# 4 Industrial policy and technological sovereignty

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## 1 Introduction

In times when the prosperity and welfare of an economy depend on mastering and using the latest technologies and, if necessary, also generating them, the question of the extent to which an economy has the skills and knowledge to succeed in doing so becomes important. If an economy has and maintains such capabilities and knowledge, then it can make sovereign decisions about the use of the latest technologies.

This sovereignty and its preservation have gained attention in politics, media and in the broad public. It started with so-called digital sovereignty which has been closely related to the topic of cybersecurity – mainly driven by the significant increase in cyberattacks worldwide. Meanwhile it is not only the digital sphere that is concerned with the issue of sovereignty. Sovereignty is also important in the spheres of raw materials and energy, electronic devices, international value chains and key technologies. The sources of constraints on technological sovereignty are various, ranging from new geopolitics and economic wars, to intense technology competition and vicious-virtuous cycles of development. Trajectories of technological and economic divergence, patterns of severe economic inequality and noticeable structural changes arising from radical changes that broadly affect – positively and negatively – all sectors and industries, give rise to political considerations and concepts that seek to preserve and regain technological and, in particular, digital sovereignty.

Policymakers have been quick to identify intervention points and to arm themselves with industrial and foreign trade policy tools. The belief that the markets can solve these problems is fading, and forces are gaining ground that see active government intervention via industrial policy measures as the silver bullet. The Inflation Reduction Act in the United States, the European Green Deal and China's Belt and Road Initiative are examples. Industrial policy flourishes.

Against this background, the question remains of whether these policies are conceptually appropriate to cope with the issue of technological sovereignty. This issue takes on particular importance in phases of far-reaching structural change and fundamental transformation processes. Radically new technologies come into play, new key technologies emerge and the question is which economies can best contribute to these processes and occupy prominent positions (economically, technologically and in terms of driving the Sustainable Development Goals). Particularly in relation to key technologies, new constellations of international technological leadership will emerge, which may lead to dependencies and restrictions on technological sovereignty.

This chapter introduces the concept of technological sovereignty as a microeconomic issue. It then discusses this sovereignty and restrictions on it, in the context of a technology-gap trade model with endogenous processes of generating new knowledge and hence innovation. The chapter ends with a brief dive into industrial policy and measures to cope with and prevent technological sovereignty.

## 2 Technological sovereignty: the concept

The concept of technological sovereignty is described and defined in varying ways. The common denominator is that technological sovereignty is about the degree to which one can master a certain technology in its application and use, and also about the degree to which that technology is available or the degree to which one has access to it. Mastery is measured on a spectrum of the existing know-how and competencies that must be built up and kept ready for the production of a technology or its use. Availability results from a positioning on a spectrum from pure self-production to complete procurement.

For the purpose of this chapter, the following definition of technological sovereignty is used (EFI, 2022):

> *"A national economy has technological sovereignty if it can itself provide and further develop a technology it deems critical for its welfare, competitiveness and ability to act, and if it can participate in its standardisation and is able to apply and to source this technology from other economic areas without one-sided structural dependency"* (translated from German).

### *2.1 Technological sovereignty as a microeconomic problem*

The use of technologies in the production and use of goods and services is subject to the decisions of companies, whether private or public, public institutions and infrastructures, and users, especially in the household sector. Sovereignty in the use of technologies thus first and foremost concerns microeconomic actors.

At the micro-level, operators or users are sovereign in a technology (i) when they master it, and (ii) when it is available to them. As to mastery, a sovereign approach to technologies means that they are well understood by their operators and users in accordance with the respective objectives. For that understanding, proper technological knowledge, comprising know-how and competencies, is required. One is not sovereign in these technologies if one does not have the knowledge to master them (lack of mastery). As far as availability is concerned, one is sovereign in dealing with a technology if one has it at hand and can use it. The availability of a technology is limited if one cannot afford it or does not have access to it for other reasons (lack of availability).

Lack of mastery and lack of availability – alone or together – mean that one is dependent on others to use a certain technology and, hence, is no longer sovereign in this respect. Such dependence is associated with high usage costs, which can be so high that one does not use a certain technology at all, although it is useful in its own right.

*2.2 Technological sovereignty: between autarky and division of labour*

How do operators and users of certain technologies achieve technological sovereignty? Well, the greatest degree of sovereignty in a technology is achieved when one generates this technology oneself and makes it available to oneself. In such cases, one is autarkic in this technology with full technological sovereignty.

This argument, however, neglects the positive effects of the division of labour – or the underlying managerial decision to 'make or buy'. Individual economic autarky does not guarantee that the best technology is available, but only the quality of technology that one is able to provide oneself. And this quality may well not be at the top of the range. In such a case, it may make sense to acquire better technology in the marketplace. If there are suppliers of a corresponding technology, then a calculation of the advantages according to the 'make-or-buy' principle must be made, in the sense of comparative performance-price ratios. In doing so, the price of procuring the technology needs to include the costs of building up and maintaining the corresponding competences and skills needed to operate and use the purchased technology, so-called absorptive abilities (Cohen and Levinthal, 1989). Comparing the performance-price ratios of buying and of making comprises the make-and-buy decision.

If this comparison leads to the decision to buy, then the degree of technological sovereignty of the buyer results from the quality of the absorptive capabilities (mastery) on the one hand, and the possibility of acquiring the technology on national or international markets (availability) on the other. Risks and resulting costs that may limit technological sovereignty must be contrasted with the costs and disadvantages that would arise if opportunities from the division of labour were not exploited and autarky were pursued.

*2.3 Restrictions on individual economic sovereignty*

Restrictions on individual technological sovereignty are not likely to occur in the case of in-house production of technologies. If technologies are acquired from others, then restrictions on individual technological sovereignty can be caused by two factors: restrictions on the ability to acquire the technology (lack of availability) and lack of technological knowledge (lack of mastery).

When companies acquire technologies on markets, there may be constraints on the procurement side. For example, it is possible that the supplier of a technology encounters problems that lead to supply-chain disruptions, delays, quality degradation or even a complete supply stoppage. If the acquiring company has not diversified its procurement and instead relies entirely on one or a few suppliers, its sovereignty is compromised by a lack of availability. In the international context, trade embargoes and other trade restrictions, however justified, can limit the technological sovereignty of companies. Even though the problem of availability is primarily caused by the supply side, it is really triggered by the lack of a corporate diversification strategy on the part of the procuring company. Obviously, such a strategy is not costless as the firm has to manage numerous procurement relationships, with different prices and qualities of the technology concerned.

As an alternative to diversifying procurement, a firm's willingness to reshore a technology when sovereignty constraints arise can also help maintain or restore its sovereignty. Costs are involved in this decision too. Significant factors influencing these costs are the know-how and the competences to generate and develop the technology for which reshoring is considered. To the extent that the necessary know-how and competences are lacking, they must first be invested in.

In case the reshoring firm's level of know-how and competence is close to that of a supplier of the 'critical' technology, costs of reshoring are comparatively low – an expression of technological sovereignty. However, if the supplier's know-how and competence in the critical technology are far ahead, then the reshoring firm's own provision of the technology is associated with potentially high costs. These include the time costs of building up the know-how and competences related to the technology, or losses in the quality and performance of the technology – cost related to a lack of mastery. Hence, retaining sovereignty in the mastery of a technology via reshoring is costly, and these costs express the degree of dependency on the supplier.

### *2.4 Technological sovereignty and its policy relevance*

Technological sovereignty at the individual economic level is one of the problems that the management of every firm has to cope with. Being able to successfully counter restrictions on technological sovereignty in a preventive manner and anticipating associated problems at an early stage depends on the quality of management. It is part of the normal business reality that in this context management is also subject to misjudgements and, viewed ex post, can make wrong decisions that sometimes lead to considerable losses, and even to company bankruptcy. When markets are efficient, they ensure that these errors are detected and evaluated. This problem of firm management is of political relevance, if at all, only if the markets do not fulfil their tasks accordingly. Seen in this light, technological sovereignty must be regarded as a problem of individual economic actors. It is not relevant to the economy as a whole, and thus possibly not relevant to economic policy.

At the aggregate level, however, the assessment may be different if many companies and users in an economy, entire industries and sectors, are restricted in their technological sovereignty. This can occur with systemically relevant technologies that are of great importance to a broad spectrum of industries, companies and users. These include digital technologies in particular, along with other so-called key technologies from new manufacturing, bio- and life sciences, or the field of new materials. These represent important input factors in a number of industries and are the key to further developments. Furthermore, they are not easily substitutable by alternative technologies in the short and medium terms. A restriction of sovereignty in a key technology thus has negative consequences not only for the supplier and/or buyers of this technology, but also for many other players who depend on this technology. Digitalisation technologies, especially memory chips and semiconductors, show these characteristics.

Key technologies are of outstanding importance for the development of an economy and the international competitiveness of its industries. For this reason, the problem of technological sovereignty in key technologies is of particular importance. If the companies in an economy do not master a certain key technology, or have only limited access to it, dependencies arise because of a lack of technological sovereignty. Because of the systemic nature of such technologies, a problem arises for the economy as a whole, and not just a problem of individual economic actors. And accordingly, technological sovereignty becomes an issue relevant to economic policy.

## 3 Conceptual foundations of technological sovereignty in an international context

Policy interventions to establish and secure technological sovereignty can be justified in the context of industrial policy and trade policy considerations. The relevant theoretical basis is provided by technology-gap growth models (eg Fagerberg, 1987; Verspagen, 1992; Stiglitz, 2015) and models of technology-gap foreign trade (eg Krugman, 1985, Cantner, 1989; Dosi *et al*, 1990). Both model types have in common the concept of the so-called technology gap.

The comparison of actors on the basis of their respective technological knowledge, comprising know-how and competences, can be expressed as a technology gap. Technology gaps depend on two characteristics of the knowledge generating activities: (1) new (technological) knowledge is, instead of being treated as pure public good accessible to everyone, considered as a latent public good that offers innovators considerable protection against immediate imitation; (2)

new (technological) knowledge is endogenously generated and used, hence differs between actors, and is not distributed evenly among all actors.

The characterisation of new knowledge as a latent public good (Nelson, 1991) implies that its widespread use after invention occurs only after a certain period, during which users and imitators need to build up appropriate absorptive capacities (Cohen and Levinthal, 1989). Accordingly, such new knowledge is not immediately available to all actors to the same extent. This gives rise to technology gaps between actors. These gaps can change over time, depending on the relative rate of knowledge accumulation between economies, and technological spillovers between them.

Endogenous modelling of the generation of new knowledge is associated with external learning effects (positive dynamic scale effects): the stock of technological knowledge built up – or what has been learned so far – has a positive influence on its further development, ie on its improvement through new technological knowledge. Because of such learning, knowledge differences between actors, however small they may be, increase continuously.

### *3.1 Technology-gap growth models*

Technology gap growth models are based on the endogenous formulation of the growth of economies. The core driving factor is technological knowledge, which grows endogenously over time. This gives rise to innovation and productivity growth. Models of this kind are suitable to explain non-converging comparative growth of economies. Based on the aforementioned learning dynamics, an economy with a higher volume of production (Stiglitz, 2015) or a higher accumulated knowledge level (Verspagen, 1992) than another, exhibits comparatively stronger growth of productivity or knowledge stock, and thus of GDP. Accordingly, the leading economy grows faster than the following economy – a diverging dynamic.

An economy lagging in terms of this growth dynamic may learn from or imitate the leading economy by tapping into its superior or more advanced stock of knowledge. This use of external knowledge, so-called spillover effects, creates the potential for catching-up via additional growth of knowledge and hence innovation and productivity growth. This counteracts the tendency for the lagging economy to fall further behind in growth. The magnitude of the addressed learning effect depends on the level of the technological gap between economies in two ways. First, the larger the gap, the more can be learned. Second, the larger the gap the more difficult it is for the lagging economy to understand (absorptive capacities) the latest knowledge of the leading economy. The combination of both relationships results in an inverted U-shaped pattern of exploitable spillovers. Accordingly, up to a certain threshold value of the technological gap, a lagging economy can increasingly take advantage of spillovers and catch up through external learning. Above this threshold value, however, spillover effects diminish in potency, leading to reduced catching up or even falling further behind.

### *3.2 Technology-gap trade models*

Comparative advantages in the production of tradeable goods (including services and technologies) determine – in combination with factor prices – the foreign trade structure of an economy. In technology-gap trade models, these comparative advantages arise from internationally differing technological knowledge entering production and application of these goods, and are therefore directly related to the technology gaps between trading economies.

In a multi-goods context, the comparative advantages of one economy over another in these goods can be ranked in ascending order. This so-called comparative advantage function is a measure of how much the two countries differ in the level of technological knowledge that goes into their production of goods: it thus stands for the technological gap. The function takes the value 0 if there is no gap. As the deviation from 0 increases, there is an increasing gap. With negative values, one country leads, with positive values the other leads. The slope of this function indicates how much the technological gap changes as one moves from one good to the next.

Some goods, such as raw materials or rare earths, cannot be delivered by all trading countries, and substitutes for them do not exist. With these goods, the supplying economy has an absolute advantage. In terms of the comparative advantage function in these goods, the slope is infinite, implying an infinite technology gap. In cases in which both economies could provide a certain good, the comparative advantage can be so great that it comes close to an absolute advantage on the part of the technology-leading economy.

The conversion of the comparative advantages of an economy into competitive advantages takes place via the relative factor prices compared to another economy. These competitive advantages in turn determine the trade structure of an economy. The higher the relative factor prices of an economy, the greater the technological lead in producing a given good has to be, in order to be competitive in that good. This means that economies with relatively high factor prices tend to export goods in which they have a larger technological lead. Economies with low relative factor prices are able to export goods for which the other economy's technological lead is much less pronounced (or even reversed).

Technological change and changes in relative factor prices between economies affect the patterns of foreign trade. By applying the above model of endogenous new knowledge generation based on learning effects, the comparative advantages in the production of goods in which an economy has a technological lead will improve continuously. Relative factor prices are affected via the trade balance adjustment. In case of an export surplus of the technologically leading economy over another economy – due to, for example, new knowledge leading to goods of improved quality-price ratio – relative factor prices of the technology leader need to increase. This changes the trade structure by shifting the production of some goods to the lagging economy, thus restoring the trade balance.

The strength and the direction of the combined effect of new knowledge generation and changes in relative factor prices depend on the demand structure in the trading economies and on the pattern of technology gaps between them (function of comparative advantages). Assuming stable demand structures, in case the increase in the technological lead is stronger than the increase in relative factor prices, the range of goods the technology leader produces and exports will increase. In case of a reverse relationship between changes in the technology gap and relative factor prices, the range of goods the lagging country is able to take over in terms of production and export will increase.

### *3.3 Dynamic positioning and sovereignty of a country in a technology-gap context*

On the basis of the endogenous learning-driven process of generating new knowledge, a country that gained through its technological lead a comparative advantage in some goods will not lose, but rather reinforce that advantage over time. Four trade-technology constellations are interesting in this respect:

*North-North*: In the North-North trade context, the trading countries will each have a technological lead on some goods but a lag on others. As more new knowledge is generated in all of these economies, and goods are improved accordingly, the basic structure of comparative advantage will change little, but will become more pronounced for each good. The changes in relative factor prices required to restore trade balances in such a constellation are rather modest, so the terms of trade of the economies do not change much. In terms of technological sovereignty, the specialisation of each economy in certain goods where its respective technological advantage is increasing means a weakening of the other economy's ability to master those technologically advanced goods. Dependencies can arise for both economies, so they are mutual in nature. In the event of availability problems due to strategic trade policies, the 'attacked' economy has a bargaining chip at its disposal: the goods in which it has a technological lead allow to it to counteract the strategy.

*North-South*: In a North-South context however, countries in the

North have technological leads in all high tech-based goods, whereas the South has advantages in no- or low-tech goods. As high-tech will increasingly be important in the North's economies, the North will be at an advantage, while the South will be at a disadvantage. With the generation of new knowledge in the North and in the South, high-tech goods will be more improved in the North than in the South, and high-tech goods will be improved more than low-tech goods. Hence, the structure of comparative advantages will change in favour of the North and deteriorate for the South, leading to trade imbalances. To restore this balance, factor prices in the North need to increase relative to the South. This increase is usually not large enough to compensate for the increasing technological lead of the North, inducing a continuous improvement of North's terms of trade and worsening of South's. The increase in the North economy's technological lead in a rather broad range of goods weakens the South economy's ability to master them. In case of availability problems induced by strategic trade policy, the South has few tools to counteract. Bargaining chips via goods the South in which has a technological lead are rare and presumably not powerful enough. However, retaliatory trade policy could be implemented.

*Old technologies-new technologies*: While generating new knowledge to upgrade and further develop existing technologies might limit opportunities to existing incumbents that have long mastered these technologies, in new technologies for new goods there are still major opportunities. In a trade structure in which one economy is rather specialised in old goods and another in new goods, comparative advantages in old goods do not change much in response to newly generated knowledge. For new goods, however, comparative advantages change quite intensely and may reach a level close to absolute advantage. In such cases, changes in relative factor prices leave the specialisation structure more or less unaffected. The terms of trade of the economy producing new goods improve, whereas those of the other economy worsen. Over time, technological sovereignty becomes an issue: for the economy specialised in old goods, the ability to master new goods and the technology behind them tends to weaken, as does the power of old goods to serve as bargaining chips in case of availability issues.

*Key technologies*: Key technologies are a crucial input into innovative development of a large number of technologies. The importance of mastery and availability of key technologies thus goes way beyond their own industries. In an international trade context with an endogenous process of generating new knowledge, further development of key technologies has impacts in three ways. First, if an economy does not specialise in a key technology, its technological gap in that technology increases and so does its lack of mastery of it. Second, the comparative advantage of the economy producing and exporting the key technology increases because of its growing technological lead. Changes in international relative factor prices required to restore trade equilibrium lead to a higher international price for the key technology. As the terms of trade of the lagging economies deteriorate, it becomes increasingly expensive for them to acquire the key technology. This reduces the ability of these economies to acquire a key technology – availability becomes increasingly limited and technological sovereignty declines. Third, in the lagging economies, the reduced availability of the key technology and its higher price will constrain the process of improving goods in all industries that use the key technology as an input. Consequently, the process of generating new knowledge in these industries slows, leading to a further deterioration of the terms of trade.

The interrelationships described above and the associated loss of technological sovereignty of an economy in a key technology apply in particular if lagging economies do not themselves specialise in a key technology, and thus do not seek related comparative advantages. However, key technologies are quite broad and often represent a bundle of different individual technologies. In this case, there may be an international division of labour and thus a specialisation structure within a key technology. In such a context, the question of technological sovereignty may arise less.

### *3.4 Dynamic comparative advantages*

In an environment of endogenous, learning-driven processes of generating new (technological) knowledge, the main outcome is a pattern of divergent development. Applied to international trade, this results in an uneven distribution across economies of the welfare-enhancing effects of new knowledge. The concept of comparative advantage – or, in conjunction with factor prices, competitive advantage – determines this outcome because it establishes a particular pattern of international trade that is difficult to escape under endogenous learning.

Hence, for an economy attempting to position itself in international trade more favourably, following this principle of comparative advantages will not be helpful. These comparative advantages determine the structure at a given point in time and are thus static. To overcome that problem, an economy could look at dynamic or created comparative advantages. They are relevant for the goods for which an economy can change the comparative advantages in its favour over time through its own research and innovation activities – and thus also its positioning.

In a dynamic context, what matters for a country is not simply to specialise, but in which goods it specialises. In order to prevent the technology gap in an economy from becoming too large over time, the aim should be to specialise in goods with high potential for improvement through new knowledge, science and innovation.

In these, the economy may not yet have comparative advantages at a given point in time. In such a situation, moving via static comparative advantage into a trade structure in which the economy specialises in established but less-dynamic goods would be statically efficient but dynamically inefficient (eg Stiglitz, 2015; Cypher and Dietz, 1998). In order to comply with dynamic efficiency, static inefficiencies must be accepted, ie specialisation must take place in goods that do not (yet) have comparative advantages, but for which there is high technological innovation potential. In this way, the technology gap of an economy can at least be kept small. This has positive effects on income and prosperity, and on the level of knowledge required to be able to use high-tech goods manufactured abroad.

The focus on dynamic comparative advantages is especially significant in situations of major structural upheaval and transformation, driven by radical new technologies, and in which new technological leadership is emerging. Concepts of free trade based on certain assumptions, including the non-existence of external learning effects (knowledge accumulation), are less helpful here (for example, Greenwald and Stiglitz, 2014).

## 4 Industrial policy to establish and safeguard technological sovereignty of an economy

Decreasing technological sovereignty, as illustrated by the endogenous processes of generating new knowledge described above, and thus increasing the technological dependence of an economy on other economies, is a problem of political relevance. For an economy to avoid such vicious circles, a way out is to choose a trade structure consisting of goods with high potential for further innovative development. Such an ambition might go against its static comparative or competitive advantages, but can be justified by dynamic comparative advantages. To maintain such a specialisation requires industrial and foreign trade policy interventions to protect the chosen patterns of trade until they become self-sustaining.

*Lack of mastery*: Key to technological sovereignty is the knowledge to master technologies. Decreasing innovation capacity and technological know-how should be an alarm bell for firms. And it should also be so for policymakers, as this can in aggregate be seen as a systemic failure at national level. In terms of the mastery of goods and technologies, measures are needed to build up knowledge and hence know-how and as competencies. For key technologies, this needs to apply to the area of the key technology itself, but also, and especially, to the areas of user industries. The promotion of science and research, of training, further education and academic education, of transfer activities to the economy and society, and of innovation activities in these fields are primarily to be thought of here. Hence the large toolbox of research and innovation policies is applicable, with two reservations. First, the effects of these measures will be seen only after some years. Second, the knowledge required to create, develop and use the goods and technologies concerned will probably not be built up to the required quality entirely without in-house production. In order to counter this, it is then necessary to think about measures to keep or even build up the production and further development of these goods and technologies in the domestic market – even against static comparative advantages.

*Mastery through availability*: Industrial and foreign trade policy measures are suitable for keeping the process of generating new knowledge and the production of goods in a national economy. These could include subsidies for selected goods and (key) technologies or other means of export promotion, protectionist measures against imports of superior goods and technologies, and support for reshoring and even for building up facilities of production and of entirely new development in the domestic economy. Such measures ensure that these goods and technologies are produced and further developed domestically (availability) and that learning effects can be generated and used (mastery).

This has two consequences for policy implementation. First, these measures should be implemented for a limited period – at most until international competitiveness in the good or technology is achieved. Second, as far as can be identified, the measure should be implemented when a good or (key) technology is still young, the rate of exploitation of its technological and economic potential is still high, and the technology gap compared to the technology leader not too large. Particularly in the young phase of a new (key) technology, the risk is still quite high of being left behind internationally right from the start. Arguments in favour of young-industry protection or young-technology protection are relevant here.

However, the more mature and established a good or a technology is at the international level, the less one should think of bringing their production home. In such circumstances, other concepts for maintaining technological sovereignty need to be considered. Industrial policy support can also be thought of as supporting goods and technologies only in selected areas. This addresses the structure of an intra-industry and intra-technological specialisation. Several economies are technology leaders in an industry or a (key) technology, but each in a different subsector or niche. This contributes to mastery and availability, albeit in specialised areas. In principle this calls for a portfolio view, implying the technological sovereignty of an economy depending on its mastery of a balanced portfolio of (key) technologies – in some a comparative advantage is achieved, in others not.

*Special availability concerns*: Availability concerns are an issue when it comes to rigid strategic trade policy and trade wars. The factor of mastery is rather a side aspect here. In such cases, the solution depends on the balance of power. If each of the involved economies has a bargaining chip at hand, any 'attack' on sovereignty can be reciprocated. If such an interdependency does not exist, and on the contrary a situation of overdependency exists, then a country might be tempted to opt for an industrial policy directed towards self-sufficiency and import substitution to cut its over-dependency. However, this is not as straightforward as is looks. In case the availability issue is credible and expected to last, the price of the blocked good or technology goes to infinity, creating domestic business opportunities. Domestic but also international investors may jump in. Public support is not necessary here, or could involve only complementing certain research infrastructure (research organisations, universities, etc). This has the advantage that in case the original private investment pulls out the research infrastructure can be continued in the same or a different direction.

In view of these various measures, industrial policy appears to offer a toolbox that can effectively cope with lack of technological sovereignty and can preserving technological sovereignty. Governments around the world are increasingly resorting to this type of measure. It is to be hoped that this does not open the door to the widespread use of industrial policy, under the guise of preserving technological sovereignty.

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