5. Projects of incremental innovation

In *chapter 3*, it was concluded that in technology fields, the social process of establishing common working standards could explain the outcome of innovation projects. To analyze this process in empirical cases, it was proposed that in projects of incremental innovation, collaboration is based on *practices of monitoring technical standards and sanctioning nonconformity (P1).* It was argued that in such projects, where technologies are typically developed based on technical standards, the innovation praxis tends to reproduce technical knowledge, conform to design rules, and involve familiar partners instead of innovating from scratch.

This proposition is evaluated on the basis of two examples of component development in the wind energy industry. This chapter compares the two cases. *First*, the field of component development is characterized (5.1); *second*, it is shown which practices of knowledge integration could be observed (5.2); *third*, the reader learns how collaboration was organized (5.3); fourth, it is discussed which discussed which institutional barriers occurred and what they caused. Finally, the results are summarized and preliminary conclusions are drawn.

5.1 Positions of partners in the field

This section illustrates how the two fields of incremental innovation studied were structured. Both fields of component development were organized around a large WTM collaborating with a medium-sized German component supplier. In both cases, high power asymmetries between the development partners could be observed. In both cases, the collaboration structure resembled a hierarchical innovation network with a large WTM dominating technology development.

However, the two cases differed in two respects. First, the relative position of the component suppliers vis-à-vis their customers: On the one hand, we had an established component and market leader; on the other hand, the component developer was a newcomer and niche product supplier. Second, the cases differed in the cause of the collaboration: an order development in case A and a joint R&D project that turned into a supply relationship in case B. This had direct consequences for the regulation of the collaboration.

5.1.1 Case A: An incumbent supplier and market leader

The first case of a component supply relationship developed a relatively large component that is installed in the nacelle of wind turbines. The case is a story about a supplier company that developed a new component for an existing type of wind turbine of a large European WTM. In fact, the component is part of the drive train of the wind turbine, which consists of three large components: rotor, gearbox and generator. The component thus plays a prominent role in the architecture of wind turbines.

The supplier, whose daily development and production practices were observed, is a medium-sized company based in Germany. The company is one of the pioneers in the wind energy sector and has been specializing in such technologies for more than forty years, as expressed by the strategy and marketing manager (A-Org01): "*We are one of the pioneers in the wind industry. We have been in the wind industry since the beginning. We supplied the first [major components] for wind turbines in 1977. At that time, wind turbines were still assembled in garage yards. [The company] only does wind, can only do wind, and thinks only in wind. That starts with the management and ends with the guard. We can do nothing else.*" As the interviewee points out, the company has evolved from a pioneer to a globally recognized specialist and market leader. Today, the company is an established supplier of electromechanical components for almost all leading WTMs.

5.1.2 Case B: A newcomer and niche product supplier

The second case also involves a medium-sized German supplier of wind turbine components. Compared to the first case, however, the component is part of the rotor and much smaller than in case A. In fact, the component is part of a system that stops the rotors from turning, for example, during maintenance. Therefore, compared to the first case, the second component is smaller, relies on less electromechanical engineering knowledge and plays a less prominent role in the wind turbine architecture.

The two cases also differed in terms of the social position of the component suppliers in the wind energy industry. In the first case, the company had been supplying components for decades and had become a global specialist and incumbent. In the second case, the component supplier was a newcomer to the wind energy industry. Before entering the market, the company had supplied components to the rail vehicle industry. It was only at the beginning of the 21st century that the company decided to enter the wind energy market, as the product department manager (B-Org01) recalls: "*They decided on wind power because, unlike today, it was still booming eleven years ago.*" To position itself as a newcomer, the company decided to expand its business activities into the wind energy market and developed an idea for a radically new component together with an applied research institute. The company was able to establish a joint R&D partnership with a leading WTM, which evolved into a component supply relationship.

Figure 2: Field of component development

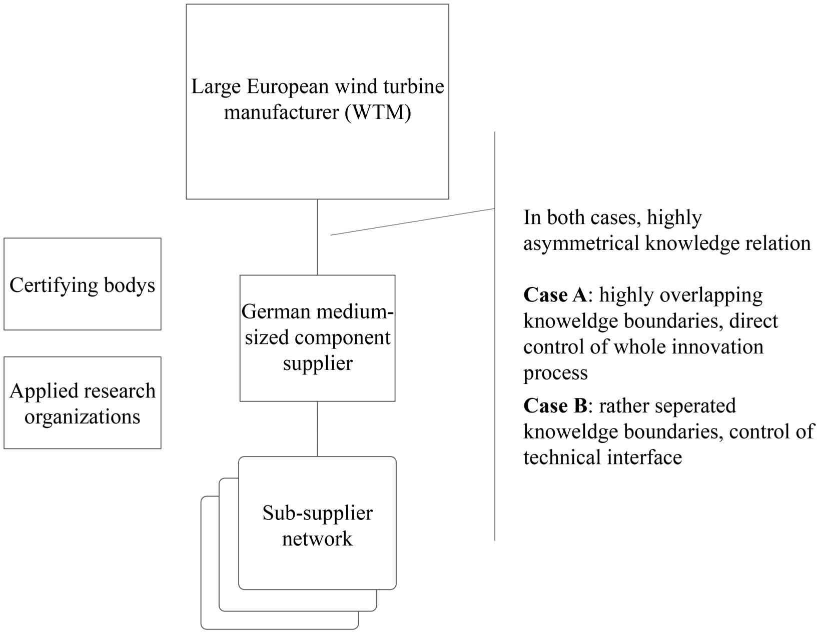

Figure 2 illustrates the field of technology development in cases A and B. The collaboration structure takes the form of a hierarchical innovation network with a large European WTM at the top. Consequently, strong power asymmetries characterize the collaboration in both cases. However, the observed supply relationships differed significantly in terms of the underlying practices of knowledge integration. In case A, these processes were highly institutionalized, while in case B, the collaborative relationship had just changed from an R&D partnership to a supply relationship.

5.2 Analysed practices of knowledge integration

After describing the two studied technology fields, this section shows which practices of knowledge integration could be observed in the two cases. In section 2.2, knowledge integration was defined as the combination of specialized and complementary knowledge to accomplish specific tasks. In both cases, a large WTM and a supplier company were the main actors that combined their knowledge to design a new product that could be integrated into wind turbines.

5.2.1 Case A: Highly regulated product development

In both cases of incremental innovation studied, knowledge integration took place in the process of designing the new component. In the first case, where the component was part of the drive train of wind turbines, a component supplier combined its internal expertise with technical specifications provided by the customer (WTM). The project manager coordinating the development activities reported that the customer provided a large amount of technical requirements that the supplier had to translate into a working prototype. In this case, as the project manager suggests, product development was more a task of reducing uncertainty than of inventing something new:

> *[W]e are now getting huge amounts of load information. In some cases, it's several gigabytes of data. We have to process it computationally. (...) The less accurate they are or the more uncertainty they contain, the more uncertainty we get [in the component]. (A-Org01, Project manager)*

Interestingly, in this case the component development was largely pre-defined by technical standards and implemented on the basis of standardized engineering procedures established in the development company. Apart from detailed technical requirements, the component design was largely based on industry standards. In addition, quality standards such as loads and performance criteria were defined in detail by the customer. The project manager (A-Org01) mentioned that his colleagues used standardized engineering procedures such as the Finite Element Method (FEM) to implement the customer's technical expectations. technical expectations:

> *We get [from the customer] so-called wind simulations for different turbine configurations and locations. These are also classified via the [industry standard]. We then run simulation calculations over the entire lifetime of about 20 years. We need the complete data for the structural-mechanical verification, e.g. FEM calculations.*

As these results show, the knowledge integration process has two characteristics. First, knowledge was easily combined across the organizational boundaries of the companies involved – WTM on the one hand and the component supplier on the other. Second, the knowledge integration process was highly regulated, based on routinized engineering procedures used to translate the customer's detailed technical expectations into a new product design. Another interviewee responsible for internal R&D added that in addition to these development routines, testing procedures were also highly regulated:

> *At the moment, it is standard practice for us to test every component we build up to its rated load. (...) This enables us to ensure that every component that leaves the yard works reliably within the requirements. (A-Org01, R&D component technologies)*

As you can see from these quotes, both the design and testing processes are highly standardized. These well-established working standards facilitate the integration of complex technical knowledge into a new component.

In fact, as the project manager (A-Org01) suggested, the component was basically defined hierarchically by the customer based on industry standards, the customer's technical standards, and the component supplier's own technical standards: "*In addition to the industry standards, there are also customer requirements that define even stricter requirements under certain circumstances. In addition, we also work with our own interpretation guidelines.*"

In conclusion, the knowledge integration process in this case was institutionalized in the form of the customer's technical standards and established working standards for how to design, build, and test new components. In essence, the development company's main task was to combine technical standards based on well-established working standards. Consequently, the project manager (A-Org01) metaphorically characterized the knowledge integration process as arranging a "large bouquet of configurations":

> *That is a large bouquet of configurations that have to be taken into account at the end of the day during development.*

5.2.2 Case B: A new component supply relation

While knowledge integration in the first case was characterized as the combination of technical standards based on well-established working standards, the second case presented a different picture. The knowledge integration process was much less institutionalized. In fact, it started as a joint R&D project. Together with an applied research institute, experts from the component supplier specialized in technologies used in the rail vehicle industry developed the "idea" of a radically new component for wind turbines in order to differentiate the company from component suppliers and competitors already well established in the wind energy industry. The product manager (B-Org01) remembers:

> *At that time, two or three people from [the rail vehicle components division] had the idea and developed it together with the Fraunhofer Institute.*

While in the first case the component supplier was an established and leading specialist in the wind energy industry, in the second case the supplier company started as a newcomer with limited experience in product development for WTM. In particular, as the design engineer (B-Org01) recalls, the company had to learn how to deal with shorter innovation cycles and increased price competition: "*[W]e were not used to very cost-oriented development here in the company. (...) This means that for many development steps in railway technology we could say that we knew roughly where we would end up (...). In retrospect, we then looked at what the fun really cost, also taking into account economies of scale.*" Compared to the first case, the supplier's engineering processes were not yet institutionalized because it was a newcomer to the wind energy industry. The company had to establish new working standards in order to be able to work with large WTMs.

It was the component supplier that, after developing a first product idea, actively initiated an R&D project together with a large European WTM to develop a working prototype and gain a first foothold in the wind energy industry, as the product department manager (B-Org01) added:

> *Once the "electric vice" was developed, a partner was sought (...) and the concept was presented to them. They were enthusiastic because this company sells its wind turbines only with a maintenance contract and maintains the turbines itself.*

After establishing this new component supply relationship with a large WTM, the component supplier took a niche position in the wind energy industry. The component was radically new because it incorporated a technological principle that deviated from the established technological paradigm used by competitors. That is, instead of using hydraulics to generate holding forces, which was the primary component technology in almost all existing supplier relationships, the newcomer introduced an innovative solution based on electronics. Thus, the company introduced an innovative component that deviated from established technologies. In doing so, the company positioned itself in a market niche.

Consequently, the component supplier not only acted as a newcomer, but more importantly for the understanding of this case, it also remained a niche product supplier for a technologically rather "simple" component, as the product department manager (B-Org01) explains below. As a result, there were few knowledge interdependencies on either side of the partnership and thus strong power imbalances in favor of the large WTM.

[The customer] uses them as a relatively simple component because they themselves have a very complicated control system in the tower.

In conclusion, as Figure 5.1 shows, the practices of knowledge integration observed in the two technology fields crossed the boundaries of three actors:

(1) a large European WTM, (2) a component supplier, and (3) a network of subcomponent suppliers. In both domains, the collaborative structure took the form of a hierarchical innovation network, with the WTM at the top dominating the development activities of the component supplier.

However, the cases differ significantly in terms of the position of the component supplier in the field. These positions had a direct impact on the knowledge integration process. Case A tells the story of a supplier relationship between a component developer and an incumbent; in this case, the knowledge integration process combined technical standards based on highly regulated engineering procedures.

Case B showed the opposite. Here, the knowledge integration process, as well as the entire supplier relationship, was hardly institutionalized. Component development was initiated as a joint R&D project. In the early years, the component supplier struggled to adapt its engineering procedures to the working standards of the wind energy industry, such as short innovation cycles. Knowledge integration mainly took the form of joint R&D and creative engineering. In order to gain more customers and to expand its innovation network, the component supplier tried to "impose" product improvements on its main customer in order to broaden its product range and to leave the occupied market niche, as the product department manager (B-Org01) reflects:

You could say that we forced it on them a bit, but we played with open cards (...). We also said that we expected new customers with the [advanced components] and that we could sell the [component] in higher quantities so that the price would eventually become lower due to volume effects. This was also a reason why the customer agreed.

As these findings show, in contrast to the first case, the second component supplier took a position as a newcomer and niche product developer in the field. Due to these different positions in the field (incumbent vs. newcomer), the application of standards played a different role in the two technology projects, as will be discussed below.

5.3 Realizing technology development

The previous section introduced two technology fields that were very different in terms of the supplier firm's position (an incumbent vs. a newcomer). In this section, the impact of these structural configurations on the organization of the two technology projects is shown. It will be the case that in both cases the coercive imposition of technology development was the dominant social process of technology development. WTMs imposed their standards on component suppliers due to their superior power positions.

5.3.1 Case A: Imposing technical standards

Starting with Case A, it will be shown how the collaboration has been coordinated in the case of a large component for the drive train of a wind turbine. It will be shown that the WTM was able to impose its technical standards on the engineering praxis of the component supplier, mainly due to its superior position of power in the field.

5.3.2 Contractually defined technology projects

In this case, contractual agreements were a central means of regulating the cooperation between the WTM and its supplier. As the key account manager (A-Org01) explains, customers often have a fairly elaborate idea of the design of the future technology prior to the start of the project, which includes key component suppliers. As a result, development contracts specify how the project will be structured.

> *Even before customers go public and announce that they want to install a new turbine, they often have a contract in place with key suppliers. The whole concept is already in place. (A-Org01, Key account manager)*

The investigated project was based on two contracts. First, as shown above, the supply relationship was firmly institutionalized, or as a strategy and marketing manager (A-Org01) stated: "*This is not the first project we've done with [this customer]. This is the umpteenth project, so we already know what they want.*" This particular development partnership included a framework contract that defined the basic agreements between the two partners, as explained by the key account manager (A-Org01): "*[I]n general, there is a framework agreement under which everything can be roughly handled, from deliveries to requests, etc.*". The production manager stated that some customers even limit the supplier's choice of subcomponents due to customer-specific quality requirements: "*There is one customer in particular who requires us to source 100 % of the components from our internal parts production*" (A-Org01, Manufacturing manager).

Second, in addition to framework contracts, development contracts further specify the "*rights and rules*" of technology development, such as ownership of newly developed components. In this way, customers limit the component supplier's ability to use new components in other projects, such as projects with customers producing smaller wind turbines, as the same expert points out:

> *Development agreements can be made specifically for such projects, including rights and rules. In the past, this was not done at all (...). Now, customers are increasingly demanding to secure the rights to these products. We would not push for that because the old approach suits us much better. It allows us to be more flexible and use the component for smaller customers as well. (A-Org01, Key account manager)*

These findings show that in this first case, framework agreements and development contracts limited the component supplier's choice of subcomponents or knowledge transfer. The key account manager (A-Org01) added that such contracts are used to define the project budget, technical requirements, project timelines, or technical innovations agreed upon by both partners: "*At the beginning of a project, you draw up a budget. How much is the component going to cost? What are the customer's requirements? During the course of the project, we check whether the project is still within budget or whether there are new findings that mean something cannot be technically implemented as planned and a more expensive variant has to be used*" (A-Org01, Key account manager).

Thus, contractual agreements pre-define projects and limit the possibilities for innovation. In fact, as the project manager explained, each technology development project for large customers such as General Electric, Vestas or Siemens is exclusive due to contractual obligations and "non-disclosure agreements." This expert speaks of "*separate development paths*" to illustrate that any knowledge integration between customer-specific technology projects is forbidden: "*These are necessarily separate development paths, as each manufacturer has its own requirements and philosophies. Of course, we are constantly developing our knowledge base and design guidelines (...). But it is definitely not the case that there is any internal merging in [component development] between different customers. There are contractual agreements and confidentiality agreements, some of which do not allow us to transfer the solution from one application to another*" (A-Org01, Project manager).

In summary, these results show that WTM uses contractual agreements (such as such as framework contracts, development contracts, or non-disclosure agreements) to impose technical standards (e.g., technical requirements, price expectations, and property rights) on component suppliers. They define the project setup before it starts, including project schedules, subcomponent suppliers, or technical designs. It was interesting to observe that such contracts impose legal boundaries that prohibit knowledge integration across custom technology projects, thereby limiting the component supplier's potential for innovation.

5.3.2.1 Central control of component developers

In addition to contracts, the WTM in Case A used technical standards to predefine component development. Basically, three types of technical standards could be observed, which together describe a pyramid. First, at the top of the pyramid are industry standards, such as those issued by the International Electrotechnical Commission (IEC). The project manager (A-Org01) explained that IEC standards for wind turbines contain chapters that also define the design of subcomponents:

> *For example, reliability must be demonstrated using statistical methods to ensure that only a certain failure rate can be expected for [a component] over its entire service life. Ultimately, this is broken down to each subcomponent, for which we have to provide the appropriate evidence. There are standardized standards for this.*

This quote illustrates the use of technical standards to control the development of external components. Such technical standards cannot be negotiated because they are defined in development guidelines. In addition, the component supplier relies on working standards and engineering procedures, such as statistical methods, to demonstrate compliance with technical standards – work that is controlled by certifying organizations such as Germanischer Lloyd, TÜV, or DEWI.

The second type of imposed standards refers to the technical requirements of the customer, which largely determine the design of the new component, as the manufacturing manager (A-Org01) explains: "*The projects are usually customer specific. Based on the individual turbine types defined by the customer: Does the turbine have large blades, what wind conditions will it be installed in, etc.? In the end, each project has its own specifications.*" Thus, in addition to industry standards, the customer's expectations control the development of components.

It is also interesting to note that, in addition to technical specifications, the customer imposes working standards on the project partners, including quality, reliability and safety standards. For example, the project manager (A-Org01) distinguishes two customer strategies for exercising normative control. Customers can either define high quality criteria or directly control the daily engineering praxis by "*questioning in detail*" the supplier's procedures and methods, such as statistical calculations or design simulations:

> *There are customers who think they can buy safety by entering higher safety factors into the calculation. Higher load factors are then specified, which we have to take into account in the calculation. The other strategy is to go into a lot of detail and maybe ask us to do more calculations and simulations. (A-Org01, Project manager)*

These findings point to a highly centrally controlled innovation praxis. In fact, the component supplier has organized its internal engineering processes according to the requirements of its four major customers, as the strategy and marketing manager (A-Org01) explains: "*Project management and the development team are customer specific, i.e. they only work on projects for a specific customer*." This shows that each project partner develops technologies exclusively for one customer. Knowledge integration between these development lines is largely prohibited, which not only increases the supplier's dependency on the customer and limits the supplier's innovation potential, but also limits the customer's innovation potential.

Time frames was also highly regulated in this case of technology development. The interviewees explained that a project typically lasts 18 months. Within this timeframe, the innovation process is divided into four stages: (1) sourcing (two to three months); (2) component development (about ten months); (3) prototype testing (about three months); (4) pilot production (about one to two months). The project manager stated that after each major project step – acquisition, concept, design, prototype – the customer approves the given result. For example, "*the concept phase is completed with a milestone, also with the customer. This phase ends with a joint meeting*." As you can see, the two organizations involved in the project partnership are linked by common working standards as well as common time concepts (milestones).

When, as in this case, the participating project organizations are structurally coupled on the basis of a common time concept, the project manager of the component supplier takes on an interesting role. He or she not only coordinates the project work and moderates the communication between the specialist departments; the project manager also maintains an exclusive communication channel with the customer (Single-Point-Of-Contact"; SPOC). Interestingly, the project manager in Case A (A-Org01) reported that he interprets his role as a "*customer's lawyer*" who ensures that the project work is in line with the customer's "*requirements*" and "*needs*":

> *Basically, I see myself here in the company as the customer's advocate, making sure that as many of the customer's needs and wants as possible are met. But we must not lose sight of our own goals in terms of deadlines, quality and costs, because at the end of the day we have to make money with the product. It is always a bit of a balancing act.*

In conclusion, these findings show how external component development is managed on the basis of common industry norms and customer technical standards. In addition, the project organizations involved share certain working standards, time frames (milestones), and exclusive communication channels between project managers (SPOC). Such a highly regulated innovation praxis makes it easier for the WTM to control external component development.

It should be noted that these findings only partially support Proposition 1. In contrast to P1, which states that in incremental innovation projects, project work is mainly organized through practices of monitoring technical standards and sanctioning nonconformity, the technology development project in Case A was organized on the basis of central control and the coercive imposition of technical standards by the customer. For the component supplier, the scope for innovation or the creation of alternative work standards was limited. However, in line with P1, practices of monitoring the customer's expectations were found in the role of the component supplier's project manager, who ensured that the customer's technical standards were met.

5.3.2.2 Working standards that control sub-component suppliers

It was shown above that, in contrast to P1, project work tends to be characterized by the coercive imposition of technical standards by the customer. This section shows that such central control is also based on work standards imposed on the entire innovation network, including subcomponent suppliers.

Sub-component suppliers tend to be preferred partners that the component supplier has "*qualifie*d" in the past to meet the quality standards defined by the component supplier and/or its customer, as the project sales expert (A-Org01) of the supplier organization studied points out: "*[w]e are gradually qualifying new suppliers, of course, to introduce a certain amount of competition*". Similar to the partnerships observed between the component supplier and its customer, the subcomponent supply network is controlled by centrally defined standards, such as quality standards. The component supplier not only imposes product prices on the subcomponent suppliers, but also imposes "*quality requirements*" that force the subcomponent suppliers to comply with process standards, as explained by the project sales expert (A-Org01):

> *It takes a certain amount of time for a supplier to really meet our high quality requirements. It takes time for them to reach a certain level of process capability.*

The strategy and marketing manager (A-Org01) adds that such development relationships are usually highly regulated, and knowledge integration is not a problem if the component supplier executes processes properly and defines technical requirements accurately: "*You are in a customer-supplier relationship here (...). They know the systems. You do a preliminary design and they work on it. That works quite well. It's more the emotional component that gets in the way. Otherwise, with today's methods of communication and data transfer, it's not a problem. You just have to define exactly what you want.*" The same manager concludes that a common understanding of quality standards and formal engineering procedures facilitates knowledge integration because it makes information sharing independent of the skills or idiosyncrasies of individuals:

> *Large companies are much simpler in terms of process capability. They also understand why we are implementing an automotive quality safety standard and why we want this part to be tested in the same way. A manufacturer from the Black Forest with twelve employees, but who is brilliant, says that we can't get this from him because he doesn't have the people for it (...).*

Finally, it was noted that the component supplier used working standards related to shared quality norms to control the entire innovation network, including subcomponent suppliers. This highly regulated innovation praxis facilitated knowledge integration by decoupling communication within the project from individual skills or idiosyncrasies.

5.3.2.3 Personal inspection and transparent manufacturing

The centrally controlled innovation praxis described above also extended to the manufacturing process. In addition to common engineering procedures, common time concepts, or communication channels between project managers, there were also common production standards. The manufacturing manager (A-Org01) explained how some customers personally inspect the manufacturing process: "*It is very characteristic of the wind gearbox industry that the cooperation with customers is extremely close. I can certainly say that we have, for example, 100 % inspectors employed by certain customers. They walk through the assembly lines here every day, looking for defects and wanting to rectify them quickly*." The project sales expert (A-Org01) describes a similar practice of personal control. Together with the company's customers, the expert personally checks whether the subcomponent developers meet the mutually agreed quality standards:

> *Some of our customers demand that we visit the suppliers, so we go there together with our customers. (...) This is included in the quality plans that we have with our suppliers. (A-Org01, Project sales expert)*

The same project sales expert (A-Org01) provides further insight into this form of personal inspection. The expert reports that customers use quality standards to control the entire supply network. In particular, for so-called "*structural components*", some customers require that production processes be "*frozen*" at certain defined points in time. This means that each production step must be recorded: "*It is recorded which processing machines he uses to produce this*." The supplier is not allowed to change the production process without the customer's approval:

> *The customer requires us to freeze these processes and only change them with our approval and that of the customer in order to guarantee the quality of the parts, i.e. that they are always produced using the same manufacturing process.*

These findings confirm the prevalence of a highly regulated innovation praxis. In the manufacturing process, standards of transparency regarding individual responsibilities and work processes facilitate direct control. For example, central monitoring takes place on the basis of a so-called "*electronic assembly and test stand protocol*." This protocol, explains the production manager (A-Org01), "*is a document that we create for the customer. (...) With this standard, the customer can of course see exactly how we [have organized our assembly] and can establish this accordingly in his processes*." This transparency makes it easier to control production, as the production manager points out:

> *Each assembly station has a computer operated by the workers themselves. They sign in with their own identification number so that the customer can see exactly which worker tightened which screw. Of course, this means that the worker is very concerned that the documentation he provides and the work he does are 100 % correct. (...) Ultimately, this is complete transparency.*

In this case, both WTM and the component supplier rely on well-defined working standards (such as process and quality standards) to regulate the innovation praxis and facilitate centralized control of component development. Manufacturing processes are also standardized. Production is tightly controlled through transparency standards and personal inspections. In this case, the prevailing work standards were not negotiated, but well established and used to coercively control the entire innovation network.

5.3.2.4 Homogeneous knowledge on both sides of the partnership

Achieving the centralized control of component development described above is easier when the technical knowledge on all sides of the partnership is highly homogeneous. Several interviewees stated that the partners involved have similar expertise, which enables the customer to define the component development. For example, the strategy and marketing manager (A-Org01) reported that large customers have in-depth knowledge of components and are therefore able to impose and monitor quality requirements:

> *The turbine manufacturers have built up a lot of [component] expertise. There are really [component] design engineers working there, some of whom came from [component] manufacturers and some of whom also work in quality assurance (...). Depending on the customer structure, they are more or less involved.*

Despite the high degree of specialization, no knowledge asymmetry between component suppliers and their customers was observed. Rather, as the quote above illustrates, strongly overlapping knowledge boundaries enabled the customer to maintain a power position vis-à-vis the component supplier and to "*interfere*" in the daily project work.

The key account manager (A-Org01) supported this conclusion. This expert stated that particularly large WTMs with high business volumes and market shares have in-depth component knowledge and professional competencies that enable them to define components in detail and impose their expectations on the component supplier: "*Our large customers have people on the other side of the development team who know the components in detail. They have real expertise and a very specific idea of what their components should look like.*" The project manager (A-Org01) adds that because large customers have inside knowledge of various components, they are able to impose technical designs on the component supplier:

> *A large system manufacturer has more experience with different component concepts. (...) Based on this experience, they can usually impose requirements on us that are different from our own philosophy.*

In summary, a relatively homogeneous knowledge base shared among innovation partners facilitates centralized control of component development. The experts interviewed speak of "*experiences*", "*imaginations*" or "*philosophies*" to describe how a large customer can impose its cognitive framework (e.g. technical designs, quality standards) on the component supplier, as the strategy and marketing manager (A-Org01) put it:

> *There are customers who really tell us that [the component] has to look exactly like this and that. (A-Org01, Strategy & marketing manager)*

5.3.2.5 Preliminary conclusions

Based on these findings, a number of preliminary conclusions can be drawn with respect to P1. In Chapter 3, it was argued that in *contexts of incremental innovation, technology projects are mainly organized through practices of monitoring technical standards and sanctioning nonconformity*. These assumptions are only partially supported by the empirical findings in Case A.

In fact, in this case, a large WTM at the top of a component development network mainly used contracts to predefine the development project and impose its technical standards (such as technical requirements, price expectations, property rights, or project schedules) on the studied component supplier. The coercive imposition of technical standards appeared to be the dominant social mechanism structuring the development of the new technology, as summarized in Table 13.

It was particularly interesting to observe that the entire innovation process, including the manufacturing process, was centrally controlled, not only by the imposition of technical standards, but also by the imposition of labor standards. Shared norms of efficiency, quality, reliability, safety, or transparency, but also exclusive communication channels (SPOC) between project managers on both sides of the partnership, as well as personal inspections of the manufacturing process, facilitated central control.

Thus, contrary to the expectations raised by P1, this technology project was largely organized on the basis of the coercive imposition of technical and labor standards. A collaborative innovation praxis characterized by horizontal negotiations was not found.

Table 12: Innovation praxis in established fields

Technical standards	**Working standards**
Customer's technical standards, mainly based on industry norms and development contracts	Shared conceptions of time (milestones); exclusive communication channels (SPOC) between project managers
Component supplier's internal technical guidelines	Shared engineering and manufacturing norms (regarding quality, reliability, security, transparency)
	Homogeneous knowledge on both sides and a technological frame imposed by the customer

5.3.3 Case B: Dominating a supply relation

The previous section showed that incremental innovation processes tend to be centrally controlled by the customer. The dominant praxis of technology development found was coercive imposition based on technical standards, development contracts, and homogeneous knowledge. This section discusses how collaboration was organized in the second case of a component supply relationship. Again, the results partly reject P1, because an innovation praxis hardly emerged. Instead, an initial R&D partnership was reduced to a simple market relationship.

5.3.3.1 The power to control technology development

Compared to the first case of a large powertrain component, in the second case of a small component, the technical design as well as the interface was much less complex and actively kept simple by the customer, as described by the Product Center Manager (B-Org01):

> *The external interfaces, i.e. the screwing points and also the connector, were the same as on the prototype. This means that nothing really changed with this connector. (...) We had suggested ideas on how to improve the electrical interface*

> *because it's very simple now, but the customer didn't want that. They didn't want to change anything. (B-Org01, Product center manager)*

Having introduced a new product idea some time ago because it deviated from established component technologies, the component supplier found itself in a niche position outside of well-established supply networks. To expand its customer network and move out of this niche market, the supplier creatively improved the original product design. According to the product center manager (B-Org01), to make the product attractive to other customers, the company improved the engineering design and added electrical intelligence to improve the component's communication with neighboring components in the wind turbine. However, the main customer showed no interest in further collaborative innovation and demanded that the interface be kept simple:

> *[Our [component] has been further developed since then. The relatively simple vice, where you could just say 'open' and 'close', has now become a very complex and complicated device controlled by an intelligent microprocessor. (...) This could become part of the wind turbine control system, but this company has no need for it.*

These quotes indicate strong power asymmetries between the two partners. It is also clear that the component supplier tried to get out of its niche position by engaging in collaborative innovation processes not only with its customers but also with other WTMs. However, the customer showed no interest and actively prohibited further innovations that would have changed the architecture of the wind turbine. In the words of the product department manager (B-Org01): "[*The customer] naturally wants to keep control of the system control as much as possible.*"

Thus, in this case, the customer coercively controlled the development of the components. The supply relationship offered few opportunities for collaborative innovation. On the contrary, the customer actively reinforced its power position and thwarted all attempts by the component supplier to introduce innovative product variants by keeping the technical interface between the component and the wind turbine simple, as the product department manager points out: "*Unfortunately, we still do by far the most sales with this company. So we are dependent on them. This is also partly due to the fact that they use our [product] as a relatively simple component because they themselves have a very complicated control system in the tower.*

Thus, although this inter-company relationship began as a collaborative R&D project, it quickly evolved into a highly asymmetrical power relationship dominated unilaterally by the customer. WTM showed no interest in establishing a praxis of collaborative innovation. It rejected all attempts by the component supplier to gain some control over the wind turbine's architecture by integrating technical intelligence into the component, which would have established certain knowledge interdependencies. Instead, the customer was primarily interested in minimizing the price of the product. as described by the product department manager (B-Org01):

> *The pressure to build this [component] and to make it cheaper came from outside.*

In conclusion, compared to the first case, a joint innovation practice was observed in Case B only at the beginning of the innovation process. However, the initial joint R&D partnership turned into a simple market relationship reduced to keeping product prices low and rejecting any further technical improvements. In fact, the customer imposed product prices and interface data on the component developer.

5.3.3.2 Technical interfaces as a power instrument

Having developed a new product and being a newcomer to the wind energy industry, the component supplier was initially a monopolist. However, a few years after the introduction of the new product, a competitor entered the market and weakened the supplier's position, as recalled by the product department manager (B-Org01): "*[Four] years ago, a large part of the team left the company and started their own business with the same product.*" The marketing engineer (B-Org01) adds: "*They had been gone for six months when they had already delivered the first component from the new position.*" The product manager points out: "*This was a real problem for us because they continued to supply this system manufacturer. Suddenly there were two suppliers, which of course meant that sales were halved.*" The monopoly turned into fierce competition between the two component suppliers. This, in turn, strengthened WTM's relative power position vis-à-vis the component supplier:

> *At that time, we were the monopolist for such components, which this wind turbine manufacturer didn't like. That's why they were happy when we split up and some employees went into business for themselves, because now they suddenly had two suppliers. (B-Org01, Product department manager)*

The emerging competition between the two component suppliers strengthened the power position of the customer. As the construction manager (B-Org01) explains, WTM usually buys components from at least two different sources (second-source strategy) and tries to impose its technical standards on each component supplier: "*[The customer] also has to realize that we are not the only supplier, that there is at least one other supplier. If one supplier changes something, the customer would also have to discuss everything technically with the other supplier.*" The emerging competition thus weakened the component supplier's monopoly position and strengthened the customer's position of technical and commercial dominance.

To regain at least some of its former monopoly power, the supplier improved its product design to differentiate its product from its competitor, as the design engineer (B-Org01) explains: "*Ultimately, it was an attempt to put together a functional package that offered good value for money and that could only be copied by our competitors with as much effort as possible.*" But once the component was improved, adds the product manager (B-Org01), the competitor quickly caught up: "*This is now new, but the competition has caught up. However, we hope to have a technological advantage.*" These findings confirm that the initial collaboration between the WTM and the component supplier, instead of establishing a joint innovation praxis, went in the opposite direction. It became a simple market relationship dominated by fierce competition.

Once again, we are faced with an incremental technology development project organized on the basis of coercion. Although the supplier company made efforts to improve its component, the WTM controlled the component supplier by simply imposing interface data and product prices, as the product department manager (B-Org01) suggests: "*Now we have the problem that although the performance characteristics of our component are well received by the customer, it is too expensive.*" A common praxis of collaborative innovation was observed only at the time of market entry, after which technology development was dominated by price competition, as the following quote shows:

> *We are currently trying to make our components cheaper. (...) This means that we already know the final price, although the product is not really ready yet. (B-Org01, Product department manager)*

In summary, despite the efforts of the component supplier, a praxis of collaborative innovation based on horizontal negotiations and knowledge interdependencies was hard to find in this case. Similar to the first case, component development was centrally controlled based on coercive power. The WTM used technical standards (e.g. a technical interface) to control its component suppliers.

5.3.3.3 Trying to leave the market niche

The previous sections have shown how a large WTM used a technical standard to control its component suppliers, reduce knowledge integration to a minimum, and minimize social interactions to simple market transactions. The innovation project was reduced to mere contract development – a situation from which the development company tried to escape.

In order to escape these dependencies and to strengthen its power position, the studied supplier tried to engage in collaborative innovation with other customers. According to the quality manager (B-Org01), only such collaborations provide the application-oriented or "*real*" knowledge needed for the development of new product variants and the expansion of the product range.

> *The know-how of a customer who is involved in the use of a product is incredibly important. (...) You also want the customer to point out weaknesses.*
>
> *You can do the best test in the world in your own dry dock, but you don't get the real knowledge from the field if you do it in-house. This can be simulated, but the real field tests are even more important.*

After introducing its new technology, the component supplier was initially stuck in a market niche. In order to get out of the niche, the supplier had to convince customers to "consciously" choose the niche product, as the marketing engineer (B-Org01) reports: "*The crux of the matter is to make the right decision, because in addition to the many hydraulic components, our electromechanical product is still a real niche product. The customer has to make a conscious choice.*" For an outsider to established supply networks, however, it is almost impossible to find new customers willing to engage in collaborative innovation processes, as the product department manager (B-Org01) concludes: "*[W]e hardly get any contact with them because when they hear electromechanics, most of them say they have hydraulics and that's fine.*"

These findings show that because the component supplier operated in a highly competitive environment where only product prices mattered, reducing production costs rather than collaborative innovation dominated interactions with other WTMs, as the product department manager (B-Org01) notes: "*You are invited and told that you don't talk about price because you are a designer and after an hour they just ask how much it costs because everything is about price. I've seen that everywhere. The cost pressure in this industry is very high.*" Therefore, no praxis of collaborative innovation could be observed in this case. In fact, when the interviewer specifically asked whether collaborative innovation processes had been initiated, the product department manager (B-Org01) replied

> *Unfortunately, it has to be said that there was no such thing. The most you can say is that they weren't willing to cover the costs. (B-Org01, Product manager)*

Thus, also in this case, component development was controlled on the basis of coercive power as the dominant social process of technology development, which minimizes social interactions and knowledge exchange to mere order development and thus limits the innovative potential of the development partnership as a whole.

Under these conditions, the studied component supplier relied on the goodwill of the WTM and used communication tactics to gain at least some insight into the customer's product requirements. With a kind of diplomacy, the company's experts tried to build trust on behalf of potential customers, as the manager (B-Org01) put it: *"[You] have to get them to show interest by acting skillfully. Sometimes it works that way, but it's a bit difficult.*" However, the innovation manager (B-Org01) remained skeptical about these attempts and perceived the established supply network as rather "closed", with WTM showing little "interest" or "willingness" to initiate collaborative innovation processes:

> *If you are looking for other customers, of course they have to be open to implementing this with you and clarifying the interfaces. If they're not, they're not interested in the product. You just need that willingness.*

5.3.3.4 Preliminary conclusions

In contrast to the first case of an incumbent component supplier and worldwide leading specialist, the second case dealt with a newcomer and product niche supplier. The empirical findings hardly support P1, which claims that in the context of incremental innovation, technology projects are mainly organized through practices of monitoring technical standards and sanctioning nonconformity. In fact, a collaborative innovation praxis characterized by the negotiation of common working standards was hardly found in either case of incremental technology development.

Although the supply relationship in Case B started as a collaborative R&D project, the project work was characterized by practices of monitoring technical standards on behalf of the WTM, which appeared here as a top-down innovation approach. A collaborative innovation praxis would require mutual dependencies and knowledge complementarities so that neither partner could unilaterally dominate the collaboration. In this case, however, the collaboration was centrally controlled. A WTM instrumentalized a technical standard (mainly interface data) to coercively control the component developer, reduce social interactions to simple market transactions and order development, and limit the innovation potential of the partnership as a whole.

A common innovation praxis was missing. As Table 14 shows, the only working standard that became established in the development and production processes of the supplier related to delivery times, which are much shorter in the wind energy sector than in the rail vehicle industry. However, even this standard was imposed by force.

Table 13: Innovation praxis in established fields

Technical standards	Working standards
Technologically simple interface data (imposed onto the supplier)	Product delivery times (imposed by the customer)

5.4 Institutional barriers and what they caused

The previous section focused on how two cases of incremental innovation projects were organized. It was shown that in both cases the coercive imposition of technical and labor standards served as the dominant social process. However, this led to a loss of innovation capability, as will be discussed in this section.

5.4.1 Case A: Loss of innovation capabilities

It was shown above that in Case A, technology development was based on the coercive imposition of a customer's technical standards, which implied that processes of combining knowledge beyond the scope of the project were prohibited. Thus, it can be argued that strict standardization led to organizational rigidity, which in turn reduced the overall innovative capacity of the network.

During the research, it became clear that in this particular case of a well-established development project, as the production manager (A-Org01) called it, the component supplier's development options were limited by the technical expectations of the customer. The project manager further explained that the company's development options were limited by the customer's specifications on how the new component should fit into the wind turbine's architecture: "*Constructively, our scope is already defined by the fact that boundary conditions have to be met. (...) We are given relatively precise specifications regarding the connection dimensions of the [component]. This defines the installation space within which we can operate*." In other words, technical standards primarily define the "mounting space.

In addition, technical standards also define the design of the component. The strategy and marketing manager (A-Org01) emphasized that in some projects the customer's technical standards are narrowly defined in order to meet a predefined product price: "*That means you have to somehow see where you can save money with the freedom you still have (...). Maybe you can design one or two components to be cheaper, but that is not innovation. That is design-to-cost*."

In this way, standardization limits the development options and the "*freedom*" of the component suppliers to be creative and to experiment. As a result, suppliers rarely create new technological innovations in highly regulated technology projects. The strategy and marketing manager (A-Org01) of Organization A reasons that when innovation does occur, it often involves minor technological improvements adapted from other industries, such as the automotive industry:

> *It's usually not a breakthrough or a huge innovation, but it really happens on a small scale where you introduce simple things like new screws (...) Often it's nothing new. The car industry has been doing it for x years. (A-Org01, Strategy & marketing manager)*

In essence, technical standards provide an impetus for incremental innovation. In fact, the component supplier studied regularly introduces "simple improvements", as several interviewees stated. For example, the key account manager (A-Org01) explained that when customers' expectations cannot be met by relying on existing technological solutions, "*you are forced to think about how to do it in a slightly different way.*"

Based on these empirical findings, the following conclusion could be drawn. The forced imposition of technical standards, which excludes practices of knowledge integration beyond the scope of the project, reduces the innovative capacity of the entire component supply network. This link between a customer's strategy to control external technology development and reduced supplier creativity is also evident in the following quote from the strategy and marketing manager, who acknowledges that customers sometimes demand the creation of "new ideas":

> *Some customers push you in the direction of coming up with new ideas yourself. (...) But there are also customers who just want a proven and cost-effective transmission. That's what they specify. (...) Then there are no gimmicks and no experiments. It just has to work. And of course there are no innovations. (A-Org01, Strategy & marketing manager).*

Customers sometimes even use technical standards as an instrument to minimize creative problem solving and experimentation. As the key account manager (A-Org01) explains, the primary motivation behind this strategy is to reduce the "cost of energy": "*Ultimately, it's always about presenting something at the best possible cost. You can always improve the technology, but that doesn't necessarily make it cheaper. At the end of the day, the only thing that matters is the cost of energy. What does it cost to produce a megawatt hour of electricity?*" Thus, standardization of technology projects may increase the efficiency of components and reduce energy costs, but it also risks reducing the ability to innovate.

A key reason why the imposition of technological standards reduces the innovative capacity of innovation projects is the lack of social integration between the suppliers of the main components of the wind turbine, such as the rotor, the generator and the gearbox. The interviewees explained that both electrical and mechanical components are technologically interdependent. Therefore, the key account manager (A-Org01) argues that an "*optimized*" technical design of a wind turbine should include interactions between all components – and their suppliers, because increased social integration between component specialists could increase innovation capacity:

> *When a customer comes to us, they only ask us about the mechanics and then wonder why the component is way too expensive. They may have budgeted extra costs for one component to compensate for the other. But he won't let us talk to the manufacturer of the other components to find the optimum solution.*

As this quote suggests, customers often prohibit information sharing among the specialized manufacturers of mechanical and electrical components within the wind turbine, instead of increasing social integration among these component suppliers. During the research, the interviewees discussed the topic of increased social integration among component specialists under the keywords "system solutions", "system integration" or "system coordination." For example, the project sales expert (A-Org01) criticized poorly developed collaborative arrangements that result in "everyone doing their own thing": "*The whole issue of system coordination is going to be a huge problem because everyone is cooking their own little soup. Everyone is trying to get their partner on board as much as possible, but at the same time they are trying to share as little information as possible.*"

Due to the technological interdependencies between components, system integration is apparently an ongoing debate within engineering communities, as the sales expert adds: "*We are slowly realizing that the component manufacturers need to be brought on board because the forces coming from the rotor shaft may be significantly higher or the individual components may stimulate each other. I think people are becoming more and more aware of this.*" Another expert confirms that technological interdependencies have made the entire industry more "open" to collaborative innovation. In fact, this manager suggests that horizontal collaboration between WTMs and their component suppliers is an emerging phenomenon:

> *The industry has become more open (...) What's happening now is that people are discussing these things with us and not just focusing on our component, but also asking what can be changed. (A-Org01, Key Account Manager)*

In conclusion, this section has associated the social process of coercive control of component development with a loss of innovative capacity. Despite the technological interdependencies between the major components of a wind turbine (e.g. rotor, gearbox, generator), customers actively prohibit social integration and information exchange among the specialized suppliers of all major mechanical and electrical components of a wind turbine. This strategy leads to organizational rigidity, which reduces the innovative capacity of the entire network.

In mature technology fields, innovation tends to take the form of small technical improvements resulting from incremental adaptation of technical standards, including standards used in complementary industries such as automotive or aerospace. For "*big technological steps*" or radical innovations, on the other hand, suppliers depend on their customers, who have the application knowledge as well as the infrastructure needed to test new components under "real conditions," leading the key account manager (A-Org1) to conclude: "*We can only advance technologies internally, and then we are dependent on customers. The really big steps are usually driven internally [by the component manufacturer].*"

It turns out that a fairly mature field of onshore wind energy technologies is not doomed to reproduce existing technologies. As new generations of wind turbines become larger and heavier, component suppliers are being "pushed" into new technology areas such as lightweight construction, as the R&D expert (A-Org01) explained: "*The fact that the power classes are increasing has a positive effect. The larger systems are getting heavier and heavier, but they are also being designed more and more in the direction of lightweight construction.*" The interviewees stressed that the continuous growth of wind turbines is driving technological innovation, which could even lead to radically new technologies, as the strategy and marketing manager (A-Org01) concludes:

> *[As we move further into the offshore market and into the eight megawatt range, we will also look again at the space standard. We have just launched an initiative in this area. Imagine you are in a space capsule and we want to be 100 % sure that we come back to earth safely. We will certainly go beyond the automotive standard.*

5.4.2 Case B: Remaining trapped in a market niche

The second case told the story of a newcomer to the wind energy industry. It introduced a new technical standard, but was unable to break out of its market niche. The product idea was supported by the top management and mainly driven by the head of the product department. He initiated product improvements, brought internal departments such as manufacturing and engineering together to solve technical problems, and tried to expand customer relationships around the world, he recalls: "*I have now visited [major customers] in and around Germany myself. I've also been to China six or seven times, and we're still trying, but I'd say we haven't really made a breakthrough yet*" (B-Org01, Product Department Manager). Up to the time of the study, the company had not succeeded in establishing further cooperation, although it had tried to set up a new supply network, as the design engineer (B-Org01) explains:

> *The feedback was that they all thought the features were great, but they weren't using them at the moment. (...) You can then deduce where the shoe pinches and where it doesn't.*

From its position outside the established supply networks, the component supplier relied on "*reading between the lines*" to identify customer needs. However, until the time of the investigation, the supplier had no additional supply relationships with large WTMs. The product center manager (B-Org01) attributed this to increased market competition and customers' unwillingness to test uncertain, potentially less reliable technologies: "*They are all under a lot of cost pressure and also under pressure that all their systems have to work. Availability has to be very high, and as a result, they are all now very afraid to embrace technological innovation.*" The same manager concludes that when WTMs introduce radically new technologies, they tend to do so alone or with trusted partners:

> *When [wind turbine manufacturers] innovate or improve something technically, they do it internally. No information about what they are doing is shared with the outside world. They may also improve certain components, but they do it with the existing suppliers.*

In conclusion, in this case, the component supplier were unable to act as an institutional entrepreneur and break out of the market niche. The customer's strategy of controlling component development created a barrier to further technological innovation. In addition, the component supplier failed to initiate additional innovation projects with other large WTMs. As a result, the company remained an outsider to established supply networks. The company remained structurally excluded from innovation projects through a "*cloak of silence*", as the product center manager (B-Org01) pointed out:

> *[T]his is all done under a cloak of silence from the public.*

5.5 Interim conclusions

This book examines the institutional barriers to collaborative innovation. This chapter discusses the extent to which incremental innovation processes are organized through practices of monitoring technical standards and sanctioning nonconformity (Proposition 1). For this purpose, two empirical examples of component supply relationships between a medium-sized German component supplier and a large European WTM were presented.

The empirical evaluation was divided into four sections: first, the positions of the relevant actors in the field were characterized; second, the practices of knowledge integration involved were described; third, it was shown how the cooperation was organized; and fourth, the observed outcomes were discussed. This section provides a preliminary summary of the empirical findings (cf. Table 15 and draws conclusions regarding the research question.

In both cases, it was observed that the respective WTMs imposed their technical expectations on the component suppliers due to strong power asymmetries. In case A, the customer instrumentally used development contracts to pre-define the technology development. In addition, the WTM centrally controlled the technology project based on common work standards such as time frames (milestones), exclusive communication channels (SPOC) between project managers, and personal inspection of manufacturing processes. Based on these findings, coercive power was identified as the dominant mechanism of technology development.

Table 14: Fields of incremental innovation

	Case A: Large component	**Case B: Small component**
Knowledge Integration	Based on highly standardized working procedures, a component supplier combined technical standards to design a new prototype	Through a joint R&D project, a component supplier collaboratively developed an innovative product
Realizing technology development	The WTM uses development contracts, technical standards as well as shared working standards (e.g. shared milestones) to coercively control technology development	The WTM coercively controls component development based on a technologically simple technical standard as well as fierce market competition between its suppliers
Institutional barriers	Rigid standardization of component development (e.g. prohibiting knowledge integration between component specialists) reduces the innovative potential of the whole supply network	The lack of collaborative innovation processes involving a large WTM caused the component supplier to remain trapped in a market niche

The second example of a small component (Case B) was also dominated by hierarchical control and the imposition of standards. In this case, however, the WTM simply used technical standards to coercively control the component supplier. An initial collaborative R&D project turned into a simple market relationship without collaborative innovation.

Consequently, the findings partially support the assumptions of P1, which postulated that incremental innovation projects are mainly organized through practices of monitoring technical standards and sanctioning nonconformity. Initially, it was expected that technical standards would play a central role in incremental innovation projects, but that coercive power would be irrelevant due to interdependencies and knowledge complementarities. However, the empirical cases revealed that coercion, central control, and hierarchical dominance characterize technology development in areas of incremental innovation.

This lack of collaborative innovation could also be associated with institutional barriers. In Case A, rigid standardization implied that learning and knowledge integration between component specialists could not take place, although due to the technological interdependencies between the rotor, gearbox and generator of wind turbines, knowledge integration would be required to optimize the overall system architecture.

In Case B, the customer explicitly prohibited further innovation. At the same time, the component supplier failed to engage in innovation projects with other WTMs to broaden its product range. Due to this lack of collaborative innovation, the company remained trapped in a market niche.

Thus, both cases showed that coercive control based on rigid standardization reduces the innovation capability of the entire component supply network. Wind turbines are complex technologies with many technical interdependencies between components. Since coercive control prevents component suppliers from collaborating on the further development of components and system architecture, coercive power jeopardizes the optimal performance of wind energy technologies and reduced the innovation capabilities.