Uwe Cantner (Friedrich Schiller University & University of Southern Denmark), **Dirk Fornahl** (University of Bremen), **Stefan Kuhlmann** (University of Twente) (editors) *The New Role of the State for Transformative Innovation: International Research Handbook*
Published by Edward Elgar: EU-SPRI Forum on Science, Technology & Innovation Policy

Part I: State, Capitalism, Innovation, and Welfare

Innovation Commons: New innovation policy for a digital economy

Jason Potts
Blockchain Innovation Hub, RMIT University, Melbourne, Australia
jason.potts@rmit.edu.au

ABSTRACT.
This chapter argues that innovation is evolving because the economy is evolving – specifically that as the economy transitions from a substrate of industrial to digital technologies, then the institutions of innovation become increasingly decentralized. A key feature of this evolutionary transformation is the growing significance of the innovation commons and toolkits for user innovation (Allen and Potts 2016, Potts and Davidson 2016a, 2016b; von Hippel 2016; Potts 2019, 2020; Berg et al 2019a). However, this also means that innovation policy needs to adapt, and in a particular way. We need new institutions for innovation in a digital economy. Innovation policy should be redesigned to enable us to get to these new institutions.

1. INTRODUCTION

The entrepreneurial engine of market capitalism is powered by industrial innovation, but that engine is governed by public policy to sharpen and shape incentives for private organizations to invest in innovation. This innovation policy works by creating property rights in ideas and by tax-funded support for inputs to innovation, including skilled labour, primary research, tax credits for R&D, and through industrial policies, including government procurement to directly and indirectly support new technologies (Bloom et al 2019).

The economic institutions that govern innovation predate the industrial era. However, since the 1980s a tangle of digital technological trajectories (computers, the internet, software, search, open source) has begun to disrupt the economic organization of innovation in two specific and interrelated ways. The first is the massive growth in *information* as an input (and output) of innovation. Digital technologies significantly lowered the cost of information, causing an explosion in the quantity of information produced and consumed in the economy, with the innovation sector a major beneficiary. Data became a new economic resource and input to both production and innovation.

The second is the rise of the *commons* as an increasingly effective institutional mechanism to organize production and innovation across a range of areas (von Hippel 2005, Benkler 2006, Ostrom and Hess 2006, Frischmann et al 2014). The theory of innovation commons is a 'prequel' to the Schumpeterian model that argues that the commons is an efficient institution for the entrepreneurial discovery process of value (Potts 2019). By cooperatively pooling ideas, data and experiments about news uses of technology and the costs of development, Schumpeterian entrepreneurs can discover new opportunities under conditions of extreme uncertainty. Innovation commons are already effective institutional technologies for a range of open-source technologies (e.g. Allen 1983, Harhoff et al 2003, Bessen and Nuvolari 2018). The stronger claim advanced in this chapter is that the economic benefits of innovation commons will continue to develop across all sectors due to the spread of the digital economy.

The rise of the innovation commons is also due to the growth in education and skills and the diffusion of digital capital (e.g. computers) into households, which shifts innovation activity to the edges. As the overall organization of innovation becomes more decentralized, it touches more local information which becomes a further input into innovation. The innovation commons and toolkits are new 'institutional technologies' for innovation. It is perhaps useful to think of these as the latest epochal general-purpose technologies (GPTs). The innovation commons fits the definition of a GPT as an increasingly pervasive and dynamically improving technology that 'initially has much scope of improvement and eventually becomes widely used, to have many users, and many Hicksian and technological complementarities' (Lipsey et al 2005: 43). A characteristic of all GPTs is a higher social than private return due to substantial externalities. GPTs are therefore supplied by the market below the socially optimal level. Recognising the innovation commons and toolkits as a GPT indicates an important role for public policy to support and protect the innovation commons.

Modern innovation policy is designed to target the strategic investment decisions of innovating firms in an industrial market context. The innovation commons, or any conception of knowledge as a common pool resource, is not part of that design. Commons-based approaches have long been overlooked in public policy analysis of shared economic resources in preference for either market-based solutions, which incentivise entrepreneurial response and private investment (and tax revenue), or for public regulation-based solutions, which facilitates government planning (and votes). But as Ostrom (1990) discovered, commons can be highly efficient economic institutions across a variety of circumstances. The falling costs, diffusion and capability-enhancing affordances of new digital technologies make the commons an increasingly effective institution for the organization of innovation (Davidson and Potts 2016b, Allen and Potts 2016, Potts 2018, 2019). The purpose of this chapter is to advance an analytic framework to guide innovation policy reform across this transition to a digital economy.

2. WHAT IS A DIGITAL ECONOMY?

Industrial innovation is characterized by technological trajectories and general-purpose technologies (Lipsey et al 2005). An industrial economy evolves as general-purpose technologies (such as steam, steel, electricity and plastics) enter an economy as firms and households adopt the new technology, tracing out an S-shaped adoption-diffusion trajectory through distinct markets and sectors. Schumpeter described this industrial form of economic evolution as a process of 'creative destruction'.

But digital evolution is characterized by what Dopfer and Potts call *general dimensional technologies* (see Potts 2020) which has implications for spatial and temporal scale of the evolution of the digital economy. General dimensional technologies evolve differently to general purpose technologies because digital is a kind of *lingua franca*, enabling interoperability and universality, in which anything digital can connect and interact with anything else digital. Digital evolution compresses *time scale* changes, occurring much faster than industrial evolution because the adoption process experiences much more powerful feedback and occurs largely in parallel. Similarly, digital evolution occurs on much larger *spatial scales* than industrial technology because it builds over digital networks (ICT infrastructure) that have already been woven globally. This combination of generality in space and time makes digital evolution a qualitatively different process of economic transformation than that of industrial evolutionary processes. It is why digital technologies are a new form of economic evolution implying a qualitatively different type of innovation system.

A useful way thinking about the difference is that general dimensional technologies have 'Coasian' externalities in adoption, whereas industrial technologies have 'Pigovian' externalities in adoption. In industrial technologies, the externalities from adoption, both positive and negative, are efficiently internalized by public policy action (variously taxing and subsidizing, say, in line with Pigouvian micro analysis) and dealing with each one individually. But with a general dimensional technology, externalities of adoption affect all other digital technologies, and thus are shaped far more powerfully by coordination through both entrepreneurship and public policy.

Industrial adoption is a logistic-diffusion innovation process that occurs technology-by-technology, and can be analysed through technological trajectory. Policy problems and issues, as the externalities of the innovation, arise along the trajectory, which begins localized in space and time and then spreads through an innovation-diffusion process through a region, market, industry, sector and nation. Policy solutions to the innovation problems of industrial economies were usually separable and decomposable. Problems that touched trade and commerce could be dealt with in specialised monetary policy, competition policy, trade policy, or development policy. Problems of the social control of business and specific technologies had solutions in industrial policy that could be targeted to each sector (usually by an associated industrial planning ministry).

But digital evolution is that of a general dimensional technology, and general dimensional technologies present different types of economic problems – specifically relating to rationality, trust, privacy, joint production and consumption, zero-price value, and emergent complexity – because they have different economic properties. The time scale means this can happen fast, and the spatial scale means this can happen globally, so externalities are hard to contain (or capture). Standard industrial economic policy models that are adapted to slow diffusion-scale and regional, national, and sectoral focus will be poorly suited to cope with the externalities of digital evolution, which happens much faster, and at global scale.

The fast and global dimensions of digital technologies also bring new types of problems. For instance, a key new problem is *rationality*, the ability to choose well guided by incentives, because you need access to platform tools to be rational. Rational choice is co-produced with digital platforms and algorithms. Digital evolution will also change the overall *pattern of consumption* in society the relation between private versus public consumption in respectively private and public spaces. Industrial technologies hewed between private consumption in private space and public consumption in public space, as public goods. But general dimensional technologies tend to be characterized far more by private consumption in public space, and public consumption in private space, requiring more complex coordination and organization of technology adoption and use. Digital evolution also presents fundamental new problems in *trust*, because we require trust not in people or firms (the counterparty) but in a platform or system. It also implies a different time and space scale of trust. Temporally, digital platform trust is *ex ante* trust, you need to trust before you adopt; whereas industrial trust is *ex post*, in which problems will be resolved through human or administrative processes after the event. The spatial scale of digital trust is also broader, requiring trust to extend beyond local mechanisms. Trust problems therefore cross industry and technology boundaries, extending across digital networks.

For consumers, lock-in and addiction caused by platform interdependencies, and powerful feedback effects between consumption items, are core problems. For producers, there are powerful winner-take-all effects owing to the platform nature of increasingly many markets. For entrepreneurs, the discovery and coordination of the positive externalities from adoption is how value is created. Specialized knowledge and capital investments are required to gain access to production and consumption platforms. Furthermore, the *digital lingua franca* means that privacy has a higher cost, and economic choices become more interdependent. Moreover, digital technologies create new problems of *participation* in digital production and consumption, a problem of *digital literacy*. That is unevenly distributed in the world today, just as text literacy and numeracy was a problem in early industrial economies (resolved through public provision of mass education). Uneven levels of digital literacy create problems of access to knowledge and services, employment and occupational mobility, and therefore income and economic security. The socio-economic problems of a digital economy arise because of the speed and global scale of such changes interacting with the uneven access to the means of production and consumption.

The digital economy also brings new opportunities that innovation can unlock. Consider three. First, digital evolution will upgrade of *human rationality* by outsourcing choice to machines. Where the industrial economy brought automation in production, the digital economy brings automation to decisions and transactions. Of course, to be rational in this context means access to adequate tools for economic operations. Second, digital evolution offers a path to resolution of *ecological problems* and environmental externalities caused by the success of industrial economies, through much smarter use of resources and appropriate technologies, and linking these into global information systems with feedback. And third, digital evolution can supply *new economic infrastructure* for trade and exchange through digital money, digital assets and ledgers, and digital property rights through blockchain technologies. By lowering the cost of trust through time and space, this lowers transaction costs and enables promises and contracting to work better, increasing economic efficiency through digital platform governance. Digital platforms can now supply the institutional technologies for base layer economic infrastructure – money, rules, identity, contracts, registries – that were recently only supplied by nation states.

In a digital economy, innovation reaches much further than in an industrial economy, beyond just industrial technologies (of the sort Schumpeter wrote about), and deep into the domain of 'institutional technologies' (Davidson et al 2018).

3. THE INNOVATION COMMONS

To understand this evolution, we need to move beyond a model of the economy largely in terms of firms, markets and governments, but to a broader institutional toolbox that also includes commons, clubs and blockchains (Berg et al 2019).

An innovation commons is a type of *commons*, which is a governance institution as a set of rules that govern a particular group of actors to enable them to both access and create a shared community resource a.k.a., a *common pool resource*. So, an innovation commons is an institutional mechanism for organizing and coordinating resources for innovation, and compares to alternative institutional mechanisms such as markets and hierarchies. A commons creates community property, rather than private or public property. The other type of private order is a club, which are a species of *local* public goods. In a club, a group of people come together and create a shared resource if they were able to effectively exclude non-contributors (Buchanan 1965). A commons refers to a good (the common pool resource) that is rivalrous but non-excludable, such as a fishery. Since Garrett Hardin explained 'the tragedy of the commons', it was believed that efficiency demanded that commons be transformed into private goods or public goods. Ostrom (1990) began the rehabilitation of the commons by showing, in practice and theory, the conditions under which the commons could be an efficient institution for particular types of resources.

	excludable	non-excludable
rivalrous	Private goods	Common goods
non-rivalrous	Club goods	Public goods

The theory of *innovation commons* was recently developed by Potts (2018, 2019),[1] and is a 'prequel' to the Schumpeterian model that argues that the commons is an efficient institution for the entrepreneurial discovery process of value. As Potts (2019) explains:

[1] See also Allen and Potts (2016), and Potts and Hartley (2015).

> "The innovation commons is the true origin of innovation. It is the source from which the subsequent markers of innovation emerge—the entrepreneurial actors, the innovating firms, the new markets, and so on. … The origins of innovation, and therefore of economic growth, begin with the emergence of governance technologies to create common-pool resources in information about opportunities."

By cooperatively pooling ideas, data and experiments about news uses of technology and the costs of development, Schumpeterian entrepreneurs can discover new opportunities under conditions of extreme uncertainty. A commons is thus a critical innovation infrastructure in the early stages of a new technology.

The existence of the commons opens a new institutional solution space for innovation policy design beyond just private and public goods. So, innovation can be produced (or governed) under different institutional configurations. It can be produced in *markets*, in *hierarchy* (firms in markets, under different degrees of competition), or in *governments*. It can be produced in *networks*, and in *clubs*. And innovation can also be produced in the commons (e.g. open-source software).

In the case of an innovation commons the shared resources are 'resources for innovation'. But that can refer to many different things, including physical resources, access to other people and their ideas and experiments, as well as information. In a natural resource commons—such as a grazing pasture, a fishery, or a forest—it's usually pretty clear what the resource is: such as the grass, the fish, or the bounties of the forest. And the 'commoners' are those who seek access to those resources and will in turn be governed by the institutions pertaining to that commons. Rules governing the commons are necessary to control the risk of exploitation through free-riding, a situation known as a 'social dilemma'. The resource is finite, and at risk of collapse if everyone just takes all they want. There will therefore be a collective interest in establishing private incentives to mitigate that risk, to preserve the resource value of the commons.

An innovation commons is a species of knowledge commons, and thus a potential resource of uncertain value, rather than a known resource of known value. An innovation commons is a solution to the innovation problem but not a solution that comes from the state, but rather from civil society. For this reason, the innovation commons does not usually form part of the various instruments of innovation policy.

What are the innovation resources in the commons? Some are normal economic goods. Access to equipment or kit (e.g. in a hackerspace). But there are other pooled inputs in the innovation commons with very different properties, in particular what Hayek (1945) called 'information of time and place' that accumulates in a commons and can be read by those in the commons as a map of the extant opportunity, and its costs and benefits, that attaches to whatever the new idea or technology is that defines the innovation commons. In an innovation commons, often the most valuable resource is therefore local information.

Innovation commons also tend to be temporary, due to the value of the key resource in the commons, namely information about opportunities. To this end, an innovation commons is born of fundamental uncertainty about the prospect of a technical opportunity, and a collective action problem in addressing it in the need to pool highly distributed and often specialized information, but once realized, the functional rationale for the commons collapses, and so most likely then will the commons. Innovation commons are temporary for the very reason they exist: uncertainty engenders their creation; and the resolution of that same uncertainty instigates their collapse.

An innovation commons is unlike a natural resource commons in that the resource does not already exist but must be created, which is the purpose of the commons. The resources that constitute the value of the innovation commons have little value until they are in the commons because they combine with other bits of distributed information and knowledge. The value of access to the commons thus *increases* with the number of other agents in the commons, assuming each additional agent contributes some information, which is obviously unlike a congestible natural resource commons. The value of the innovation commons comes from the value of the pool of information that is gathered there, and the inferences that can be made from access to that total set of information. An individual can learn and discover new information, or the meaning of the information that they already have in a way that would be costly or impossible in the absence of that institution.

The innovation commons exists for several reasons: (1) because of uncertainty about the nature of new ideas and the entrepreneurial opportunity its represents; (2) because cooperation expresses efficiently in a commons, successful groups can form that are highly technologically progressive; (3) because the commons is an efficient mechanism to distribute power in the development and adoption of an idea, making it difficult to control the path of development of a technology once it is in the commons, thus ensuring that power never attaches itself to a technology; and (4) because of uncertainty about the most effective innovation institution to develop the idea.

The more the innovation commons is used to develop new ideas and technologies, the better quality the information, and the better will be the private and social decisions that follow. Entrepreneurs will be acting with better information. So there will be less failure (loss of resources), and less costly path-dependency (institutional failure). Because new ideas are exposed to wide and disinterested scrutiny, latent externalities will be revealed and realised sooner. This will also present fewer opportunities for rent-seeking protection by technology incumbents. The innovation commons is a crucial part of a national innovation system, in the sense of an institutional matrix of solutions to the innovation problem. Yet an innovation commons is not a government part of the national innovation system, but arises from civil society. Government cannot create this, but it can inhibit it. The effectiveness of innovation policy as the suite of government innovation institutions will therefore depend on the natural efficacy of the innovation commons.

4. TOOLKITS ENABLE INNOVATION WITHOUT SPECIALIZATION

For most of human history, local information advantages have utterly dominated gains from specialization. From the Neolithic to the industrial revolution, all innovation was user innovation. The rise of *industrial innovation* was bootstrapped from the massive gains from *industrial production*, and the rise of supporting institutions, including factory organization, the growth of markets, and the extension and enforcement of intellectual property rights. During this era – broadly 1820s-1980s – the gains from specialization dominated the costs of local information, and so the industrial innovation model was the most efficient organization of innovation. However, one of the most transformative of industrial innovation trajectories was digital computation, as the adoption and diffusion of increasingly cheap and powerful computational hardware and software platforms and the growth of the internet.

One consequence of this innovation trajectory is the diffusion into households of significant technological capabilities due to the growing stock of digital and computational hardware, software and access to knowledge. Growing education and skills meant a growing mass of not only physical but also human capital in households that could be deployed for innovation production. The digital innovation trajectory also transformed industrial production with the advance of digitization, computer control and process automation, CAD-CAM and factory robotics, and well as supply chain automation is shaping a new type of factory and distribution system that is far more specialized in capital and technology inputs and more universal in outputs (e.g. Shapeways, Foxconn, Amazon, Alibaba), meaning that the margin of competition is shifting from Schumpeterian product innovation to Chandlerian process innovation.

This increase in household capital stocks and the development of networks and platforms infrastructure to support innovation has led to a quantitative rise in the amount of user or free innovation in society (von Hippel 2005, 2016). That growth reflects the evolution of the innovation system itself, as a shift in the balance between net benefits of specialization and agency costs in firms versus the net benefits of local information in households, without any agency of transaction costs. From the perspective of institutional economic analysis, the industrial trajectory that has powered the rise of free innovation has, in addition, fundamentally shifted the efficient organizational structure of innovation in the economy toward coproduction. Free innovation represents a shift in the efficient solution to the economic problem of innovation. It is a far more distributed and decentralized innovation architecture, made possible by its far greater use of local information.

An endogenous growth model

Consider a simple analytic model for free innovation conceptualized in terms of three factors of production: human capital, toolkit capital, and local information. In a free innovation production function, households produce free innovation (Y) by combining *human capital* (H), *toolkit capital* (K) which is *distributed non-rivalrous capital* (i.e. a common pool resource as infrastructural knowledge capital, a capital pool), and *local information* (L). Our free innovation production function is formulated as an endogenous growth model (Romer 1990) with output a linear function of capital, which in our model means that it has two infinitely scalable factors of production, in this case: toolkit capital, and local information. Users + design capabilities combine two different types of knowledge: local/ situational knowledge with generic / heuristic knowledge.

Human capital H is the knowledge of the household innovator; the rules and capabilities that they have and can bring to an innovation problem. In the context of user innovation, human capital is mixed with toolkit capital in a particular local context. In free innovation there is no analogue of a savings rate or consumption function. Instead, we have an upload rate, (analogous to *savings*) as a measure of the effort expended to translate human capital into codified knowledge made available as toolkit capital. A *toolkit* refers to the suite of inputs into user innovation, as encapsulations, useful abstractions, objects, heuristics, scripts, modules, plug-ins and capabilities, usually organized on a platform, that are complementary inputs into distributed user-driven idiosyncratic production. Toolkits can originate on the user or producer side. Toolkits built by users create a common pool resource for a community of innovators (von Hippel and Katz 2002, Potts 2019). Toolkits built by manufacturers facilitate efficient co-production, allowing manufactures to shift need related aspects of product and service development to users, who have a comparative advantage in that local information (von Hippel 2003, Franke and von Hippel 2003).

Toolkits are a specialized form of capital that encodes domain specific knowledge that relates to particular complementary processes. Conceptually, toolkits are a type of infrastructural capital good, as a stock of codified community knowledge about a particular domain or project. Because they are, in general, made of information and software, toolkits are distributed and non-rivalrous, and depending on access control can be either excludable or non-excludable. They are a species of club good or public good and will have some governance mode. Toolkit capital is built through *investment* to 'unstick' local context-specific embedded knowledge from human minds and specific environments and encode into generic rules.

We can interpret toolkit capital into an endogenous growth production function model by exploiting the same core insight of the role of *knowledge externalities* that drives endogenous growth models (Lucas 1988). In the toolkit model, knowledge externalities also derive directly from the spillovers from investment in K, which is the public product of private investment by human capital (H) to translate knowledge, ideas, capabilities and information into an encoded rule-based form of information I. Crucially, K is a *non-rival* capital good with marginal innovation productivity as a function of H. In our simple model, innovation with toolkit capital has the same dynamics as industrial innovation under conditions of knowledge spillovers. The same basic analytic result follows, namely that there is no limit to growth because the factor under accumulation never runs into diminishing returns is equally true for free innovation as for knowledge in the context of industrial innovation. In the industrial innovation model, externalities work through knowledge spillovers from firms and human capital circulation (Lucas 1988). In the free innovation model, the knowledge externality works through knowledge encoded in non-rivalrous capital. Thus, intellectual property rights create a positive incentive effect for private investment in industrial innovation but have a negative incentive effect on free innovation. There are therefore three ways to improve free innovation: (1) increase access to K; (2) increase upload rate s: (3) increase exploitation efficiency H.

From the perspective of society, this toolkit capital mechanism works to make efficient use of distributed local information to solve the innovation problem. Hayek's conception of the economic problem as a knowledge problem, and of the price mechanism as an efficient institutional solution to a knowledge problem, is analogous to the way toolkit capital can also make use of distributed local information. A deeper understanding of the economic significance of free innovation leads us to make the same argument about 'the use of information in innovation' (*qua* 'the use of knowledge in society') in specific relation to the fundamental coordinating mechanism. The proper analogue of Hayek's price mechanism in the case of free innovation is toolkits and platforms, as institutional mechanisms made of uploaded information (libraries, rules, designs, messages) that coordinates local information to facilitate a decentralized innovation order. As Benkler (2016: 199) explains:

> "The critical advantage that these user-innovators have over the normal subjects of innovation studies is hyper-localized and contextual knowledge. It turns out that human practices and needs are much more heterogeneous and quirky than firms can readily research, identify, and specify as research targets. The real world is too diverse, too complex, for firms to explore comprehensively."

Local information is a widely distributed free resource yet needs to be used *in situ*. It is very costly for producers to extract. If local information is an input, then producer innovation is costly to deliver. But information that can be compressed and codified relates to knowledge about production and process that can be formed into rules that can be combined with local information to create innovative value. Free innovation is a decentralized solution to the innovation problem because the locus of problem solving (users) is perfectly mapped to the distribution of local information (users). Local information is a *renewable resource* because new users, households and problems are continually entering the system, refreshing the supply of local information. Local information is also a good that is protected by agents themselves, usually in the form of *privacy*. Users develop behaviours and tools, including rights, to hide local information and to keep local information contained.

Platforms are a new institutional infrastructure for innovation systems, where they facilitate search-and-match functions between innovators, facilitating more open, network-based collaborative approaches to innovation, with complex strategic consequences for firms. The simple economic model of a platform is a two-sided market. Toolkits and libraries are platforms in this same sense, in that they facilitate matching between user innovators with specific needs and others with partial components of solutions.

Implications of free innovation for industrial organization and patterns of global trade can also be discerned. The margins of Schumpeterian competition will shift from product innovation toward *process innovation* as firm competition occurs at the margins of generalized manufacturing and distribution capabilities that take special purpose designs as input. This will change the regional geography of industrial organization and diminish the sense in which we meaningfully refer to 'industries' organized around supply chains for classes of commodities. These forces of industrial reconstitution predict a re-localization of manufacturing and an uncoupling or shortening of global supply chains. Overall, this predicts a globalization of ideas and designs, with a re-localization of things and resources.

The evolution of an economy with both free and industrial innovation will begin to look different to a full-fledged industrial innovation economy. Instead, more innovation shifts to the household sector and toward process innovation in fabrication. This model predicts that with the growth of the free innovation economy we will likely see:

- diminishing importance of intellectual property and venture finance
- rise in significance and scope of platforms and toolkits
- growing importance of open access, open standards, open knowledge institutions
- shift in organization competition toward process innovation,
- diminished product specialization in firm innovation capabilities
- shortening of global supply chains (atoms)

- globalization of innovation information commons designs (bits)

The purpose of the free innovation policy model is to create user and household capabilities for local problem solving through innovation. It seeks to foster development of a community and public innovation resources that are open access, and that resist enclosure. Free innovation policy will be focused about reform of intellectual property to protect household use, and to support and facilitate the development of free innovation infrastructure.

Free innovation is a species of *distributed innovation* that harnesses or unsticks distributed information. This has important considerations for the economic theory of innovation policy. Specifically, it suggests a policy reorientation away from the industrial policy-inspired mega-planning and hierarchical institutional coalition control initiatives that have dominated innovation policy (e.g. regional, sectoral and national innovation systems, triple-helix, smart-specialization, mission-oriented goals, etc). Instead, free innovation policy emphasizes the discovery and welfare-enhancing qualities of a bottom-up, civil-society-led global innovation framework that is powered by information platforms and new technologies, rather than high-level bureaucratic control.

5. INNOVATION POLICY FOR A DIGITAL ECONOMY

What implications for policy and the role of the state? Note that there is a clear direction of institution evolution due to digital transformation. The new capabilities of digital platforms that lower search costs and increase the power of distributed processing, all push and pull in the direction of decentralisation. These technologies make it easier and less costly to innovate from the edges with local provision of innovation tools and infrastructure. We see this clearly in industries such as software, with the rise of open-source production and innovation. Yet, at the same time, there is a clear role of the state in innovation in supporting the development of the innovation commons, and critically in protecting it against enclosure from corporate platforms

First, at a high level, in relation to the policy target, the role of the state is to facilitate the transition from an industrial to a digital economy. This is the historical context of the current policy challenge: to ensure a transition to an innovation system that is institutionally appropriate for a digital economy. From the theoretical perspective of *general dimensional technologies*, there is a single overarching goal for economic and social policy, namely the transition from industrial evolution to an economy characterized by digital evolution. Web3 is enabling new economic administrative and financial infrastructure to be supplied by private organisations. This is because over time, the average cost of making economies – i.e. institutional technologies – has fallen. In web3, the cost of designing and implementing an ‘economy’ – i.e. building a money, rules and institutions, exchange mechanisms, registers, etc – has fallen such that organisations other than whole countries or nation states can do this. This means that macro policy is no longer an exclusive concern of nation states, but also applies to L1 blockchains and DAOs, for instance.

Second, new types of infrastructure are required – i.e. platforms, protocols and toolkits. The institutional organization of innovation is increasingly best done as a commons, and those will need to be supported. There will be a continual risk of pressure to enclose the parts of the commons as they inevitably reveal themselves to contain valuable information

(Potts et al 2022). So, there is a role for public policy, not as public ownership, which would imply regulated governance, but something closer to the National Park or Public Library model, where public access is established at public cost but citizens are free to visit and make use of the non-rival resources as they choose. Toolsets for identifying and extracting information from 'midden heap' commons need to be developed, and funding models to support this work will also be needed (Eghbal 2020).

Third, from an innovation commons perspective, this is policy not focusing on supporting innovators (i.e. friends of innovation), but on fighting those who block innovators (i.e. enemies of innovation, Potts 2019: 216-9), which can be other parts of government or corporate interests and the coalitions they build (Juma 2016). Barriers to innovation come not only from fixed costs/sunk costs of R&D, but from coalitions to block new technologies because of the 'creative destruction' the new technology will inflict upon extant capital, skills, rents etc. An increasingly important role for innovation policy in navigating the transition from industrial to a digital economy is to get the losers from innovation to 'stand down', whether by negotiating Coasean exchanges, or otherwise through political bargaining.

Fourth, commons-based innovation policy for a digital economy should target support to *open-knowledge institutions*, specifically open science, such as gold-standard open access, and endeavours to release public experimental resources or to facilitate public access. A legislative approach is to recommend, require or mandate open access and open knowledge principles as condition of public funding. A specific mandate would be a presumption that, where practical, public research and innovation resources be opened to community access for experimental use, including exploring ways to enable and facilitate community and civilian involvement in technological research and applications. Examples could include white spectrum use, or experimental test beds. Policy targets should seek to re-enfranchise public innovation and government research property (e.g. spectrum, airspace, research tools) to community innovation.

Fifth, commons-based innovation policy should also, where possible, reinterpret government mandates for service delivery by federal agencies (e.g. health, education, transport, social services) to support free innovation, rather than seeking to control or restrict or compete with producer innovation, and to explore opportunities for user-led free innovation in the co-delivery of public goods and services. Overall, this amounts to provision of public infrastructure and support to enable self-provisioning (e.g. in education, home schooling curriculum; health, elderly care infrastructure and tools for support, disability support; social housing, special housing needs, etc). Such an approach transforms these from a client model of public services to the characteristics of club goods – privately produced local public goods. While there may be efficiency losses from reduced centralization and standardization of supply, benefits may accrue from local information gains that feed into user-innovation, and which may then be copied or diffused into other locations.

6. CONCLUSION

David (1989) showed it takes several decades for a GPT to impact the economy due to the need to re-organize production. That is what is happening with free innovation now. We are entering a new economic era, and an associated new era of innovation that is broadly open decentralised innovation on platforms, protocols and toolkit, all of which are institutional species of commons. This is a transition from the Schumpeterian era of industrial innovation trajectories and industrial innovation policy based on intellectual property, R&D support and national innovation systems. The main GPT in this new era is not electronic circuits, digital computers, and so on, for they are late industrial, but open knowledge innovation commons for pooling and sharing designs, such as toolkits.

This chapter has reviewed the theory of innovation commons (Potts 2018, 2019) and the theory of innovation toolkits (von Hippel 2016), both critical innovation infrastructure in the early stages of a new technology, in the context of the transition from an industrial to a digital economy. Digital technologies significantly lower the cost of creating pools of innovation resources, and using these common pool resources as inputs and tools for innovation. Digital innovation commons and toolkits are a layer 1 global public infrastructure for innovation in the 21st century. The policy implication here is modelled on national parks, as support for the complex commons infrastructure with private order overlapping governance and support, as the innovation commons analogue of Park Rangers, i.e. publicly paid workers in the commons, protecting, educating, fighting cases, solving maintenance problems (Eghbal 2020). There is a clear and important role for the state in supporting the development of the innovation commons and open access toolkits, and critically in protecting it against enclosure from corporate platforms.

REFERENCES

Aghion, P., Howitt, P. (1992) 'A model of growth through creative destruction' *Econometrica*, 60: 323-361.

Allen D, Potts J (2016) 'How innovation commons contribute to discovering and developing new technologies' *International Journal of the Commons*, 10(2): 1035-54.

Allen, D., Berg, C., Davidson, S. Potts J (2021) 'Property rights, knowledge commons and blockchain governance' Dekker, E., Kuchar, P. (eds) *Governing Markets and Knowledge Commons*. Cambridge University Press

Allen, R. (1983) 'Collective invention' *Journal of Economic Behavior and Organization*, 4(1): 1-24.

Benkler, Y. (2006) *The Wealth of Networks*. Yale University Press: New Haven

Benkler, Y. (2017) "Peer Production, the Commons, and the Future of the Firm." *Strategic Organization*, 15(2): 264–74

Berg, C., Davidson, S., Potts, J. (2019) *Understanding the Blockchain Economy: An Introduction to Institutional Cryptoeconomics* (Edward Elgar)

Berg, C., Davidson, S., Potts, J. (2019a) 'Capitalism after Satoshi: Blockchains, dehierarchicalisation, innovation policy, and the regulatory state' *Journal of Entrepreneurship and Public Policy* 9(2): 152-64.

Berg, C., Davidson, S., Potts, J. (2019b) 'Blockchain technology as economic infrastructure: Revisiting the electronic markets hypothesis' *Frontiers in Blockchain*

Bessen, J., Nuvolari, A (2016), 'Knowledge sharing among inventors: some historical perspectives,' in D. Harhoff and K. Lakhani (eds), *Revolutionizing Innovation: Users, Communities and Open Innovation*. MIT Press: Cambridge, MA.

Bloom, N., Van Reenen, J., Williams, H. (2019) 'A toolkit of policies to promote innovation' *Journal of Economic Perspectives*, 33(3): 163-84.

Buchanan, J. (1965) 'An economic theory of clubs' *Economica*, 32(125): 1-14.

David, P. (1989) 'The dynamo and the computer: An historical perspective on a modern productivity paradox' *American Economic Review*, 80(2): 355-61.

Davidson, S., Potts, J. (2016a) 'A new institutional approach to innovation policy' *Australian Economic Review* 49(2): 200–7.

Dopfer, K., Pyka, A. Potts, J. (2015) ‘Upward and downward complementarity: The meso core of evolutionary growth theory’ *Journal of Evolutionary Economics*, 26(4): 753-64.

Eghbal, N (2020) *Working in Public: The making and maintenance of open source software*. Stripe Press: San Francisco, CA.

Frischmann, B. M, Madison, M. J and Strandburg, K. J (2014). *Governing Knowledge Commons*. Oxford University Press.

Gambardella, A., Raasch, C., von Hippel, E. (2017) ‘The user innovation paradigm: Impacts on markets and welfare’ *Management Science* 63(5):1450-1468

Harhoff, D., Henkel, J., von Hippel, E. (2003) ‘Profiting from voluntary information spillovers: how users benefit from freely revealing their innovations’ *Research Policy*, 32(10): 1753-1769

Hayek, FA (1945) ‘The use of knowledge in society’ *American Economic Review*, 35(4): 519-31

Juma, C. (2016) *Innovation and its Enemies*. Oxford University Press: Oxford.

Lipsey, R, Bekar, C., Carlaw, K. (2005) *Economic Transformations: General purpose technologies and long run economic growth*. Oxford University Press: Oxford.

Lucas, R. (1988) “On the mechanics of economic development,” *Journal of Monetary Economics*, 22, 3–42.

Ostrom, E. (1990) *Governing the Commons*. Cambridge University Press: Cambridge.

Ostrom, E. (1996) ‘Crossing the great divide: Coproduction, synergy, and development’ *World Development*, 24(6): 1063-84

Ostrom, E., Hess, C (2007). ‘A Framework for Analyzing the Knowledge Commons’ In Hess, C and Ostrom, E eds. *Understanding Knowledge as a Commons*. Pp. 41–82. Cambridge, MA: MIT Press

Potts J, Harhoff D, Torrance A, von Hippel E (2021) ‘Social Welfare Gains from Innovation Commons: Theory, Evidence, and Policy Implications’ SSRN https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3915997

Potts, J. (2018) ‘Governing the innovation commons’ *Journal of Institutional Economics,* 14(6): 1025-47.

Potts, J. (2019a) *Innovation Commons: The origin of economic growth*, Oxford University Press.

Potts, J. (2019b) ‘Foreword’ *Innovationspolitik för Tillväxt* [Innovation Policies for Growth] Ratio Institute: Stockholm, Sweden

Potts, J. (2020) ‘Evolution of the Digital Economy: A Research Program for Evolutionary Economics’ Forthcoming, The Research Agenda for Evolutionary Economics, Kurt Dopfer (ed) (Edward Elgar), Available at SSRN: https://ssrn.com/abstract=3736320

Potts, J. Davidson, S. (2016b) ‘Social costs and the institutions of innovation policy’, *Economic Affairs*, 36(3): 282-93.

Potts, J. Hartley, J. (2015) ‘How the social economy produces innovation’ *Review of Social Economy*, 73(3): 263-82.

Romer, P. (1990) “Endogenous Technological Change,” *Journal of Political Economy*, 98: S78-S102.

von Hippel E (2016) *Free Innovation*. MIT Press: Cambridge, MA.

von Hippel, E. (1988) *The Sources of Innovation*. New York: Oxford University Press.

von Hippel, E. (1994) ‘Sticky information and the locus of problem solving: implications for innovation’ *Management Science*, 40(4): 429-439.

von Hippel, E. (1998) ‘Economics of product development by users: The impact of sticky local information’ *Management Science*, 44(5): 629-644.

von Hippel, E. (2005) *Democratizing Innovation*. MIT Press: Cambridge, MA.

von Hippel, E., Katz, R. (2002) ‘Shifting innovation to users via toolkits’ *Management Science* 48(7): 821-33.