incentives for innovation, development, and diffusion. The EU Horizon programmes make dedicated research funding available for specific research areas with practical applications, such as fighting cancer or cleaning

oceans. DARPA as an innovation agency is most well-known for their competitions, where they promise large financial rewards for any team achieving ambitious technological goals in early-stage development. After early development, the US military budget is used as practically unlimited purchasing power for the fully developed products, thus enabling the scaling of production. National development banks such as the German KfW use instruments like guaranteed loans or targeted bonds with subsidized interest to encourage diffusion of innovative products through the economy (Mikheeva and Ryan-Collins (2022)). This approach of “de-risking” investments is widely used in the context of the green transition or industrial policy. Common to these instruments is that they typically operate in a framework where the state funds research and de-risks development for private enterprises, which develop the finished products and reap the profits from selling them at monopoly prices by using patents (Gabor, 2021).

From the perspective of planning, this is a promising approach to think of as a central feature for how innovation can happen in a planned economy. Furthermore, there is a large amount of literature detailing various advantageous features of mission-oriented innovation. These range from mission-oriented innovation systems, taking the focus away from the central actor, and more towards an ecosystem of actors (Geels, 2019), the appropriate geographical scale of missions (Wanzenböck and Frenken, 2020), to how missions can evolve and adapt to governance challenges (Janssen et al., 2021). They describe various institutional, political, and practical aspects of how mission orientation is to be conceptualized and implemented. However, there are also two important shortcomings in the missions discussion so far: Democratic control, and scalable implementation.

The central actor in the mission-oriented innovation system is the “Entrepreneurial State” (Mazzucato, 2013). It has been argued recently that to make such an entrepreneurial state, the key is a purpose-driven and agile bureaucracy (Kattel et al., 2022). Even though designing and carrying out the missions can involve the citizens (Mazzucato, 2021), the central coordinating body is still a state agency. The section on accelerated democratic missions will discuss why democratic control is important in both deciding and supervising the mission, which raises non-trivial questions on how to institutionalize such a democratic process. This is particularly important since missions aim to solve “wicked” problems (Wanzenböck et al., 2020), in which positive and normative aspects cannot be disentangled, and which in all likelihood do not have exclusively technological solutions, but require a mix of social, political, and behavioral change.

Furthermore, while this literature makes a plausible case that it can deliver results that are more aligned with social needs for technology than market-based approach, there is nothing inherent in the mission-driven approach that will deliver effectiveness, efficacy, and efficiency in bringing about (technological) solutions to this mission. While the literature contains some discussion of the best means of achieving the ends (the missions), for example, through market shaping, it focusses mostly on qualitative approaches to institutional and procedural design. While these are important, they are not themselves sufficient to achieve a superior innovative performance. This paper suggests that such superior performance can be achieved through centering the use of quantitative and digital tools to monitor, scale, and effectively use technological advances, thereby extending the mission approach to a full-fledged planning approach. This approach to planning progress, termed “accelerated democratic missions,” is outlined in the next section.

Planning progress

None of the proposals reviewed so far has been found to be adequate as the centerpiece of innovation and structural change in a planned economy. This section will now outline a proposal that could serve as such a centerpiece, based on two parts: A technology-push mechanism called

“screening and scaling technologies,” and a demand-pull mechanism called “accelerated democratic missions.” It will first introduce its main components, then its key advantages over existing proposals. Furthermore, the proposal is designed in a modular way, so that the individual components are interdependent, but open to be replaced without negating the overall structure.

Screening and scaling technologies

Screening and scaling technologies concern the translation of new ideas and scientific breakthroughs into new products and services; the research and development needed to go from a concept to a finished good, and the scaling of the production of that good for broad use in the economy and for consumption. It thus acts on the supply side of innovation (technology-push innovation), selecting promising technologies and applying them to create public value. There are several aspects how democratic planning can improve the research and development process, which will be discussed starting from the early stages of research to the later stages of scaling up production of existing goods.

At the start of the development process is an invention, which could be a new concept, a scientific breakthrough, or an idea for a new application for an existing technology.⁴ There are plausible mechanisms why a planned economy could generate more inventions than a capitalist system, depending on policy choices: First, if the planned economic system allows for more free time, there might be more room for experimentation and tinkering, generating more ideas. Second, more funding could be allocated to non-profitable purposes such as education and science, which would again lead to more candidate inventions. Third, since invention is likely no longer happening inside companies, behind paywalls, and protected with patents, increased openness of inventive activity allows more scope for collaboration and knowledge spillovers, which are an important part of generating inventions (Bloom et al. (2013); Myers and Lanahan (2022)). Fourth, there could be institutional innovation in the way that science is set up, which could allow for more scientific progress. However, none of these advantages directly follow from a planned economic system, and are thus not sufficient for a case why planning would lead to a higher rate of socially useful innovation.

To develop viable technologies, the next step consists of selecting promising inventions from the set of ideas, researching and developing them to maturity, and producing them at scale. As discussed in the section on kickstarter-type proposals, this process takes significant time and resources, and the decision how to invest such resources is the one where planning can deliver the highest benefits. Under capitalism, the decision which ideas get developed into products is typically made by financial institutions: Banks giving loans to companies for specific projects, or venture capital institutions giving equity funding to startups. Lenders make a profit from the interest rates paid on the loan, while equity investors such as venture capitalists make a profit by eventually selling the shares for a higher price. The event of selling a startup directly on the stock market (initial public offering) is a rather rare event, more typically startups get bought by a larger existing company that wants to incorporate the technology into its existing range of products. Since only a small minority of startups manage this exit within the required time frame (typically 3–5 years), the successful startups need to generate large excess returns to compensate for the failure of the many other investments (Da Rin et al., 2013). Thus, both the initial stage of receiving funding in the first place, and then growing to a viable and enduring business or exiting profitably, are both extremely selective, and only a small minority of startups survive. The challenge for planning is then to find an alternative way of selecting the technologies to develop and scale up, and to design the complementary investment strategy and institutions.⁵

There are two criteria that are important for selection. One is the public value that the technology would create if it were fully developed. There is particularly good evidence from the pharmaceutical sector that in the current innovation system there is a misalignment between the development of new medicines based on profit incentives and medicines that would provide public value (Dranove et al. (2020); Byrski et al. (2021); Dubois et al. (2015)). While public value is not objectively measurable and always the result of a social contestation, a more democratic approach can orient the direction of innovation closer to societal priorities Mazzucato, (2018b), see also Koning et al. (2021)).

The second criteria for selection is the technological potential, that is, its potential for further improvement, for additional applications, or for being an input to other important technologies. An indicator of further improvement is experience curves, which indicate how rapidly the costs of a technology fall with time and production (Farmer and Lafond, 2016). For a given technology, the experience curves are predictable (Lafond et al., 2018), and they vary substantially between technologies, which matters for optimal investment decisions Way et al., (2019), also see Way et al. (2022) for an application to the energy transition). Another consideration for the technological potential is how widely applicable the technology is to fulfill different functions, and how well it can be combined with other technologies (Fleming, 2001; Hall et al., 2001). This is also crucial for diffusion, which will be discussed next.

The last step is to scale up production, apply the technology in different sectors, and develop complementary innovations (diffusion). An important aspect for planning diffusion is that the overall impact of a technology can be predicted early on. Experts in the field can identify *ex ante* which projects are likely to have a higher impact, which can be seen, for example, in the fact that *ex-post* influential projects tend to be more crowded by researchers (Hill and Stein, 2019). Furthermore, there are features of the technology that can predict its overall impact, such as the novelty of the combination of previous technologies used (Kim et al., 2016). The early impact of a technology is then highly predictive of further future impact (Mariani et al., 2019; Higham et al., 2019). Innovation in technologies that are inputs into other products then percolates through networks of innovation to related technologies (Pichler et al., 2020) as well as through supply chains (McNerney et al., 2022). Furthermore, as production is scaled up, the experience curves introduced above determine which technologies can be produced most cost-effectively (Lafond et al., 2022). Lastly, since developing complementary innovation is crucially important for deriving the full benefits from an important technology (David, 1990), link prediction methods can identify which other technologies could be combined with the technology under consideration (Krenn et al., 2022).

It is important to note that the description of the screening and selection process described above is to a first approximation independent of the exact institutional setup and thus compatible with a variety of models of planning. There have been substantial discussions on which incentive structures are adequate for innovation in planning models (see e.g. Laibman (2001) and Kotz et al. (2002)), and there is ongoing research which funding allocation mechanisms work for states within capitalism for different stages of technological development. Most importantly, the institutional design will likely depend on the design of the planning system, for example, the resource allocation mechanism and the nature of democratic and decentralized decision-making processes. Nevertheless, the institutional setup is of course a key determinant for successfully screening and scaling technologies, and a few necessary features can be outlined. Of particular importance in this context is the so-called “Collingridge Dilemma,” introduced by Collingridge (1982) (see also Genus and Stirling (2018)). It states that (1) it is hard to foresee the impacts of a technology until it is fully developed, and (2) that changing the trajectory of the technology becomes more difficult as the technology becomes more developed and entrenched. One way to overcome this dilemma is constant democratic involvement and oversight during the entire development process

(Stirling (2008); Smith et al. (2005)). Here it is important to balance two considerations: First, adequately developing and assessing technologies requires substantial expertise that is built through long-term involvement. In the mission-oriented frameworks, the institution often suggested for this is a state-owned innovation agency, which acts both as a funder and as an oversight board for teams developing new technologies. Second, to orient the development of the technology towards public value, it would be desirable to involve an institution representative of the citizens. This could be, for example, a sortition-based citizen council, representative boards, or participatory formats (see also Sutherland et al. (2012)). These two considerations could be balanced by creating separate entities, for example, an enterprise tasked with the technical details of the development, and an oversight board appropriately composed to represent citizens, who give input to the normative aspects of the development project and consult on further funding approval. In a joint entity of experts and citizens, they would not only make important decisions on how to develop the technology, but also actively co-create it and participate in design choices.

Accelerated democratic missions

Democratizing missions. There are two key locations of democratic decision-making when it comes to missions: (1) Who gets to decide the mission to be pursued and (2) democratic oversight during the carrying out of the mission. As was discussed above, the typical approach to missions is relatively agnostic about who decides the missions, and prefers either a bureaucratic (Kattel et al., 2022) or innovation agency (Mazzucato, 2013) approach to who gets to carry out the missions. This paper puts forward two different democratic mechanisms for solving (1) and (2).

The mechanism for democratically deciding missions is highly non-trivial, since large amounts of democratic debate have to be condensed into a one-dimensional mission (such as “fighting cancer”). This is to a first approximation independent of the exact institutional design of where and how such missions are discussed. This paper argues that algorithms can help to significantly reduce the complexity of the aggregation of information here, and both simplify and democratize the process of deciding missions. In the simplest case, one can imagine a scenario where all citizens (and possibly organizations or representative institutions) are asked to provide a plain-text input on which missions they think should be pursued in the coming planning period, which problems should be solved.⁶ Using the progress in natural language processing, these plain-text suggestions can be aggregated and condensed into a set number of “candidate” missions through identification of common themes among large numbers of proposals.⁷ With input from the wider planning boards, experts, citizens, or other institutions, these candidate missions can be refined into a set of finalized missions in a deliberative and participatory democratic fashion.

Importantly, once the missions are decided, the democratic oversight cannot end there. As discussed above, the Collingridge dilemma means that constant democratic oversight and input through the technological development and the completion of the mission is crucial (Stirling, 2006). As with screening and scaling technologies, a sortition-based council could fulfill this role, or another representative board. The key difference is that for screening and scaling technologies the normative goals are to be determined in the process of developing the technology, whereas with accelerated democratic missions the goal is decided in advance. Similarly to screening and scaling technologies, the exact incentive structures and embedding in the general planning infrastructure is flexible and will depend on the type of planning implemented. Due to the uncertainty involved in which technological solution will be best suited to fulfill a mission it seems appropriate to employ institutions which allow for sufficient experimentation and pursuit of multiple approaches in parallel. A key advantage of planning will be to disentangle the technological uncertainty which is

inherent to any ambitious development project from the financial uncertainty of the developers, allowing for the technological decision to be made purely for non-financial reasons, in contrast to market competition in capitalism.

To decide on the mission, democratic discourse and decisions can be aided and accelerated by algorithms, however, ultimately the very nature of discourse limits the appropriate applications of algorithms. Similarly, institutional questions cannot be fully circumvented through algorithmic governance. Where algorithms can make a real difference is how well and how fast missions are carried out, which is outlined in the next section.

Accelerating missions. There are three areas in which algorithms and better planning can accelerate the innovation and structural change associated with the mission, which will be discussed in turn.

The first area where machine-aided decisions can accelerate missions is in matching the problem definition from the mission statement to the possible solution space. Generally, the search space for a possible solution for any given mission is vast, both because of the combinatorial problem outlined above, but also because they often require a mix of technological, social, and other solutions (Wanzenböck et al., 2020). However, searching large combinatorial spaces is exactly what machine learning has demonstrated promise in (think of AlphaFold). Algorithms can act as recommender systems Krenn et al., (2022); Zhang et al., (2019) for which technological solutions might be appropriate to a given problem, and help to significantly reduce the uncertainty currently experienced in this process of combinatorial discovery. Given the input of the mission statement (still in natural language form), the machine could recommend a list of solutions it predicts to be both feasible technologically and helpful to solving the mission. This is intuitive, for example, for the discovery of new medicine, where a description of the symptoms and the research available for understanding the disease could be input into such a prediction problem, which then outputs functions that candidate remedies should perform, such as binding to certain disease agents or destroying certain cells but not others. But there is no reason why similar approaches should not work beyond medicine, for example, in dealing with certain environmental challenges, new ways of manufacturing and producing goods, or better software.

Once a set of potential (technological) solutions to the mission have been identified, the next step is to find feasible technologies to develop this solution. Through the screening and scaling mechanism, more technological solutions will be available at any time, with sped up development processes, so the matching between missions and potential solutions is both possible and non-trivial because of the complexity of the matching problem. In essence, this is a mapping from functions to features (Choi et al., 2012; Fantoni et al., 2013): Which technologies are able to perform a given function, and which combination of technologies can perform all the functions together that can fulfill this mission? Again referring to the example of medicine above, this would mean going from functions needed for curing a disease to candidate molecules or cells which could perform these functions.

Once the solution(s) to be pursued have been identified and decided by the committee, more detailed plans can be devised through detailing the steps needed to develop the technology. The prediction algorithms and modelling that can be employed to help in allocating funding to the development process are similar to those discussed in the section on screening and scaling.

Discussion

This paper aims to open the discussion on planning towards more dynamic perspectives explicitly incorporating change. There are adjacent literatures to which one could look for an inspiration on

how to craft such a model. One such literature is the degrowth discussion, in which there are some explicit discussions, for example, on “convivial” technologies (Vetter, 2018; Grunwald, 2018). As a counterpoint, in the left accelerationist literature, there are more radical and possibly more optimistic accounts for how a progressive agenda could be built on accelerating technological progress (Williams and Srnicek, 2014; Srnicek and Williams, 2016; Hester and Srnicek, 2023; Hester, 2018). Furthermore, the field of science and technology studies has provided detailed case studies on particular technologies, which can be generalized into guiding principles on which technologies to select (Felt et al. (2016)). Technology ethics is one field attempting to provide such guiding principles for design, which can be evaluated for their adequateness in models of planning (Jasanoff, 2016). Approaches to the co-creation and social alignment of new technologies can be found in the literature on technology assessment (Grunwald, 2018). While none of these proposals can be directly utilized in a model of economic planning, they all are partially compatible with different models of economic planning, and can provide valuable insights.

There are several challenges to be considered with the model for planning technological progress outlined here. First of all, there needs to be much better data. Apart from patenting and public announcements, there is no real way for the public to know what research and development is happening in the private sector, which constitutes about two thirds of R&D spending in the Global North. For coherent and democratic planning, it would be necessary to understand which technologies are being developed, and how these efforts could be redirected. While some of this re-orientation can happen bottom-up (e.g. workers in companies developing fossil fuel-based technologies choose to switch to clean tech development), since the private R&D constitutes such a large part of overall R&D effort this will necessarily involve planning. The data for this planning will need to be collected, which in itself is a non-trivial task.⁸

A second difficulty for using the evidence presented here for planning is to disentangle the effects of economic and technological constraints. For any newly developed technology under capitalism to be developed into a product, it must be both technologically and economically feasible, where the latter means that it needs to plausibly make a profit for the company that develops it. However, externalities are pervasive in new technologies, both positive externalities like spillovers to other companies which make their technological developments easier, but also negative externalities like increased environmental damages, increased burden on workers, or other social costs. This presents two substantial challenges to planning: First, if planning wants to reorient technological development towards public value instead of private value, it needs a way to understand and potentially measure such public value (Mazzucato, 2018b). Second, when using the evidence presented above, it needs to be understood that it was produced under capitalism, and thus it will simultaneously be constrained by the technological and economic selection. While technological constraints will still be relevant for planned progress, the economic constraints will be both relieved and transformed. While likely any post-capitalist planning system will likely not require any given product to be profitable, there might be other constraints placed on allowed environmental or social costs produced by any technology. This should not completely invalidate the current evidence on the dynamics of technological progress, but being conscious that it might change these dynamics is vital to good planning.

Conclusion

This paper studies how dynamics and change can be incorporated into models of economic planning. To this end, it proposes a two-part model for innovation: Democratic accelerated missions and screening and scaling technologies. Democratic accelerated missions steer innovation by

eliciting democratically formulated demands for new technological capabilities, and planning research and development projects to meet these demands. Screening and scaling technologies acts chiefly by selecting promising early-stage technologies and developing them towards final products, where the main criteria for selection are the public value the technology creates, and the inherent technological potential for further development and applications. Together, these models combine advantages of algorithms for large-scale information processing with a thoroughly democratic decision-making and oversight. This ensures that technological progress happens at a fast rate, while being directed towards technologies that are socially beneficial.

There are several avenues for future research on the dynamics of planning. There are interesting questions on how to integrate the planning progress model here with static models of planning for allocating goods. This concerns, for example, the trade-off between further improvements in existing goods versus developing new goods, or the amount of resources to be dedicated towards production versus development. An important consideration is the institutional setup of the decision-making on and implementation of technological progress. In particular, there is a fine balance to be struck between incorporating technological expertise on the one hand and adequate democratic decision-making and oversight on the other hand. In particular, while there is no direct algorithmic governance in the proposal outlined here, the algorithms in the recommender systems, the language models for summarizing the democratic discussion, and the models underlying the technology investment decisions, need to be designed carefully so as to not implicitly bias the decisions taken. Last but not least there is potential for experimenting with both algorithmic and institutional innovation even in the current innovation system. Parts of the model presented here can be implemented, for example, through state or quasi-state actors such as public research funders or innovation agencies. Gaining practical insights would help to test the feasibility of the model, and allow it to be adapted and developed further. Combining advances on the institutional setup and the algorithmic side of modelling and predicting innovation will open new possibilities for developing the planning progress model further.

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Notes

1. See also [Legault and Tremblay-Pepin \(2021\)](#) for an overview of those models.
2. To phrase this differently: The current debate on economic planning still assumes that the main posterboys of capitalism are Amazon and Walmart in their ability to deliver goods fast and cheap ([Phillips and Rozowski, 2019](#)), when the posterboys of capitalism are actually Apples iPhone, Teslas electric cars, and

- DeepMinds AlphaFold. To compete with competition, a planning model has to offer a convincing alternative of how to produce such progress, that is to say, to reformulate the problem of planning itself.
3. Note that this argument does not imply that there is an inherently privileged position of certain experts or groups to be able to weigh the costs and benefits of any arbitrary set of different technologies. It does, however, imply that being able to understand the implications and costs of even one technology can take years or decades, and this knowledge is not trivially communicated to a large number of people, along Hayek's famous argument (Hayek, 1945).
 4. The following section uses a linear conception of technological progress from invention to innovation to development and scaling to production (Godin, 2006). This framework is also used in planning innovations in the public sector, for example, by measuring "technology readiness levels" (Heder, 2017). However, there is substantial criticism leveled at such linear notions; for an influential account, see Dosi (1982).
 5. Another way of framing the selection of technologies as the crucial step in the investment decision is to again consider technological progress as combinations of existing technologies, as discussed above (Arthur, 2009). The paper by Weitzman (1998) makes a powerful case that such combinatorial spaces are very large, and searching them by human exploration alone is infeasible. The availability of time and resources severely constrains how much of this space can be searched, that is, limits the number of technologies that can be developed at any point in time. Thus, prioritizing which technologies to develop is crucial. Identifying and screening early which technologies might be promising to develop, before large amounts of research have been invested, is then highly important to be able to deliver technologies that are actually feasible.
 6. One challenge to this is that not all desires and needs are easily formulated. A possible way to circumvent this would be representation through other individuals or institutions. But this problem is highly interlinked with the problem of democratic decision-making in a planned economy in general; it is not specific to missions, thus, this paper will not attempt to formulate a general solution.
 7. This includes the possibility that the proposals by different citizens and organizations can be weighted or partially aggregated. The partial aggregation could be used to, for example, have geographically coded missions. Weighing schemes can be designed, for example, to make minorities heard, or to account for organizations representing a multitude.
 8. See the discussion in Menon (2022) for a discussion on the crucial role of building appropriate data infrastructures for planning.

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