Theoretical Framework
Chapter 2

Outline

As described in Chapter 1, knowledge valorisation is important for achieving a broad societal impact of knowledge. At the same time, knowledge valorisation is not an easy process and many barriers exist across the value chain. These barriers include difficulties in knowing what to study and understanding what opportunities arise from academic research; knowing why stakeholders would engage in this complex process; and knowing how stakeholders should collaborate to ensure a societal impact of knowledge.

This chapter describes the theoretical lens through which these barriers and approaches to address them are studied. The theoretical lens builds upon a weak interpretation of the linear model of innovation which is aligned with a systems perspective on innovation. Combined, these two theoretical models lead to the introduction of the valorisation cycle which forms the basis of the research conducted in this thesis.
2.1 Theoretical framework: the linear model of innovation

The limited effectiveness of knowledge valorisation efforts has often been blamed on the implementation of policy measures and support systems that are based on an oversimplified conceptual understanding of knowledge valorisation processes. Many articles describing the complexity of knowledge valorisation processes start by refuting such oversimplification, which is here referred to as a strong interpretation of the linear model of innovation.

To understand the validity of this rejection, let's first examine the origins and evolution of the linear model. The beginning of the linear model can be traced back to Vannevar Bush's report to the president 'Science: the Endless Frontier' in 1945 in which he described the existence of a relationship between basic science and applied research and furthermore highlighted that applied research would ultimately lead to socioeconomic benefits (82). Industrialists later added development to the three-step model, as an activity to bridge applied research and socioeconomic benefits. And finally, economists added the steps of production and diffusion necessary for the delivery of those socioeconomic benefits to finalize the innovation process (82).

A strong interpretation of the linear model states that the steps of basic research, applied research, development and finally production and diffusion are connected in a directly causal, one-directional manner with no feedback loops or iterations. Although such a strong interpretation has never been proposed by the initial contributors to the model, scholars often use this strong interpretation as a straw man model, only to refute it in support of alternative models they introduce (83). Nevertheless, the model can serve as a heuristic tool that aids in understanding innovative processes if a weak interpretation is taken, which is more in line with original contributions to the model's development (83). The following paragraphs outline three important differences between a strong and a weak interpretation of the linear model and describe how a weak interpretation of the linear model supports an improved understanding of innovation processes.

2.1.1 Division of labour: basic research in universities and applied research in businesses?

First of all, a strong interpretation of the linear model implies a clear distinction between basic and applied knowledge and furthermore states a clear division of labour for these different types of research. However, the distinction between basic and applied knowledge has never been defined as clear-cut (83). Rather than making a distinction between basic and applied research, many scholars have now adopted a way of thinking that sees a quest for understanding and considerations of use as orthogonal dimensions, leading to a matrix of four quadrants (84). The quadrant which combines a quest for fundamental understanding with considerations of its use, referred to as Pasteur's quadrant, has received much attention in the context of knowledge valorisation. This quadrant emphasizes the importance of conducting research with the objective of gaining understanding, rather than just applying already existing knowledge, while still being receptive of the relevance of such understanding for application. As such, it demonstrates that the distinction between basic and applied science is not clear-cut and research can both benefit scientific understanding and be used in application.
A strong interpretation of the linear model of innovation additionally assumes that universities and companies are the only relevant stakeholders. In contrast, as emphasized in the Triple Helix and the New Production of Knowledge models, many different actors are involved in different phases of innovation. The widely adopted triple helix model conceptualizes research and innovation as an interplay between universities, industry and governments. It is this interplay that shapes the knowledge-based economy (85). The quadruple helix, developed in later stages, extended this model to also include the user as a relevant stakeholder (86, 87). In a weak interpretation of the linear model, it is said that instead of a clear division of labour, each strain in the triple or quadruple helix can in its own way contribute to the different phases of innovation, with phases defined as agenda setting, research, development, production and dissemination.

A weak interpretation of the linear model would therefore not limit itself to a clear distinction of types of research and division of labour. Rather, it would argue that different stakeholders can contribute to different steps in the innovation value chain. Moreover, basic and applied research should not be seen as distinct categories, since research can contribute to gaining understanding while simultaneously taking the use of the resulting outcomes in consideration.

2.1.2 Science outcomes: necessary and sufficient for innovation?

A second difference between the strong and weak interpretation of the linear model relates to what happens with the outcomes of science. A strong interpretation of the linear model would state that science is both necessary and sufficient for innovation. As a consequence, it implies science outcomes automatically trickle down to downstream development (sufficiency) and that innovation cannot occur without input from science (necessity).

Let’s first examine the idea of necessity. The recognition that science (i.e. a quest for understanding) is not-necessary for innovation is not new. Many innovations originated during development processes or in the market place and science was only used in later stages to understand the workings of such innovations. The development of the steam engine and the airplane are prominent examples of that. Nevertheless, in our knowledge-based economy, science is a non-trivial contributor to innovations. In some sectors, like the life sciences, the dependence on science for innovation is larger than in others, and such sectors are often denoted as ‘science-based’. In such sectors, patents that build directly on scientific advances are more impactful than others, and – vice versa – papers that were cited by patents were also found to be high-impact papers in the scientific domain (88).

Recent studies have further emphasized the importance of science in laying the groundwork for many innovations, at times with significant temporal or cognitive lags (89). Such contributions include a thorough understanding of technical problems, publications of negative results and the development of novel research approaches. The research outcomes accumulate in a reservoir of knowledge (90) that can be exchanged and used by different public and private stakeholders to develop innovations (91).

Thus, whereas a strong interpretation of the linear model would argue that innovation can only occur through accumulation of results from the scientific enterprise, in a weak interpretation of
the linear model science, development efforts and market developments together contribute to innovation. In science-based sectors the relevance of science may be higher than in others, but in both sectors, innovation can also occur without building upon improved understanding that results from scientific research.

Examining the idea of sufficiency, it has been made abundantly clear that investments in science are non-sufficient to generate economic competitiveness and growth (92). Even the first steps of dissemination are not obvious and it has been widely recognized that scientific publication alone is insufficient to ensure the use of research results (93). Indeed, a range of factors influence the uptake of research findings in practice (94) and numerous bottlenecks exist in the translation from science to development and innovation. The existence of these bottlenecks, however, do not indicate that science does not contribute to innovation, rather it indicates that the process is not self-evident. It is therefore important to identify where and how these bottlenecks occur in order to support spillovers and knowledge exchange.

In conclusion, a weak interpretation of the linear model of innovation does not state that science is both necessary and sufficient for innovation. Rather, it argues that science is an important contributor to innovation, especially in some sectors. In these sectors, continued research efforts in the scientific domain contribute to establishing a reservoir of knowledge which can be used by other stakeholders for innovative development. Additionally, a weak interpretation of the linear model recognizes the existence of many bottlenecks in the translation of scientific research findings to innovative outcomes and argues that these bottlenecks should be thoroughly understood and addressed.

### 2.1.3 Science to innovation: a one-way street with no turning back?

Thirdly, and perhaps most importantly, in a strong interpretation of the linear model, the sequence of steps is fixed, without allowing for feedback or iterations. Such a strong interpretation is at odds with the empirical reality, since innovation does not occur in a fixed manner and iterations and serendipity are of high importance for innovation processes (95). Sometimes, technological innovations precede scientific understanding and at other times scientific advances are made possible by technological innovations (69). That being said, radical innovations often build upon advanced insights that are established in the science domain and combined with existing knowledge to be translated into innovations in later phases (96). Considering significant time lags between the accumulation of scientific insights and the development of new innovations, challenges encountered in these latter phases do not occur in parallel to the scientific research that preceded them, but rather inform new and refined research projects (83).

Modelling innovation as a system consisting of more or less linear subsystems therefore does not aim to be prescriptive on how innovation should be conducted, but rather is meant to describe the territory and serve as a map (83). In the empirical world, stakeholders are likely to encounter problems which necessitate deviations. To describe all such possible deviations in a conceptual model would lead to an overly complex model. Such complex models do not necessarily contribute to improved understanding: a higher degree of connections and a higher density are related to a lower comprehensibility of conceptual models (97). Rather, by conceptually describing...
and ordering the subsystems of innovation, stakeholders can see the big steps in innovation processes, and deviations to innovation processes can be put into a broader perspective. At the same time, recognizing the interactive nature of elements within the innovation cycle, does not necessarily imply that in the empirical world all steps are executed in an interactive manner. Stakeholders can thus use a weak interpretation of the linear model to reflect on and understand which deviations are necessary for their specific innovation process, as well as evaluate the consequences of such deviations.

2.2 Systems of innovations

While a weak interpretation of the linear model recognizes that there is no clear division of labour, it does not provide further insight into which stakeholders contribute to innovation. Understanding the context in which such stakeholders operate, however, is of importance to understand why they would engage in knowledge valorisation processes and what barriers might hamper their engagement. To complement the weak interpretation of the linear model, the systems of innovation theory is therefore used to understand how the contextual background of different stakeholders might drive or hinder their contribution to innovation processes.

The systems of innovation theory describes that interactions between different actors within public and private sectors are necessary for the production, diffusion and use of new and useful knowledge (98). As outlined above, a range of complementary resources and capabilities are essential before scientific advances are translated into “innovative products, services, processes and/or business activities”, i.e. before knowledge valorisation can occur. These resources and capabilities include research findings, intellectual property rights, knowledge of markets, manufacturing capabilities, quality assurance, regulatory compliance and knowledge of legal standards (99). Since these resources and capabilities do not reside in one organization, partnerships between different organizations are needed (100). Such organizations include public research institutes, small and incumbent companies, patient groups and regulatory bodies (101).

The systems of innovation theory is primarily used to inform policy decisions on how to improve innovation performance, by outlining which actors contribute to a certain innovation system (e.g. national, regional, sectoral or technological innovation systems) and what functions they employ (102). It therefore takes a macro perspective to innovation, rather than focusing on the micro level of individual innovations and entrepreneurs (102). Although this is in contrast to the aim of the current thesis – which is to study knowledge valorisation processes at micro level – it is useful in understanding how interactions between actors shape, and recursively are shaped, by their institutional context. According to the systems of innovation theory, organizations belong to one or more institutions, where an institution represents “common standards of communication and information, a common set of interpretations, and a shared view of values and meaning” (103). The organizations are thus steered by, and at the same time shaping, what is considered acceptable in terms of activities and outcomes (103). In this sense, it is important to note that
one organization can belong to multiple institutions. For instance, a pharmaceutical company can have a research department which belongs to the “science” institution and a development department which identifies more with the “business and development” institution.

Knowledge valorisation thus results from activities conducted by a network of organizations, with each organization delivering complementary capabilities and resources necessary for converting scientific research advances into added societal value. The differences in the institutions to which these organizations typically belong, however, also form a main barrier for collaboration. Being organized in specialized silos, practitioners do not necessarily have the skills to collaborate across the boundaries of their own institution (99). This is even true for hybrid organizations that combine rationales from different institutions (104). To fully benefit from innovative progress, interaction between different systems should therefore be improved, but this should not lead to systems assimilating each other’s approaches. Rather, it is the diversity between modes of interpretation and objectives that leads to innovative performance (103).

In conclusion, although often posed as contrasting theories, a weak interpretation of the linear model of innovation can be seen as complementary to the systems of innovation perspective, where the first describes the different phases that constitute innovation processes and the second highlights that a wide variety of actors is involved who each operate within the boundaries of institutions that are dependent on their own norms and values.

### 2.3 Valorisation cycle

A model that uses a weak interpretation of the linear model to describe knowledge valorisation is the valorisation and technology transfer cycle (VTTC), see Figure 2.1. This model describes ten different phases of knowledge valorisation that can be distinguished in the life sciences (105). Additionally, it hints to a systems of innovation perspective by highlighting that these phases can be subdivided in three groups that are characterized by distinct discourses.

According to this model, three different phases belong to and create the scientific discourse: idea, the empirical cycle and realization. Ideas refer to research ideas that may be informed by articulated demands. Research is conceptualized as an empirical cycle in which ideas are evaluated upon feasibility and viability. Whereas feasibility refers to the practical aspects of performing the research and interpreting the results, viability evaluates whether the generated knowledge has meaning outside the specific empirical setting and thereby has value to external actors. The third step in the scientific discourse describes that results can be captured in different tangible and intangible ‘realizations’, such as patents, publications, reports and products.
FIGURE 2.1 | Valorisation and Technology Transfer Cycle as presented in Pronker, 2013 (105).
Within an economic discourse, the model describes that realizations are further developed in a proof-of-concept phase where results from the empirical cycle are validated in either a pilot or a prototype. A pilot refers to the development and testing of a ‘service’ in a real-life setting, such as the testing of a new clinical guideline. A prototype refers to the development and testing of a ‘product’ in a real-life setting, such as the testing of a New Medical Entity (NME) in a preclinical model. In the subsequent evaluation phase, a series of steps that evaluate different aspects of new products or services are conceptualized. As examples, the model mentions (clinical) safety, (clinical) efficacy, quality, legislature and ecological impact. The third phase that is modelled in the economic discourse is upscaling, which is described as ensuring the product or service can be delivered in a sufficient volume.

Finally, in the valorisation and technology transfer cycle, four phases take place in what is phrased a market and policy discourse. Introggression in the market conceptualizes the approaches to introduce new products and services and facilitate adoption. Such introgression is described to be positively impacted by consideration of the affordability, availability and accessibility of new products and services, as well as the organizational structures and relationships that steer and coordinate these aspects (i.e. architecture). After this introgression, the phase of client and consumer feedback describes systematic approaches to review satisfaction with and adoption of new products and services. The last two phases describe the identification of new unmet medical needs on the basis of consumer feedback and market analysis, and the translation of those needs in articulated demands which inform idea generation in the science discourse. The model notes that unmet need identification is shaped by dominant scientific paradigms, which may open up new possibilities. The model also notes that diverse external factors, including mass and social media, public opinion, commercial considerations and policy realities, influence the prioritization of demands in terms of agenda setting.

The VTTC was further developed into the valorisation cycle to improve the link with the systems of innovation perspective. The valorisation cycle describes ten different phases of knowledge valorisation processes as a map for stakeholders. There is, however, no division of labour and different stakeholders can engage in processes within different domains. Moreover, the science domain doesn’t distinguish basic or applied research, but emphasizes the importance of research with the aim to improve understanding, regardless of whether considerations of use are taken into account. Finally, although the numbering of the phases might imply a specific sequence, they are used as a reference tool and should not be interpreted as a fixed order in which steps are to be conducted. Building upon a systems of innovation perspective, it additionally describes that certain phases are generally conducted in a specific institution with its own norms and values. This model uses the word domain to encompass discourses, methods, approaches and behaviours that are considered acceptable.
The economy discourse of the valorisation and technology transfer cycle is rephrased as the business development domain, which refers to rationales of developing new products, services and processes with the purpose of introducing them on the market. The market and policy discourse from the valorisation and technology transfer cycle is split in two separate domains. The market domain refers to context in which new products, services and processes are implemented to be used by specific stakeholders. Although it may include a monetary exchange in return for such implementation, this is not necessary, as is the case for the implementation of new clinical guidelines in a ‘market’ of health care professionals. The policy aspect of this discourse is rephrased as the society domain in which multiple societal stakeholders contribute to unmet need identification and demand articulation. This includes policy makers, industry, lay people and academics themselves. The policy discourse is left out of this model, since it interacts with all four domains by shaping the boundaries in which these domains operate, for example the aspects that NMEs are evaluated upon or policies that influence science processes. The science domain is characterized by a quest for understanding, regardless of whether activities within this domain also take considerations of use for the resulting outcomes into account.
2.4 In conclusion

In conclusion, rather than building upon a condemned strong interpretation of the linear model, in this thesis a weak interpretation of the linear model of innovation is used as a theoretical lens to understand the different phases of innovation and how they relate to each other. In addition, it describes how certain phases are generally conducted within specific domains that are guided by their own norms, values and behaviours.

Through this theoretical lens, science is understood to encompass research activities that contribute to improved understanding, while business development activities can translate the resulting knowledge into new products, services and processes. Whereas science is not necessary for innovation, in the science-based life sciences sector, it does play an important role in innovative processes. This thesis therefore primarily focuses on innovation that is the result of scientific advances, a process which is also called knowledge valorisation.

Being appreciative of the non-sufficiency of science for innovation, it aims to study how valorisation processes can be improved. While recognizing the iterative nature of innovation, consisting of feedback and feedforward loops, these deviations are not discussed in detail. Rather, this research aims to refine the map of innovation processes in general to facilitate understanding on how to improve knowledge valorisation processes. The research design that is used to accomplish this research objective is described in the following chapter.