States of Innovation: How the state shapes production transformation

Antonio Andreoni and Rainer Kattel

Abstract

Historically, state formation and industrialisation have been linked by a mutually constitutive relationship. Industrialisation has been shaped by the state (or lack thereof) via industrial and innovation policy. The formation of state institutions, governance and bureaucracy structures have played a key role. By designing, implementing and enforcing state policies, these structures have constructed and mediated the continuously evolving relationship between state, industry and markets. Equally, industrialisation and the formation of new powerful organisations and interests have shaped the political economy of the state and policymaking. In this chapter we discuss three historical forms of the state – 'developmental', 'entrepreneurial' and 'innovation-driven' state and focus on the evolution of this state-industrialisation relationship. Comparative historical cases – i.e., Germany, USA and China – are used to flash out different configurations of "states of innovation", as well as evolution in policy framing, instruments and challenges.

Keywords

Industrialisation, States of Innovation; State Capacity; Developmental State, Entrepreneurial State Innovation Challenge-driven State.

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1. Introduction

Historically, industrialisation and state formation have been linked by a mutually constitutive relationship. Industrialisation – a process of continuous change in the productive structure of the economy and extent of the market – has been shaped by the state (or lack thereof) via a range of policies, in today's terminology industrial and innovation policy. The formation of state institutions, governance and bureaucracy structures have played a key role. By designing, implementing and enforcing state policies, these structures have constructed and mediated the continuously evolving relationship between state, industry and markets. Equally, industrialisation has shaped the political economy of the state, its internal structural formation and policymaking. Thus, state and industry are linked by a mutually constitutive, historically-path dependent and dynamic relationship (Andreoni and Chang, 2017).

The majority of today's industrialised nations moved their first steps in the industrialisation ladder in the early nineteenth century. All today's industrialised countries have been using industrial policy more or less consistently since then (in some cases even earlier; Reinert, 2008). Britain was the first and only *early industrialiser*, as it had started its industrial development already from late eighteenth century. In a few decades, Britain had acquired a dominant position given its aggressive imperialism, and the limitations imposed on the policy space of other nations – i.e. unequal treaties (Chang, 2002).

The industrialisation pathways of so-called *late industrialisers* can be traced back to the mid of the XIX century. Germany, the United States, France and Japan with some delays joined, and indeed leapfrogged, Britain with a series of technological and industrial innovations – for example in heavy industries such as chemicals (Perez, 2001). These technological advancements and innovations were coupled by the development of new institutions in areas like banking. For instance, in 1853, Japan was forced to open its economy and, as a result, its feudal political system collapsed. The so-called Meiji Restoration of 1868 started a modernisation phase for the country, followed by a fast process of early industrialisation which made Japan one of the so called 'Big Five' nations by the end of the World War I (Ohno, 2013). Differently from the other early industrialisers, however, Japan regained its policy space only in 1911 with the end of unequal treaties.

The *recent industrialisers* (or *late developers* in Amsden's 1989 terminology) – such as South Korea, China, Brazil and Malaysia – include several of today's middle and upper-middle income countries which have started a sustained industrialisation journey only during the second half of the XX century. They industrialised during the last phase of the global policy regime established after the WWII, governed, among other institutions, by the General Agreement of Tariffs and Trade (GATT). However, while Brazil made use of industrial policy discontinuously since then – with a significant retreat during the 1980s and 1990s – South Korea and China in particular have continuously relied on and upgraded their industrial policies since the 1970s. Following on their footsteps, a group of *emerging industrialisers* includes a number of recently graduated middle income countries – Vietnam and Indonesia for example – and low-income countries, especially in Africa – Ethiopia being perhaps the strongest case.

In this chapter we discuss three historical forms of the state – 'developmental', 'entrepreneurial' and 'innovation-driven' state – and focus on the evolution of this state-industrialisation relationship.

Comparative historical cases – i.e., Germany, USA and China – are presented to flash out different configurations of "states of innovation", as well as evolution in policy framing, instruments and challenges.

2. Industrialisation as structural transformation: Co-evolving dynamics of change

Industrialisation is a structural transformation process involving changes in the sectoral composition of the economy (Kuznets, 1973). A country's economy is composed of different sectors, each of them including several sub-sectors. Sectors (and sub-sectors as their components) are linked to each other by a set of interdependent input-output relationships determining a country's unique economic structure (Pasinetti, 2007; Andreoni and Scazzieri, 2014). Other types of structural interdependencies such as technological linkages also link different sectors and sub-sectors of the economy. Industrialisation is thus about a change in the sectoral composition of the economy – measured in terms of value addition or employment, or both (Reinert, 1995) – but it is also about evolving changes in the structural interdependencies linking sectors of the economy (Hirschman, 1977; Andreoni and Chang, 2019).

The industrialisation journey of the different group of countries – early, late, recent and emerging – presents multiple differences across groups, but also a number of similarities between groups. Differences because depending on when they started their industrialisation journey, they had a different *policy space* delineated by varied international political economy and rules (Wade, 2003), but also faced a dominant *industrial paradigm* (Perez, 2001) which was different. Similarities because they had to go through a similar sequence of industrialisation steps and for each of them faced similar types of *industrialisation challenges* in transforming their economies. Moreover, they all faced similar types of *state capacity formation and industrial policy governance challenges* in driving industrialisation at early, intermediate and more advanced stages of development. Finally, all countries have gone through initial pre-industrial phases in which state building, resource mobilization and macroeconomic stabilisation in an open economy were critical in *preparing industrialisation*.

It is also important to note that many countries attempt industrialisation but fail to do so, experience premature deindustrialisation or partial industrialisation (Reinert and Kattel, 2004; Andreoni et al., 2021a). Countries in the former Soviet Union and Latin America serve as most recent examples of such halted and indeed backwards dynamics. While the reasons for such dynamics are often unique there are common challenges around constrained policy space provided by the so-called neoliberal Washington Consenus, weak policy implementation capacities despite emulating and copying policies from advanced economies, and outright state formation failures.

Building on Andreoni and Tregenna (2020) we identify five different types of industrialisation challenges which are common across the experience of late, recent and emerging industrialisers. These challenges are related to different steps in the industrialization ladder, from initial forms of integration into the regional and global economy to more significant transformation of the domestic production-technology base and, with it, the capability to compete in innovation.

First, all countries face the challenge of breaking into the global economy, especially at early stages of their industrialization when access to technologies and external demand are paramount. This has become an increasingly important challenge. In their analysis of the shifting patterns of manufacturing internationally, Haraguchi et al. (2017) found that the global industrial sectors have become increasingly concentrated. The G7 countries no longer command the same high share of global manufacturing as was previously the case, yet their share remains high and the new successful entrants – China in particular – have gained significant market shares. These countries have erected several entry barriers, including developing global scale economies, international and domestic institutions and capabilities for technological development and innovation. The emergence of major national champions and multinational companies operating globally has also introduced new forms of direct and indirect (via global supply chains) competition in middle-income countries' domestic markets. Such competitive environments can lead to asymmetrical integration into global markets whereby only a specific, typicaly low value-added segment of a value chain emerges in a developing economy without wider domestic linkages and impact on employment and wage (Reinert and Kattel, 2004). This persistent concentration and compression in global manufacturing – both at the country and sectoral levels – have made it very difficult for the other countries to break into low, medium- and high-tech activities respectively.

Second, integration into regional and global value chains (R&GVCs) has been seen as a pathway for industrialization. By linking up into GVCs, business enterprises have the opportunity to move to more profitable and/or technologically sophisticated capital and skills-intensive economic activities – higher value-creation potential – and capture the value created from them. Companies can specialise in specific production tasks or components, preferably 'high-value niches', while avoiding the building up of entire vertically integrated industrial sectors or blocks of industries (Milberg and Winkler, 2013). The idea of a selective form of specialisation in tasks, driven by capturing value opportunities, might encourage companies to upgrade incrementally towards activities such as research and development (R&D), design and downstream post-sale services. First-tier suppliers and original equipment manufacturer (OEM) companies in low and middle-income countries, however, face multiple challenges in linking up to the R&GVC, especially moving into more technologically sophisticated segments of R&GVCs. First, focusing on the production of low-value-added parts and components does not automatically lead to the upgrading of domestic technological capabilities, especially given the endogenous asymmetries characterising GVCs (Chang and Andreoni, 2020) and the higher capability threshold that companies have to reach to engage with digital production technologies (Andreoni et al., 2021b). Moreover, in a number of cases, middle-income countries that have attempted to integrate globally have also ended up 'de-linking domestically' and hollowing out the domestic manufacturing sector.

In contrast, by linking up to international companies and system integrators while 'linking back' to local producers and local supply chains – local production system development – domestic companies can capture international demand and learn from exporting. South Korea and Taiwan between 1970 and 1990, and China in the 1980s and 1990s, all started their industrialisation by linking (backwards) to global supply chains and adding value (forwards) in electronics and other industries, starting in particular from those characterised by short technology cycles (Lee, 2013). With the expansion of the local production system, more opportunities for backward integration also open up, as domestic companies start importing more intermediate goods while diversifying their export baskets. Over the last two decades, a very small number of middle-income countries have been successful in linking up

while linking back. That is, only a few of them have managed to involve OEMs, and first-, second- and third-tier domestically located companies in value addition processes. There are several reasons why very few countries managed to overcoming the linking back challenge. They include the need to diversify the productive capabilities base of the economy, develop a wide range of technical, production and organisational competences and build several specialized institutions, including technology and research centres, universities, and development banks.

In order to link up and back successfully, countries which have reached a middle-income status have to address a fundamental problem of technological upgrading. And they have to do that fast enough to overcome the so called 'Red Queen Effect' – that is, the fact that "middle income countries have to move to innovation-based growth more quickly, just to stay in the same place, let alone move up" (Kang and Paus, 2019:3). Sectoral value chains are based on specific combinations of complementary technological capabilities – i.e. technology platforms – required to execute tasks in the different stages of the chain. Technology platforms underpin the production processes of closely related industrial sectors, as well as different product-value segments within the same industrial sector. Keeping pace with technical change effectively might be challenged by the existence of investment gaps along different stages of technological development – so called 'middle-income technology trap' (Andreoni and Tregenna, 2020). For example, firms in middle-income countries might not be able to leverage a well-funded and diversified domestic science base that provides access to generic technologies. Companies also are unable or unwilling to make significant investments in basic research, as the capital long-term commitment is prohibitive, or the long-term investment is too risky. The fact that the industrial base in these countries has limited diversification and technological depth also means that the scaling up of the new product or technology has to rely on external inputs.

Finally, those middle-income countries which have managed to reach a sufficient level of global integration, as well as have managed to build a domestic production system with firms capable to absorb and invest in technologies are ready for engaging in sustained processes of industrial innovation. Competing for innovation at the global frontier is particularly challenging, especially under the most recent industrial paradigm of the digital economy (Andreoni et al., 2021b). The 'digital capability threshold' that companies have to reach to engage in digital innovations and industrialise them is particularly high, especially in technology domains such as artificial intelligence, data science, robotisation, etc. Moreover, the digital economy presents new entry barriers in the form of network economies and global concentration in specific industries – especially digital platforms – and endogenous asymmetries along value chains (Sturgeon, 2017).

Industrialisation is a transformative process shaping countries' economic structure, *as well as* impacting on their social and institutional fabric (Kuznets, 1973; Abramovitz, 1989; Andreoni and Chang, 2017). Industrial policies have been a major driver of industrialisation in all successful industrialisation experiences, both across Europe and North America as well as recent and emerging cases across Eastern and Southern Asia. Industrial policy have been used to develop social capability, to provide market forces directionality, to spur technological and organisational innovation, to create new markets and institutions. As a result of these industrial policies aimed at production transformation and learning, "the state transformed the process of economic development and, in turn, was transformed by it" (Amsden 1991:286). This observation by Alice Amsden highlights the existence of co-evolving and mutually constitute dynamics of change.

3. States of Innovation: Variety of models, forms and functions

In development and industrial policy debates, state formation is often understood through the lenses of state capacity, discussing its nature, formation and change. This literature is distinctly situated in the tradition of Max Weber's theories of the state and bureaucracy. The key vantage point for authors such as Peter Evans, Theda Scokpol and others in this tradition is the idea of autonomy. The capacity of the state to act on its goals is seen in the ability to stave off or at least navigate pressure from various groups and forces in the society (Skocpol, 1985). This understanding of autonomy is best expressed in Weber's idea of bureaucracy based on political neutrality and expertise (Weber, 2002). The main elements of the state capacity in this tradition are: sovereign integrity as control over state's territory; loyal and skilled officials; raising and deploying financial resources (including changes to taxes and earmarked funding, and ability to borrow); area-specific skills; and adaptability of state capacities (Evans, Rueschemeyer and Skocpol, 1985; Cingolani, 2018). The latter are explicitly seen as key elements of the state capacity. For instance, Weiss 1995 calls this the transformative capacity of the state (Weiss, 1998).

Such Weberian notions of capacity have been in the last decade complemented by what can be called the Schumpeterian alternative. Above all, Breznitz has shown that some of the key innovation agencies in the US, Finland, Sweden, Israel, Ireland and Singapore were not central Weberian agencies with "embedded autonomy" as assumed by developmental state discussions by Evans and others referred to above (see, e.g., Evans, 1995) but rather (at least initially) peripheral agencies (Breznitz and Ornston, 2013; Breznitz, Ornston and Samford, 2018). These agencies were crucial sources of policy innovations necessary for promoting rapid innovation-based competition through explorations in innovation policy, driven partially by continuous, radical experimentation in their core mission and by the existence of sufficient managerial capacities (or slack) (Karo and Kattel, 2014). These agencies' peripheral status was a vital component of their success. It reduced the likelihood of political interference and opened up space for policy experimentation and the formation of new public-private interactions. Thus, the Schumpeterian alternative to the core Weberian state capacity discussion argues that the adaptive and dynamic traits of state capacity can be engendered by initially peripheral and essentially non-Weberian organisations. As Kattel, Drechsler and Karo 2019 have shown, such 'central-decentral' dynamics can be explained through Weber's theory of authority, in particular through the interplay between charismatic and legal-rational forms of authority (Kattel, Drechsler and Karo, 2019). Thus, from the Weberian standpoint, Schumpeterian charismatic organisational forms will in time be 'rationalised', socialised into existing legal-rational forms. Hence we can call the more traditional central Weberian agencies Weber type I and more recent Schumpeterian additions as Weber type II organisations (Ibid.).

In terms of developmental trajectories and stages discussed above, we can argue that earlier stages have historically required Weber type I organisations as there is a need to manage known risks and implement efficiently established policy solutions stable and expert-driven organisations and solutions, e.g., patient domestic capital, long-term infrastructure and human capital investments. On the other hand, moving closer to technological frontier means that uncertainty is increasing and hence the requirement for more experimental and adaptable organisations of Weber type II are needed. Importantly for our argument in this article, these organizational types co-exist and co-operate within a governance landscape, and also organisations can evolve from one type to the other. For instance, a country needs an expert-driven and stability focused central bank but also a financial regulator able

to create a sandbox for fintech companies. Or, next to a basic and applied research agencies, countries need more experimental and open-ended forms public-private collaborations.

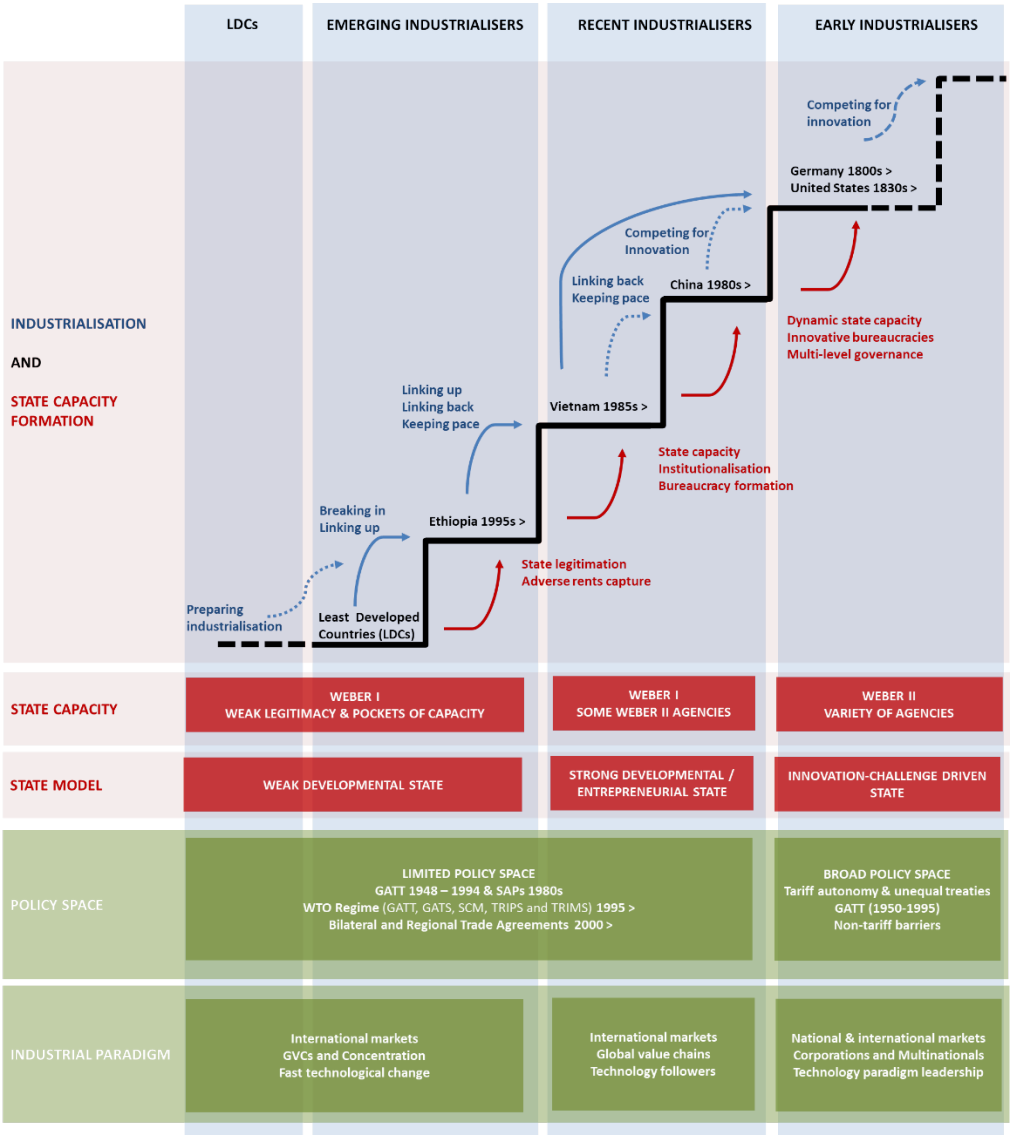
In the last three decades, we have seen two key sets of reforms take place that add additional layers to state capacity discussion. First, new public management (NPM) reforms that gathered momentum in the 1980s (Hood, 1991; Drechsler, 2005) and both expanded and limited the idea of autonomy so central to the Weberian view of state capacity. The NPM reforms, first, aimed to increase managerial autonomy of public agencies and thus enabled for instance privatisation of state-owned companies and supported the creation of at-arm's-length agencies. These practices opened the public sector up for an influx of private sector managerial practices such as strategic management (Lapuente and Walle, 2020; Ongaro and Ferlie, 2020) and digital transformation practices such as agile management (Dunleavy *et al.*, 2006). However, second, the NPM reforms also brought focus on short-term efficiencies in form of performance management practices based on measurement of inputs and outputs, benchmarking and overall stronger drive for governance indicators (Kattel *et al.*, 2014; Dooren, Bouckaert and Halligan, 2015; Drechsler, 2019). In development theory and practice, NPM-inspired reforms focused on the market-failure-based approaches and distinctly diminished the idea of state autonomy and with it, the concept of state capacity shrank around efficiency gains through liberalisation and macro-economic stability.

Second, the backlash to the NPM reforms has to led to the emergence of a set of new theories that can be brought under the umbrella of Neo-Weberian State. Introduced by Pollitt and Bouckaert in 2011, the Neo-Weberian State emphasises the importance of public organisations in providing public services and at the same time recognises the need for more citizen engagement (co-creation and co-production) in the design and delivery of public services (Drechsler and Kattel, 2009; Pollitt and Bouckaert, 2011). Dunleavy, Margetts and others have taken a step further and argue that at least some of these changes in public administrations are related to digital revolution transforming societies (Dunleavy et al., 2006; Margetts and Dunleavy, 2013). In this view, digital technologies enable and drive a deeper transformation in public administrations and services. This is reflected in the adaptation in the public sector of new working practices from (strategic) design and agile software development practices, randomized control trials and experiments from private and third sectors. As recent studies have shown, such practices are mostly taken up by new, Weber type II organisations that are often (initially) peripheral public organisations in the form of public sector design, digital and innovation labs (Tõnurist, Kattel and Lember, 2017). These working practices focus on agile processes such as prototyping and experimentation, relying on epistemological frameworks from action research and ethnography rather than economics or public policy analysis. Such practices have considerably also widened the idea of innovation from a science, technology and industrial realm to that of public services, ways of working and co-creation practices. There are, indeed, increasing number of public innovation agencies that attempt to combine both features of Weber type I and type II organisations. For instance, Swedish innovation agency Vinnova has developed strong capabilities in applying service design practices to innovation policy design while maintaining its focus on managing long-term industrial partnerships. We can argue that such organisations aim to be both dynamic and resilient by design and we can call these Neo-Weberian agencies or, in keeping with the typology developed above, Weber type III organisations (Kattel, 2022).

Figure 1 summarises the discussion so far; it maps key industrialization challenges and state capacity formation against the different steps of a stylized industrialization ladder. It also adds two further

layers to the framework – policy space and industrial paradigm – to reflect changes in the global industrialization context. Specific reference is also made to a selection of representative countries for each group of late, recent and emerging industrialisers. This multi-layered framework points to the fact that while all countries had to face similar industrialisation and state formation challenges in stepping up their industrialisation ladder, they had different policy space and developed under different industrial paradigms (bottom two layers of the framework). As a result, recent and emerging industrialisers could not use the same industrial policy instruments used by early industrialisers. Moreover, under different industrial paradigms, certain policy instruments turn to be more (or less) effective than others.

Figure 1: The Industrialisation ladder multi-layered framework



Source: Authors

One key dimension determining a country's policy space is its space in trade policy – that is, its ability to use tariffs strategically to sustain the process of industrial learning (Chang and Andreoni, 2020). Since the Uruguay Round started in 1986 and completed in 1994 and then with the establishment of

the World Trade Organisation, the global policy space has been shrinking as a result of bilateral trade agreements and the introduction of a more comprehensive set of regulations on investments, intellectual property rights and other sectors of the economy which were uncovered before. Of course, while the policy space matters a lot, it is also how countries strategically engaged with global regulations that makes a difference. In some cases, countries self-inflicted 'too early, too fast' integration into the global economy, while in others have not used the available industrial policy instruments and institutions, despite the fact that they were feasible under the existing global regime.

The third layer is the dominant *industrial paradigm* country faced when they moved their first steps in the global industrialisation ladder. Building on the seminal work of Joseph Schumpeter and later Carlota Perez (2001), with industrial paradigm we refer to both the techno-economic and organisational mode of production which are dominant in a certain period. (Whittaker et al., 2020), for example, define the experience of countries who industrialised after the 1970s in a 'network development era' dominated by GVCs as a 'compressed development' experience. Compressed developers such as our recent and emerging industrialisers – they argue – faced opportunities and challenges which are fundamentally different from those faced by early industrialisers such as Germany, Japan and the United States.

At the interface of these two layers – policy space and industrial paradigm - another key consideration is nature of financing (Kregel and Burlamaqui, 2016). Many developing countries have experienced in the past decades increased vulnerability to financial flows via the footloose nature of foreign direct and portfolio investments, and through increased foreign ownership of domestic banks. Such financialization of industrialization attempts tends to worsen the terms of trade for poorer countries (raising costs of imports and lowering costs of exports) and to re-enforce lock-in into lower value-added activities and increase financing of consumption, real estate and retail sectors rather than industrialization. Thus, the nature and ownership of development finance is a key variable in the state and industrialization co-evolution.

Thus, we can summarise our argument in (so-far) three successful ideal-typical states of innovation that capture the evolving nature of how state formation and industrialization co-evolve: developmental state; entrepreneurial state; and innovation-challenge led state. This is summarised in Table 1. At early stages of industrialisation, the developmental state is centralised and hierarchical; however the capacity of the state in implementing a wide range of selective industrial policies is weak due to limited long-term expertise in civil service, limited autonomy and state-legitimacy in conflict management (Chang and Andreoni, 2020; Harrison, 2020). State capacity formation and legitimation presupposes the emergence of a strong developmental state and the emergence of a fully-fledged entrepreneurial state increasingly focused on technology innovation and systems, also enabled by a distributed mix of Weber I and Weber II agencies and institutions (Mazzucato, 2013). The most advanced state of innovation is the one encapsulated by an innovation-challenge driven state whose mandate becomes explicitly and directly cross-sectoral-society. Weber II type of state institutions are organised within networked and multi-layered governance structure, experimenting with a challenge-focused approach. This adaptation of state capacity and industrial policy approaches, rationales and instruments also reflects the evolving industrialisation and broader societal challenges.

Table 1: Three states of innovation

	Developmental State	Entrepreneurial State	Innovation-challenge driven State
Industrialisation challenges	Breaking into Linking up Linking back	Linking back Keeping pace Competing for innovation	Keeping pace Competing for innovation
Industrial policy Rationales	Structural coordination Dependency & dualism Technology backward's Market failures	Market failures System of Innovation Technology race National security	Market shaping Public Purpose Innov Sustainability challenges Economic resilience
Industrial policy Approach	Supply-side Production & technology focused Firms' level capabilities	Supply-side Technology & innovation focused Innovation system	Demand-side Challenges & Innovation Focused Cross-sectoral-society
Industrial policy Instruments	Trade policy Subsidy policy Technology policy Development finance	Trade policy Technology policy Innovation policy Long-term finance	Public procurement Technology policy Innovation policy Long-term finance
State model	Hierarchical Centralised	Heroic Distributed	Experimental Networked and Multi-layered
State capacity and institutions	Autonomy and expertise Weber type I	Investment and system-building Webert type I and II	Challenge-focused Weber type III

Source: Authors

4. Case studies

4.1. Germany: from a developmental state to an innovation-challenge driven state

Germany's industrialisation and use of a wide range of industrial policy dates back to the eighteenth century. Under Frederick William I (1713–1740) and Frederick the Great (1740–1786), the Prussian state provided monopoly rights, trade protection, export subsidies, capital investments, and skilled

workers from abroad to develop a number of emerging (at that time) industries including textiles and metals. Starting with the early nineteenth century, the Prussian state invested significantly in infrastructures and educational reforms, especially technical schools and universities. With the increasing growth of the private sector, during the second-half of the nineteenth century the German state moved from a directive to a guiding role (Chang, 2002). The use of tariffs as a form of 'infant industry protection' remained relatively mild until 1879 in comparison to Britain and the United States, although a German customs union under Prussia leadership was already established in 1834. The last two decades of the nineteenth century witnessed a significant tariff increase aimed at cementing a political coalition between the landlords and the industrialists – known as the "marriage of iron and rye." Under Otto von Bismarck, Chancellor of Germany, tariffs were however used in a selective manner targeting heavy industries such as steel and iron. Cartel policies were also used. With the erosion of state capacity during the Second Reich (1870–1914), the state became relatively less involved in industrial development, although it still played an important role through its tariff policy and cartel policy. With the reconstruction of the German state and economy after the WWII, industrial policy came back to the centre of economic policy in Germany.

The German developmental state model: the building of an industrial ecosystem

During the first two decades after the WWII, Germany's recovery was driven by those industries in which the country had a long-standing competitive advantage and it was sustained by the high demand of investment goods from the rest of Europe. Between 1950 and 1970, investments remained high at 22-24% of national income, while exports rose from 9% to 19% of national income. The German model (Modell Deutschland), as Helmut Schmidt called it in the 1970s, was developed during this period thanks to an articulated package of industrial policies operating both at the national and regional (Lander and municipalities) levels. These policies built the foundations of today's German industrial ecosystem and are still central to its competitive global success.In the early decades of the post WWII period, he German industrial policy focused on five main axes: industrial restructuring and public ownership; regulation of the labour market; the development of an integrated vocational training system; creation of a basic science and industrial research infrastructure; and public support for industrial finance.

During the 1950s, the German government built a number of public or quasi-public special-purpose banks, whose functioning and mandate adapted over the years with the changing needs of industries. For example, the Bank for Reconstruction (KfW), founded in 1947, increasingly moved away from direct lending and became a long-term refinance bank specialized in lending to banks strongly linked with industrial companies. The Mittelstand companies were mainly served by the German Bank for Settlements (AG) as well as by a strong network of public saving banks and credit cooperatives, linked by a 'three tier' organizational structure, which allowed them to overcome scale disadvantages by aggregating credit demands (as well as savings) at the upper tiers (regional or national) while remaining strongly embedded in the local community.

From the mid- 60s until the mid- 70s Germany's investments in basic science and industrial research tended to be sectoral and technology-targeted. In 1962 the Ministry for Atomic Questions was converted into the Ministry of Research and Technology (BTFM). Three major industrial strategies were implemented. The first was on data processing and computer hardware development, which channeled resources mainly to Siemens. The second was on nuclear power, focusing on fast breeder

reactor. Third, both the federal and land governments heavily supported civil aircraft projects through subsidies and organised 'rationalisation' and concentration, which led to the creation of the MBB group, later one of the main partner in the Airbus consortium. Since the mid-1970s, the German government increasingly developed its public R&D infrastructure built around two publicly funded networks of institutes, the Fraunhofer Society and the Max Planck Society. Fraunhofer institutes were explicitly aimed at filling the gap between basic science and company-based industrial research and at overcoming the disadvantages and scale bottlenecks faced by Mittlestand companies, that is, firms with a number of employees between 100 and 500. Fraunhofer Institutes undertake collaborative manufacturing research and address technological challenges for the entire industrial system (big and small companies, public sector included). Institutes are required to balance their own budgets, which requires them to generate contract research (Andreoni, 2016).

The German Model went through important changes since the 1980s which accelerated with the re-unification. In 1982, Helmut Kohl began to reduce the role of the government by cutting public expenditure and taxes as well as partially de-regulating the labour market and promoting privatizations. With the reunification, the government adopted a dual system of industrial policy: continuity of the industrial policy for West Germany and policies directed towards East Germany. The industrial policy measures in East Germany focused on the creation and development of new SMEs (both in manufacturing and services), infrastructural investments, and the privatisation and rationalisation of SOEs (the public agency in charge was Treuhand Gesellschaft). In West Germany, industrial policy has remained very much focused on existing Mittelstand companies and their innovative capacity, especially those large medium-size companied (up to 1,000 employees), known as 'hidden champions', many of which dominate global niches, with 40%-90% of the global market shares.

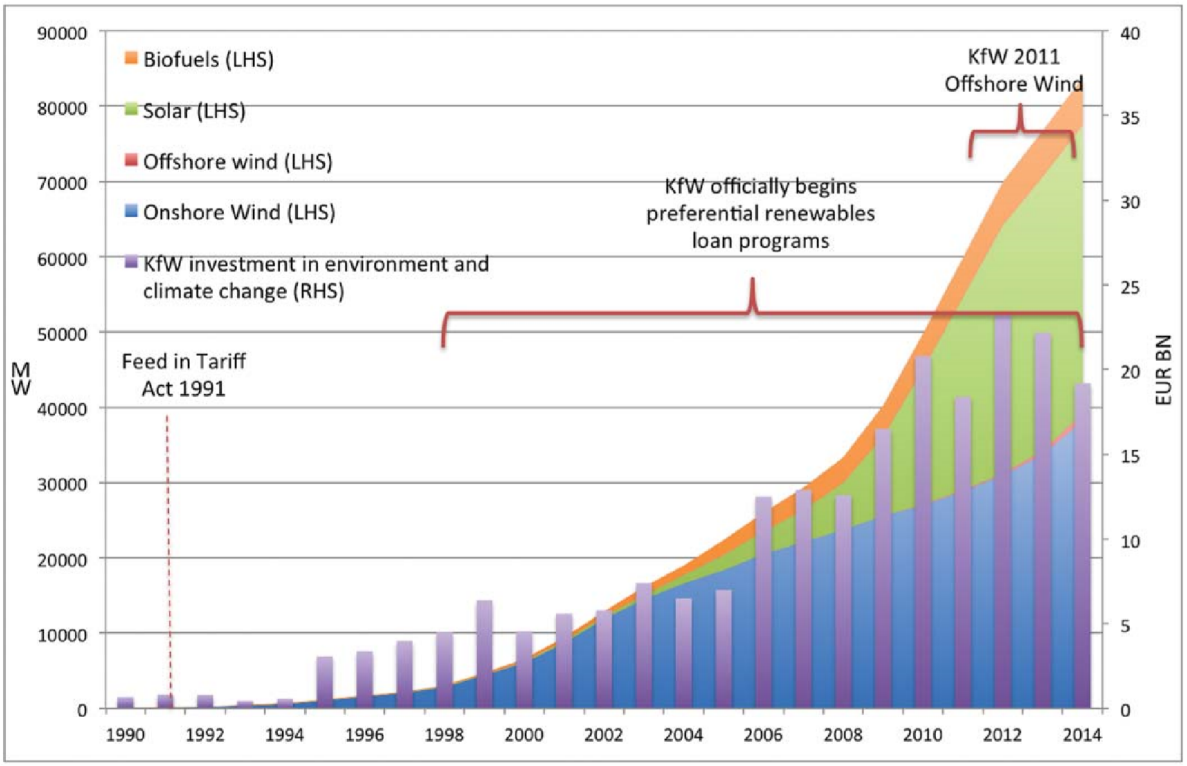
The German innovation-challenge driven state model: competing for green innovation

Together with this process of decentralization of industrial relations, the early 2000-2005 was characterized by an increasing emphasis on environmental sustainability, energy efficiency, and renewable energy (German Renewable Energy Act). KfW played a central role as an institutional arm of the government in the implementation of its green challenge innovation and industrial policy. Germany entered into the renewable energy industry as a follower, Denmark being already established as the country with the first mover advantage, and in an industry with a massive sunk cost advantage of incumbent technologies. In its early days renewable energies were costly and the market was not willing to channel significant resources into the sector.

The Federal Government relied on both demand and supply side instruments. In the late 1990s the launch of a feed-in tariffs schemes created domestic demand and subsidised domestic transition from fossil fuel to renewable energy. From the supply side, KfW was used to channel of subsidised long-term finance to promote investment in the industry, and later export promotion especially across developing countries. KfW's special renewable energies programmes entails long-term credit with subsidised interest rates and other favourable conditions. It is estimated that about 80% of wind energy plant development and 40% of the total renewable energy development in Germany have been financed by KfW, if we include co-finance projects (see Figure 2). By 2014, 3 out of the top 10 wind turbine manufacturers were German companies, Enercon, Siemens and Nordex.

In 2011 KfW became the most important promoter of renewable energies worldwide, together with the World Bank. This global influence was made possible thanks again to the IPEX export finance programme, including direct provision export and project finance. IPEX can provide this aid at favourable conditions both in its capacity as an official ECA and through its market window. KfW Entwicklungsbank and German Investment Corporation support IPEX's direct promotion of German firms by financing renewable projects in developing countries and increase global demand for this new industry (Naqvi, et al. 2018).

Figure 2. Installed renewables capacity in Germany and major programmes



Source: Naqvi et al., 2018.

Germany's use of these state subsidies was compliant with the EU regulatory framework on state aid, as the energy renewables were covered under the General Block Exemption Regulations. Other EU countries, but also other global powers like US and China have adopted similar finance schemes and regulatory exceptions to gain leadership in this new industry since the mid- 2000s. Among them China, has gained significant production capacity in solar panel. Globally in 2017, cumulative solar PV capacity reached almost 398 GW and generated over 460 TWh, representing around 2% of global power output. Utility-scale projects account for just over 60% of total PV installed capacity, with the rest in distributed applications (residential, commercial and off-grid).

4.2 The United States: from a developmental state to an entrepreneurial networked state of missions

From its early days, the US was a pioneer of industrial policy (Chang, 2002; Reinert, 2008). The infant industry argument was indeed invented by the first American finance minister (Treasury Secretary),

Alexander Hamilton, in his 1791 *Report on the subject of Manufactures* by the Treasury Secretary. The Report was, contrary to what many believe, not narrowly focused on tariff protection but discussed a whole range of (general and selective) industrial policy measures, including targeted subsidies, infrastructural development, financial development (the banking system, the government bond market), and the promotion of innovation through the development of the patent system. Between 1816 and the end of World War II, the USA had one of the highest average tariff rates on manufacturing imports in the world. Given that the country enjoyed an exceptionally high degree of "natural" protection due to high transportation costs at least until the 1870s, US industries were the most protected in the world until 1945. In 1890, agricultural products accounted for almost 75 percent of total U.S. exports, with cotton and grain products making up close to 50 percent of the agricultural export total (Ferleger and Lazonick, 1993). To overcome this situation, during this period the U.S. government promoted productive transformation via extensive range of agricultural research through the granting of government land to agricultural colleges and the establishment of government research institutes to diffuse scientific and managerial advances. In the second half of the nineteenth century, the government expanded public educational investments, promoted and invested directly in the development of the transportation infrastructure.

The United States networked model of entrepreneurial state

The industrial policy 'networked model' the U.S. adopted in the second half of the twentieth century was established during the wartime period, between 1940s and 1950s. In 1942 the War Production Board (WPB) was constituted to meet the production targets and public procurement required during WWII. The production system was subject to the WPB governance and coordination but remained a private-based system. At the core of the strategy developed by Simon Kuznets and spelled out in the Victory Plan, the WPB focused on measurement (standardisation and interchangeable parts), coordination (mainly through procurement) and transformation of the production system (ramping up production and development of scaling up capabilities). Under the lead of Vannevar Bush, the Office of Scientific Research and Development became the critical node of a networked inter-organisational system for science and technology R&D (Best, 2019).

The integration of mass production and technological innovation was achieved through a networked entrepreneurial state, made of several public agencies and schemes, many of which steered the US economy in new sectors while creating new markets (Mazzucato, 2013). This included and state agencies (e.g. the ARPA [Advanced Projects Research Agency] of the Pentagon, the NIHs [National Institutes of Health], the NSF [National Science Foundation], the National Institute for Standards and Technology (NIST), the Departments of Energy and Agriculture, and NASA [National Aeronautics and Space Administration]), industries, universities, national laboratories and other research institutes. During the 1950s and 1960s, many of these institutions were strongly focused on translating cutting-edge technological research, much of which was generated through massive public funding of R&D (especially in defence and health), into commercial use.

Throughout the Cold War period, the US implemented a comprehensive industrial policy package including long-term procurement contracts, subsidies, investment guarantees, and strategic bailouts. During this period, industrial policy in the U.S. was conducted under other names – defence policy, health policy, agricultural policy, and what have you – prompting the eminent American economic sociologist Fred Block to talk of a 'hidden developmental state' (Block and Keller, 2011). Between the 1950s and 1980s, the share of government funding in total R&D in the supposedly free-market US accounted for, depending on the year, between 47% and 65%, as against around 20% in Japan and Korea and less than 40% in several European countries (e.g., Belgium, Finland, Germany, Sweden).

This public R&D investments were pivotal in the development of key technologies especially 'defence' (computer, semiconductors, aircraft, internet) and 'health' (drugs, genetic engineering).

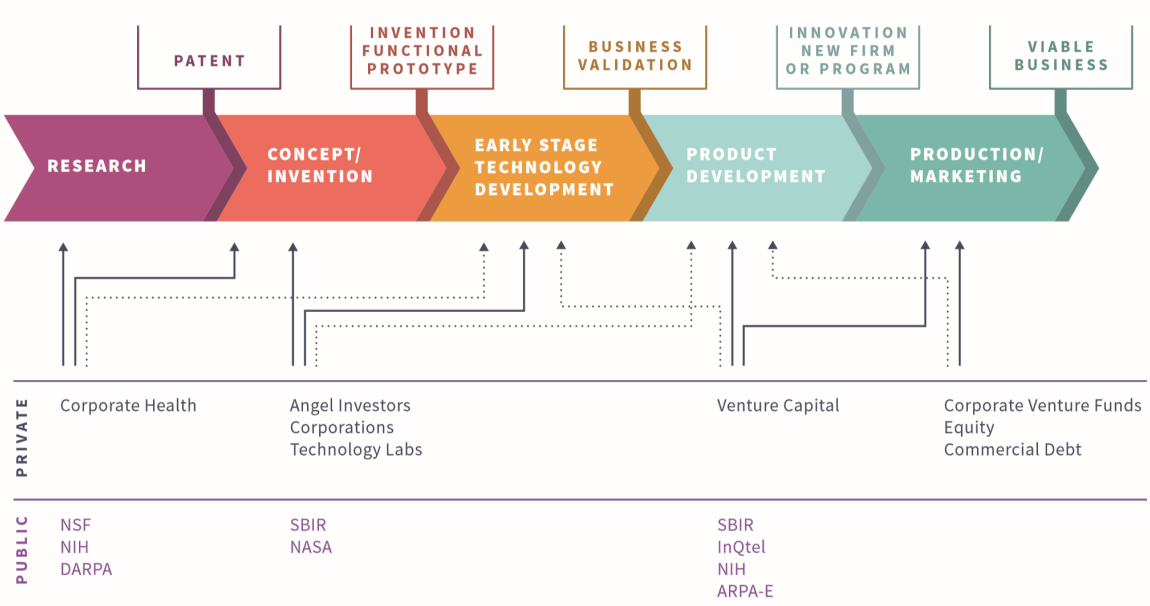
More recently, R&D funding has taken the form of grants, deferral of liability, tax provisions and exemption. Some of today's most successful industrial policy measures in the US have been introduced and continuously supported over several years. This is the case of two programs run by the Small Business Administration, namely the Small Business Investment Company (SBIC) and the Small Business Innovation Research and Technology Transfer (SBIR/STTR). These programs combine loans, R&D grants, and pre-commercial public procurement to support businesses engaged in the development and scale-up of technological systems or components (Andreoni, 2016).

The United States innovation-challenge driven state model: mission-oriented innovation

The 2007/8 financial crisis, and the subsequent sharp manufacturing loss and employment crisis, opened a new industrial policy cycle with an unprecedented one-time US$787 billion stimulus package – i.e. The American Recovery and Reinvestment Act (ARRA) of 2009. The Obama Administration first addressed the dramatic shortage of science, technology, engineering, and mathematics graduates and skilled workers via almost $100 billion of federal investment coupled with state-level initiatives. The health sector (and its industries) received another massive boost of more than $100 billion, while an ambitious infrastructural program was launched to address communication, energy, and transportation infrastructure. Finally, the possibility of inducing a techno-paradigmatic shift in the energy sector was taken up as a new pathway for systemic structural change and sustained growth. Clean-energy initiatives, mixing loan guarantees for renewable energies, electricity transmission projects, and smart grids, as well as grants for batteries and advanced materials were financed. Additionally the Advanced Research Projects Agency—Energy (ARPA-E) coordinated a new mission-oriented research venture in energy.

Historically, in the U.S., the public sector has played a key role in ensuring that each stage of the innovation chains are adequately funded, especially those stages in which private sector companies might be unwilling to pump resources. Technological development follows different stages and can be measured in different ways. Traditionally, scholars have distinguished five stages of technology development – research, concept/ invention, early-stage technology development, product development, and production/ commercialisation. As shown in Figure 3, the U.S. government has been particularly successful in developing public agencies specialized and focus on all stages of the innovation chain deploying different financial and non-financial instruments. As pointed out by Mazzucato (2017:20) "Such organisations have been 'mission driven' in that they have directed their actions based on the need to solve big problems, and in the process actively created new technological landscapes, rather than just fix existing ones".

Figure 3: Mission-oriented Finance along entire innovation chain



Source: Mazzucato, 2017:20

This model is so successful for several reasons. First, the amount of resources for R&D is extraordinary, and often exceeds private investments along the innovation chain. For example, from 1936 to 2016, cumulative R&D expenditure by NIH has amounted to more than $900 billion (in 2015 dollars), and since 2004 has exceeded $30 billion per year. However, what makes this model so successful is not simply the large amounts of resources that actors like NHS pumps into research, but also the way in which agencies are distributed along the innovation chain, how coordination is achieved to maximise returns on public investments with a balance between directive and bottom-up interactions. Third, within these mission-oriented agencies investments are 'direct' and tend to crowd-in private investments more than indirect tax incentives. Finally, by adopting this model the government can potentially introduce a number of return-generating mechanisms for its investments, including retaining equity or royalties, retaining a golden share of the IPR, using income-contingent loans, or capping the prices (which the tax payer pays) of those products that emanate, as drugs do, from public funds (Mazzucato, 2017).

4.3 China: from a developmental to an innovation-challenge driven state

Since the late 1970s, industrial policy has been an integral part of China's five-year planning. Many initiatives and policy measures, especially in the early period, were inspired by the successful experiences of Japan and Korea and focused on breaking into the global economy by linking up to value chains. The Sixth Plan (1981 to 1985) marked a more outward-oriented approach, focusing on importing technologies and developing endogenous technological and innovation capabilities. Thus, since the 1980s, China started using several policy instruments to link back and develop linkages to the local production system and keep pace with technological change. To achieve these complementary sets of goals, China adopted a selective approach to industrial policy. Strategic industries, or 'pillar industries', were identified based on their importance to China's national security and economy and growth potential.

Each targeted sector received a package of complementary industrial policy measures, including tariff and non-tariff barriers, import quotas, local content requirements, licencing systems, tax exemptions, subsidised land, and subsidised loans from state-owned policy banks. Firms from prioritised industries benefited from subsidised loans from development banks, such as the Export-Import (Exim) Bank of China, the Agricultural Development Bank of China (ADBC), and the China Development Bank (CDB). The overall financial infrastructure was also given a pro-industrial development orientation by law. SOEs played a critical role in co-ordinating processes of industrial upgrading and restructuring, in some cases limiting domestic competition to achieve economies of scale and overcome entry barriers. SOEs benefited from incentives and preferential loan terms. Finally, Foreign Direct Investment (FDI) policies were widely used by China in linking up to global value chains while creating the conditions for the development of domestic production linkages. Targeted industries typically involved high-end manufacturing, new and advanced technologies, energy efficiency and environmental protection. The automobile and semiconductor industries, for example, were guaranteed market protection in exchange for technology transfer, while increases in companies' production scales were reached through government-led mergers and acquisitions (Lo and Wu, 2014).

The market liberalisation agenda in the second part of the 1990s brought various changes in Chinese industrial policy efforts. Agriculture, infrastructure, construction and services were included in the list of pillar industries. The Tenth Five-Year Plan (2001 to 2005) marked renewed systemic industrial and technology policy efforts. Several other policy measures have been introduced since 2005 as part of subsequent five-year plans. The policy model has increasingly relied on the involvement of provinces and municipalities. As a result of this accelerated process of structural change and the new industrial policy approach, China has entered a path of indigenous innovation (zizhu chuangxin). Berger (2013:145) shows that, until 2005, there was limited evidence of domestic innovation capabilities. Thereafter, companies in high-tech sectors developed enhanced capabilities (increasingly mastering the scale-up of complex system products and processes, translating into advanced product design and advanced manufacturing, and reducing the time to the market). Companies have also developed redesign, reverse and re-engineering competencies. Thus, these companies are increasingly able to produce products with 'Japanese [good enough] quality at Chinese prices'.

Since the 1980s, China has adopted several technologies and R&D-financing policies to keep pace with technological change. In 1986, the National High-Tech Development Plan introduced the first articulated national technology strategy targeting biotechnology, space, information technology, laser technology, automation, energy and new materials. This technology plan was updated over time to include emerging technologies, such as telecommunications (1992) and marine technology (1996). The Torch Programme was initiated in 1988. It promoted (i) hi-tech cluster development around Science and Technology Industrial Parks (STIPs), Software Parks, and Productivity Promotion Centres (Innovation Clusters); (ii) high-tech business start-up services (Technology Business Incubators); and (iii) financial services for innovation (InnoFund and the Venture Guiding Fund). Indeed, China relied on a full range of financial and non-financial incentives to catch up technologically and develop innovation capabilities.

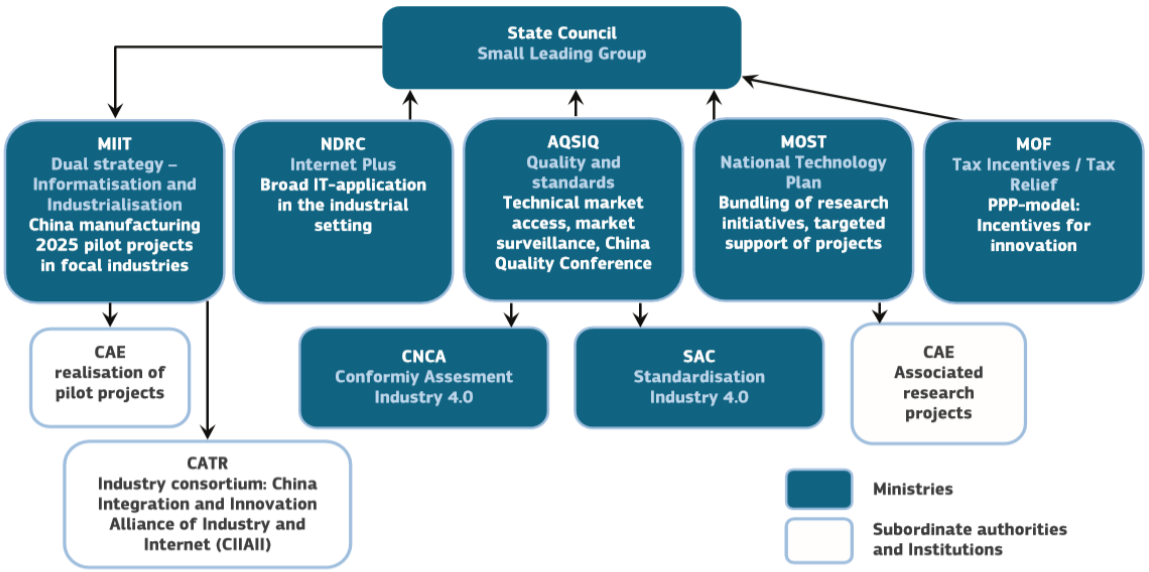
The Chinese innovation-challenge driven state: Made in China 2025

In 2015 the Chinese government launched an ambitious 10-years strategy – *Made in China (MIC) 2025* – aimed at transforming the economy along the pathway started in the 1990s towards becoming a high-tech innovative industry powerhouse. The strategy is articulated in two different phases, and the target year 2025 refers only to the so called "foundations" phase. During this first phase, the following

10 strategic sectors were targeted including: Next generation IT, High-end numerical control machinery and Robotics; Aerospace and aviation equipment; Maritime engineering equipment and high-tech shipping; Advanced rail equipment; Energy-saving and new energy vehicles; Electric power equipment; Agricultural machinery and equipment; New materials; Biopharmaceuticals and high-performance medical devices. The second phase, from 2025 up to 2049, aims at upgrading the whole Chinese economy and reduce unbalanced transformation across provinces or sectors, in particular by reaching high levels of automation and vertical integration. The third phase is finally focused on horizontal integration of the industries and broader uplifting of productivity. By 2049, China aims to belong to the top innovation-driven economies in the world.

The implementation of such large schemes calls for significant institutional restructuring and effective governance schemes. This is why MIC 2025 emphasises the importance of collaborations between universities and research organisations, and industry. Innovation alliances and demonstration centres are among the main tools MIC 2025 is using to drive innovation, diffuse new technologies, and to develop joint standards between science and industry. At the sub-national level, eight cities and five city clusters are acting as pilots for implementation of the policies. China has launched 19 provincial manufacturing innovation centres and 109 smart manufacturing pilot programmes including the National Power Battery Innovation Centre in Beijing, the National Additive Manufacturing Innovation Centre in Xi'an and the National Information and Optoelectronics Innovation Centre in Wuhan. From a state capacity and policy governance perspective, the State Council acts as the main coordinating organisation while China's Ministry of Industry and Information Technology (MIIT) is directly responsible for implementation (Figure 4).

Figure 4: Made in China 2025 Governance system



Source: GIZ; cf. European Chamber of Commerce in China, 2017

Differently from previous strategies, MIC has broaden its sectoral and technological focus including traditional industries and services, alongside previously targeted renewables, alternative fuels, artificial intelligence, cybersecurity services, integrated circuits, network equipment and software, biotechnology, energy-efficient and environmental technologies, and high-end manufacturing. The MIC strategy focuses on reducing reliance on foreign technology and improving along several critical technology/innovation dimensions – i.e. innovation capacity, efficiency, quality of industrial infrastructure, quality of outputs and degree of digitalisation. In particular, technological innovation and smart manufacturing have been targeted. Green technologies are also seen central to address the mobility challenge transition, and large investments and incentives in energy- and material-efficient production have been introduced. For example, in April 2018 the dual credit policy scheme to incentivise transition to electric cars was launched. Alongside this scheme, the Chinese government has built the largest charging stations networks for electric vehicles reaching more than 210,000 charging poles with a fast rate of growth of new 6,000 charging stations per month. Such transformative modernisation of the economy will create an enormous demand for advanced manufacturing technologies. The Chinese government aims at filling this gap with major funding support and strategic market engagement.

5. Concluding remarks

Industrial policy is central to the structural and innovative transformation of the economy. Historically, no country has managed to achieve these goals without the state playing an active role in shaping markets and industries. Industrial innovation is however both the outcome *and* a driver of state formation. They are linked by a complex co-evolving dynamics of change involving the transformation of the productive structure as much as the formation of state capacity. In stepping up the industrialisation ladder, countries are transformed by these co-evolving dynamics (or lack thereof) which unfold under different industrial paradigm and global policy space regimes.

In this chapter we introduce a multi-layered framework to contextualise industrial innovation policies and conduct a comparative political economy of industrialisation. We distilled three main states of innovation and for each of them – developmental state, entrepreneurial state and innovation challenge-driven state – we provide a stylised analysis of its main features. The analysis of these features is conducted through three historical case studies of Germany, USA and China. Specifically, we selectively review the evolution on industrial policy instruments, approaches and state institutions and how these countries have shifted from one state of innovation to another over time.

The framework and illustrative case studies have highlighted a number of emerging trends across countries. In particular, the increasing shift from a traditional form of developmental and entrepreneurial state towards a more innovation challenge-driven state. This reflects the need to address cross-sectoral-society challenges whose solutions require coordinated efforts and experimentation across several agencies and institutions. This shift has also entailed an expansion of the policy toolkit and instruments that the government can use and align to address these challenges. Another emerging trend is the focus on the energy and sustainability transition, as one of the key challenges across early, late, and recent industrialisers. Finally, changes in state forms and functions is encapsulated by the shift towards Weber II type of agencies and institutions, as well as their integration into multi-layered and networked governance structures.

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