Interlocking patent rights and value appropriation: insights from the razor industry

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Abstract:

This paper analyses a duopoly-like situation in the wet shaving industry featuring an innovation leader and a follower. In this, the leader claims to have filed "interlocking" patents. The explorative case study examines how the leader filed said patents and how their structure has affected potential value appropriation: In fact, the market leader has claimed technical elements in multiple patents, while the patents themselves do not legally overlap. This analysis will also cover triggers and boundary conditions that facilitate or limit such claim compositions. Finally, the market leader has seemingly been able to successfully appropriate value from its strategy. This work will contribute to the literature on value appropriation, the interplay between corporate engineering and IP functions as well as the economics literature on patent thickets.

Managerial relevance statement:

Only a few managers are aware of advanced intellectual property (IP) strategies that can aid them in better achieving protection than is typically possible through filing a few patents. This work studies Gillette, a company known for its superior IP strategies while revealing how so-called interlocking patents were filed successfully in order to keep competitors at bay. Compared to regular patents, interlocking patents claim a mix of the same technical elements across a range of different patents. Engineering methodologies such as function analysis have helped determine these relevant technical parameters. As a result, this approach has made it more complicated for competitors to find product variations that do not violate any patent claims from a set of interlocking patents.

This is the accepted version of the paper. The final version is available under https://doi.org/10.1109/TEM.2017.2654862

1. Introduction

Up to now there has been a long tradition of research focused on market structure, strategic interaction, and R&D [1], [2], resulting in a vast body of economic literature on technology or R&D races, those frequently assumed to be patent races. The basic assumption is that there are at least two competitors who are investing in R&D and therefore, in the best position to present a new product into the market. They file a patent in order to appropriate the returns from their investment, prevent market entry of their competitors, and achieve a dominant position in the market (e.g., [3] [4] [5, 6]). In this context, scholars have also proposed the use of preemptive patenting by the leader, whereas preemptive patenting involves filing additional patents to make inventing around patents harder for the follower [7]. The reason being is that even in the case of a product being patent protected, imitation frequently occurs [8].

The resource-based perspective provides another perspective on this topic. It highlights the importance of complementary assets or resources, which [9] have been described as being pivotal for profiting from innovation. Complementary resources continue to explain why firms conduct mergers and acquisitions in addition to establishing strategic alliances.[1] However, while a vast body of literature has been concerned with complementarity across asset or resource classes, such as manufacturing capacity, R&D competency, customer service, etc., this work will study within-class complementarity by looking at complementary patents, those defined as covering distinct elements of a technology that need to be used together for implementation [11]. So far, scholars have primarily studied complementary patents at a macro level in order to explain patent thickets based on complementary (overlapping) patents [12]. Such complementary patents held by different parties result in possible royalty stacking, where licensees have to pay licensing fees that, in sum, are higher than they would be if the patents solely belonged to one licensor [13]. One way to avoid these kinds of situations is by establishing patent pools whereby covering all complementary

[1] For a literature overview on the latter, see e.g. [10].

patents [12] [11], or entering into cross-license agreements [14]. However, little research has been conducted on how firms can shape appropriation regimes [15], in particular how complementary patents are able to emerge. There are a number of studies that have looked at patenting motives [16, 17, 18 for surveys]. Other work has pointed towards patenting strategies all of which have been known to make use of multiple, related patents to better protect the underlying technology, possibly making imitation inherently difficult [19-21]. But this work does not go into detail or helpfully explain how these patents have been actually composed in order to better appropriate value. An exception concerns those who [22] have studied pharmaceutical patents and found that, here, complementarity and substitutability has been based on a substance mentioned in different contexts, such as pure substance patents, patents describing the dosing of such substances, its formulation as a drug, or its use to treat various diseases. Outside of the chemistry-related domain, there are no substances which can easily serve as centerpieces for filing complementary patents.

This paper aims to expand this view and study an industry that has come close to the somewhat stylized race models described in the economic literature. It takes a look at the wet shaving industry with its two dominant players: Gillette, market leader, a company well-known for its superior patenting approach [21], and Schick/Wilkinson-Sword, its closest rival of the past few decades. In effect they form a duopoly, and both constantly introduce novel products into the marketplace. When Gillette first introduced its sensor razor in 1990, considered to be a landmark product, the company filed 22 patents for this device. Gillette's vice president of corporate R&D, John Bush claimed: "[We] created a patent wall with those 22 patents. And they were all *interlocking* so that no one could duplicate the product" [21, p. 110; emphasis added]. The Boston-based razor manufacturer is known for its superior patenting strategy [21, 23], one that is obviously designed to prevent others from imitating its products by preempting the technological space surrounding its newly developed products. However, the present literature lacks a description of these *interlocking* patents so far, which might be an interesting way to preempt the competition and appropriate value.

This opens up three interesting research questions: (a) How are the patents filed by Gillette that are considered to be interlocking? (b) How does the structure of interlocking patents differ from the one found in overlapping patents (those well-known in academia and practice)? (c) How has Gillette, a leader in innovation, been able to actually appropriate value from this particular strategy?

First, building on theoretical work concerning patent claim composition and combinatorics, I will propose that jointly claimed elements across patent documents have constituted interlocking patents. Then, I will use an exploratory case study design to better examine patent filings in the safety razor industry with its two dominant players. More specifically, I will analyze the patents of the Gillette Fusion Power razor in detail, specifically those launched in 2006, and compare them to the Schick/Wilkinson-Sword Quattro and Quattro Titanium Precision (aka Quattro II) model introduced in 2003 and 2008, respectively.

Building on both co-word and citation analysis known from bibliometrics for pre-selecting similar patents to compare, I will combine content analysis of patent claims with function analysis from engineering to investigate the phenomenon of joint claiming. The findings have been linked to market research on competitive products that allow for assessment into what degree value appropriation appears to have been possible here. I have found that Gillette, in contrast to Schick/Wilkinson-Sword, has not only filed more patents, but has also claimed to possess technical elements across different patents that are technically closely related. Finally, Gillette has been able to prevent important components from being imitated by competitors, and has been able to set a higher price for its products, possibly appropriating value from its patenting strategy.

The results have contributed to the product design literature by facilitating ways in which to better protect product architecture; provide insights into the engineering literature on inventing around patents while delivering new insights into the complex systems literature as complexity, in this case, having stemmed from both the product and patent claim level, making inventing around inherently and extremely difficult. The findings have also expanded

the economic literature on overlapping patents by defining them as a special case of interlocking patents; while they continue to contribute to the stream of literature on collaborative work between R&D and IP functions. And finally, they have continued to expand upon ways for practitioners to better protect their products.

In the next section, first, I will begin by briefly reviewing the value appropriation and strategic patenting literature. Two further subsections will shed light on both the product design terminology as well as the microfoundations of patent claim composition as they are pivotal to understanding how interlocking patents are able to emerge. Finally, in the theory subsection, I will build on combinatorial claim compositions and suggest how interlocking patent claims are able to emerge. Section 3 will explain data collection and analysis, while section 4 will present the results and further develop several propositions. Subsequently, I will discuss my findings related to the relevant research questions and develop two further propositions. Conclusions will follow.

2. Theory

2.1 Value appropriation by strategically filing multiple patents

Patent protection is supposed to prevent spillovers , which can dampen a firm's profits and market valuation, but as it currently stands patent protection does not fully achieve this goal [24, 25]. Even though imitation costs increase through patent protection, imitators often face shorter development times compared to the original innovators [8]. However, direct imitation of products or processes continues to be rare [26], especially in matters where patents have been previously filed. As a result, substitution occurs far more frequently, but there have also been minor improvements to a patented technology which may have violated prior patents. Hence, it is no surprise that firms are known to use *multiple* patents to better appropriate value from their products. For example, Xerox successfully shielded its products from imitation by using a large patent portfolio [27] while Thomas Edison acquired important patents around his basic one for the electric light-bulb thereby reducing competition in the market [28]. Apart from generally using multiple patents, there are several more concrete

approaches (i) such as filing patents on different technical solutions for the same functional outcomes known as patent fencing; (ii) filing of minor patents on many different aspects of a technology which is known as patent mining, flooding, or blanketing, or (iii) fencing in/surrounding a basic patent filed by a competitor with various application patents [19-21].

2.2 Definitions of product architecture, functions, and components

Product architecture describes the way functions are linked to physical components [29]. *Components* are parts of a product (potentially consisting of *subassemblies*) that perform a clearly defined *function* [30] and are characterized by multiple *design parameters* [31] which in turn define their performance.

Product architecture can also be viewed from the perspective of modularity by which a system is broken down into sub-groups (*modules*) of components. Inside the modules the components are highly interdependent (*coupled*) and highly independent across the module boundaries, while interfaces between modules facilitate module combinability (see e.g. [29] [32], [33], [34],). In contrast to *integral products* there is a high degree of component interdependency (*coupling*) inside the monolithic product as many functions do not map one-to-one with components, though its components might share multiple functions [31].

It is the nature of modularity that modules can be easily exchanged [34], yet this is not the case with integral product architectures. This implies that modular systems are much easier to imitate [35]. One prominent example in the history of business concerns IBM with its introduction of modular product design for its mainframe computers. The company lost a substantial portion of its market capitalization when hundreds of competitors started selling complementary, modular products [36].

2.3 Patent terminology and how patent claims work

The US Federal Circuit has set some terminology definitions that subsequently will be used, namely the terms *limitations* and *elements*. On the product level, the technical

characteristics such as components, subassemblies, design parameters, and functions are described as *elements*, while on the patent claim level they constitute *limitations*.[2]

In order to better assess strategies that aim to extend the legal scope of patents around some technology, as the term interlocking somewhat suggests, it might be helpful to keep in mind how patent claims work as they define a patents' boundaries [37]. A patent claim may describe a system, a process, an application etc. of some piece of technology. So from this perspective, it is known to cover different limitations (being elements such as components, design parameters, etc.) An example might be patent P covering a field effect transistor (limitation A) with a particular gate length (limitation B), upper frequency (limitation C), certain outer dimensions (limitation D), and made out of a particular material (limitation E). In general, limitations may be contained within a single claim, which would then be an independent claim[3], or they could be distributed across multiple claims, i.e. one or more independent claim(s) with a set of basic limitations relevant for all claims, and several dependent ones claiming the basic limitations by referencing the independent claims, and adding more limitations mentioned solely in the dependent claims.

Someone manufacturing a transistor that only covers such limitations as A-D would not infringe on patent P with its limitation combination A-E as the limitation E is missing in that transistor (being made of a different material). Someone covering limitations A-E (or equivalents) or someone covering limitations A-E plus a limitation F, such as a material used in combination with a specific dopant would infringe on patent P as well (see [38, 39],[40],[41]). However, the latter might even be an invention being patentable as well (as long as it is novel and non-obvious). This would lead to overlapping patent claims in a way that the owner of patent P might practice its invention in a technology space defined by limitations A to E minus the area limited by limitation F, while the later patentee may only

[2] *Festo v. Shoketsu*, 234 F.3d 558, 563 n.1

[3] All patent claims that do not refer to another claim are known as independent claims. The combination of the limitations found therein defines a patents' scope, i.e. one must at least cover all of them in order to infringe upon that patent. This means that the less limitations contained in that claim, the higher the likelihood of infringement.

practice its invention with permission from the first patentee. In the same sense, an individual who intends to invent around patent P has to be cognizant that at least one of the limitations between A-E is omitted.

To conclude, the fewer limitations mentioned within a patent claim, the broader a patents' scope. However, it is no easy task to simply omit certain limitations to obtain broad patent scope, as the prior art may have already mentioned these limitations. As a consequence, independent claims that do not fulfill criteria of patentability are frequently merged with dependent claims (that are patentable) throughout the patent examination phase. This results in many granted patents that have independent claims consisting of quite a number of limitations, which, by leaving a limitation out, may facilitate inventing around them.

2.4 Claim structures and interlocking patents

Hence, when filing a patent on a product, process, etc. one needs to claim the set of elements that describe this product or process. [4] In contrast, when filing multiple patents there are at least two principle approaches: filing a patent for each element of that product/process, or filing patents which jointly claim at least some of the elements in common, meaning that their limitations overlap to some degree. The former approach - albeit somewhat unrealistic as many elements alone are hardly patentable themselves - would lead to a (IP) modular structure [42] where each module is tied to a different IP right. This, in fact, facilitates exchangeability of the module and, for the overall product, deters appropriation once it comes to imitation protection. Hence, such a situation could hardly be described as interlocking, which aims to protect imitation. The contrary can be the case in which these patents have some limitations in common.

To summarize, the way in which patent claims are composed as combinations of different limitations suggests overall that a combination of the limitations A-D (such as A-C

[4] Of course, the limitation description can be more complicated than in the simple model given in the prior section, as, for instance, limitations can follow hierarchies, meaning that one patent may claim a "semiconductor device" with limitations B-E, another patent a "transistor" with limitations B-E, with the second claiming to be a subset of the former.

and C-D, or A-B and A, C-D) may possibly lead to interlocking patents. If the combination becomes e.g. A-C and A-D, one could have a situation of overlapping patents as well. In both cases, the patents are complementary. These considerations are the basis for answering the research questions, i.e. how interlocking patents are filed, how they can be distinguished from overlapping patents, and how they might create value.

3. Methodology

For this paper, I chose an exploratory case study approach and selected an extreme baseline case with respect to the use of interlocking patents, which would facilitate the extraction of the underlying mechanisms that play a role [43, 44], namely the Gillette company that is frequently cited due to its superior patenting strategy [see, e.g. 21]. The Gillette Fusion Power razor, introduced in the market in 2006, serves as case study object. Their razor was compared to the Quattro and Quattro Titanium Precision (Quattro II) model of Schick/Wilkinson-Sword (Gillette's closest competitor) introduced in 2003 and 2008, respectively.[5]

3.1 Data collection

In my collection I used five sources of data in order to increase construct validity: (a) prior literature describing (patent) strategies devised by Gillette, (b) a product test report by a European consumer product test agency, (c) the content of patents filed by the two companies for their products, (d) bibliometric information from patent documents extracted from the Espacenet database, and (e) the razors as technical artifacts. Unfortunately, a wall of silence among staff from Gillette and Schick/Wilkinson-Sword does not allow for the phenomenon under investigation to be approached via interviews.[6]

[5] The Schick/Wilkinson-Sword Hydro 5 model introduced in 2010 was also considered, but here only one patent family was found and hence, no analysis of interlocking patents was possible.

[6] In order to obtain additional information on the patenting strategies chosen by Gillette, I intended to conduct interviews with company staff at both Gillette and Schick/Wilkinson Sword. However, the relevant people either refused to be approached or responded they were obliged not to share any information on this topic. This behavior falls in line with the report from Blaxill and Eckardt [23].

Altogether, these sources allowed for data triangulation. Blaxill and Eckardt [23] have provided an overview concerning US patents filed around the Gillette Fusion technology. Taking this as a starting point and inspiration, I searched for Gillette and Schick/Wilkinson-Sword patents in the Espacenet database, looking at all filings in the selected time range during their products' introduction, and compared the results as well as those patents presented by [23] to the razors as technical artifacts.[7] Finally, my search yielded 22 utility patent families[8] with 49 patent applications (as of end of 2010) that, altogether, aimed to protect the Gillette Fusion Power (aka Fusion) razor. Of these 22 patent families, nine were filed on the same day. Four utility patent families with 10 patent applications protect the Quattro razor. The Quattro II, which includes updated blades and an electric trimmer located on the handle is based on four additional utility patents.

In order to assess if the patents effectively helped appropriate value, I used a test report from a leading consumer product test agency in Europe as well as measures based on forward patent citations (i.e. the ratio of self-citations received, the total amount of self-citations and the total amount of citations coming from other companies) stemming from the Espacenet database as well, which served as a robustness check.

3.2 Data analysis

As derived in section 2.4, I assumed that interlocking patents have continued to share several seemingly common claim limitations, so a pairwise content analysis of the claims was necessary. For the 22 patent families with its 49 patent applications, all of which are potentially interlocking, a direct comparison would mean 220 or 1,151 pairwise comparisons, respectively. I employed a filtering mechanism to further reduce the amount of documents to be compared, based on a similarity analysis building on citation linkages and textual similarity

[7] For Gillette, I found that one from the previous Mach3 generation did not belong to the Fusion as outlined in [23], while three further patent families (with in total five patent applications) were, in fact, part of the Fusion patent families.

[8] The term 'patent family' refers to the situation that a single invention may comprise multiple, closely related patent applications and granted patents, on the one hand internationally (i.e. the patent filings for registering the invention abroad), on the other hand nationally, i.e. several continuation filings, etc. that all refer back to a single application [45].

(in this case, co-word analysis). Figure 1 depicts the data selection and analysis process described in detail in the Appendix. This approach yielded the 36 document pairs for the comparison with content analysis for the Gillette fusion, and eight comparisons for the Schick/Wilkinson-Sword of which two raters were employed to conduct.

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insert Figure 1 about here

Furthermore, in order to elicit relationships between functions and components represented as limitations in patent claims in the Gillette Fusion, I employed function analysis (as other scholars have done so before in the context of eliciting inventing around possibilities [39] [40]). The principles of function analysis are outlined in [46], and the analysis was conducted by the first two raters plus a third.[9] The findings of the three raters were combined and the function analysis presented was agreed upon by all three.

4. Is there interlocking patent creation at Gillette?

First, the key elements of the razors will be introduced as they can be located in the patents' limitations and are subject to subsequent discussions. This part will also map the elements (components, subassemblies, and design parameters) of patent claims. The two further subsections will report on limitation overlap between patents at Gillette and Schick/Wilkinson-Sword that may constitute interlocking effects. An analysis of functions and limitation overlap follows, and finally, a brief robustness check will be presented.

4.1 The razors and their patents – an overview

Figure 2 (a) illustrates the Gillette Fusion razor with its core inovation covering the space between the blades (which is small enough to guarantee successful and comfortable shaving, but large enough to be able to clean the blades after shaving) and the number of blades (five instead of three compared to the razors of the prior generation). The cartridge itself comprises a blade unit, which consists of the blade package with its five flexible blades,

[9] The third rater also holds a Masters' equivalent in mechatronics, and at that time, was involved in a PhD program in the same subject with additional experience in filing patents himself.

a trimming blade to cut difficult-to-reach hair, and the lubricating strip for moistening the skin, in addition to the blade guard which assists in guiding the shaver (see Figure 2 (b)). The pivot mechanism is attached to the blade unit, additionally comprising a connection to the handle, which altogether forms the razor cartridge. A plunger within the handle touches the blade unit exerting a force upon it, allowing for the adjustment to the skin via the pivot mechanism. In addition, the plunger from the electric version causes the blade unit to oscillate, massaging the skin (see Figure 2 (c)). A release button placed directly on the handle enables the interchange of cartridges via the interface. There is a small power on/off button located on the electric handle, as well as a tiny display showing the power level of the battery with its housing incorporated into the waterproof handle.

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insert Figure 2 about here

The contents of the Gillette Fusion patents are illustrated in Table 1. In total, Gillette has aimed to protect ten major components/subassemblies, as the first two columns of Table 1 indicate. 16 patent families protect the cartridge, with one patent family addressing the blade design, two families the blade coating, five covering the blade package, two the trimming blade, two the blade guard, one the pivot mechanism, and three covering the handle and its connection to the cartridge. The remaining five patent families address the handle and its electrical function with two families covering the circuit and switch, and three families addressing the battery housing.

Introduced three years earlier than the Fusion, the Quattro was the first razor to feature four blades, allowing for the skin's protection through thin wires. Technically, the razor had a new form of blade exposure ideal for the skin, a novel blade-span, and a novel type of pivot mechanism (see Table 2). The Quattro II, introduced two years after the Fusion, had titanium-coated blades, a trimming blade, and an electric trimmer in the handle. Overall, the two Quattro razors involved fewer novel elements than the Fusion.

Table 1 and 2 further provide coding data for the families (familyID) and documents (DocID), which are subsequently used to refer to specific documents found within further tables.[10]

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insert Tables 1 + 2 about here

4.2 Jointly claimed limitations at Gillette

Table 3 illustrates the results of the content analysis, the search for jointly claimed limitations filed across different patent families; the summary is outlined on Table 4. These tables provide elucidation and report observations regarding the product level, such as components, subassemblies, and design parameters. Of the 36 Gillette patent pairs under investigation, jointly claimed limitations were observed in 29 pairs. Table 4 illustrates that, in fact, 19 of the 22 patent families have been connected via jointly claimed limitations. The solid lines differentiate between patent families relating to blades, the cartridge, and the handle, while the dashed lines indicate boundaries of subassemblies. It can be observed that there is no joint claiming between the handle and the cartridge, which are two distinct modules. The latter area is dominated by blade package patent applications with family #1 as the most highly connected one with ties to six patent families, followed by patent families on the blade guard, pivot mechanism, handle + cartridge connection, and cartridge dispenser. Overall, modular boundaries have appeared to impose limits to joint claiming. Hence, I propose:

P1: Modular boundaries impose boundaries for jointly claimed limitations.

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insert Tables 3 + 4 about here

As argued in section 2.3, the number of limitations within independent claims is critical for a patent's legal scope. Given that the findings show limitations that have already been claimed across different patents, the question will ineluctably emerge whether these

[10] The various documents per patent family emerge from continuation filings consisting of so-called continuations and divisional applications (i.e. applications that were split up). Within one family, the similarity of claims is, per se, very high.

limitations are claimed within independent or dependent claims. As such, Table 5 showcases two examples and demonstrates that, therein, most of the limitations appear in dependent claims in both patent filings, but some are additionally located in the independent ones. The nature of the independent claims in these examples is rather different across the document pairs as they include distinctive additional limitations. Therefore, I propose:

P2: Jointly claimed limitations primarily appear in dependent claims.

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insert Table 5 about here

4.3 Jointly claimed limitations at Schick/Wilkinson-Sword

It may very well be that joint claiming of limitations observed by the Gillette razor naturally occurs when filing multiple patents on a product consisting of multiple components/sub-assemblies. If this has been the case, one should also find such effects in the Schick/Wilkinson-Sword patents. For the Quattro razor, covered by four patent families mainly related to the cartridge, no joint limitations have been identified.[11] From the patents filed for the Quattro II, one patent family covers the cartridge, one a new blade design, and two relate to the electric trimmer in the handle, altogether complementing the earlier filings on the Quattro (with the exemption of the handle as substitutive).[12] So there is hardly any joint claiming which can be observed for the Gillette filings. This means that Gillette chose a unique filing strategy, where it is unlikely that the joint claiming effects mentioned are merely artifacts. Instead, they seem to have been carefully chosen.

[11] The term "at least two blades" was mentioned several times between two documents, but more than one blade was very common amongst razors at the time when the patent was filed, so it was not counted as joint subassembly/design parameter. The same holds true for blade exposure across the plane of a frame, as without such exposure, no hair cutting would be possible.

[12] The two patent applications of the electric trimmer (families #7 and #8) are almost identical (similarity value of 0.97), having been filed on the same day. They have more than ten elements in common, with one of the two applications covering additional numerical values such as the trimming force or weight of the electric trimmer. In this light, they are very different from the filings pursued by Gillette. Filing such almost identical patents, according to a patent professional, is a distinct and widely-known patent strategy that will not be further discussed in this paper.

4.4 Functions and joint claiming at Gillette

While the analyses has shown that different limitations were claimed across different patent families thus far, it remains unexplored up to this point why exactly these were jointly claimed. Hitherto, it is only known that Gillette claimed "all the features that we thought would be of value to the consumer" [21], p.110. Therefore, I will study the nature of the razors' functions by employing function analysis, linking them to joint claiming. Following the definitions of Pahl, Beitz, Blessing, Feldhusen, Grote and Wallace [46], I will distinguish between basic, auxiliary, special, and adaptive functions. Figure 3 illustrates the functional structure of the Gillette Fusion razor. Arrows are shown to indicate the direction of an effect by the functions, differentiating between material, energy and signal flows and, finally, mirroring how far these functions have been coupled.

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insert Figure 3 about here

Within the cartridge, various functions exist. The basic functions are cutting hair, accomplished by the (five) blades, and the handle with one each per module. There are plenty of auxiliary functions, such as the trimming blade which prevents corrosion by using an anode connected to the blades, the easier cleaning of the blades by providing a sufficiently large blade distance, etc. There are special functions such as the electronic control system for the motor, etc., and one adaptive function which is the connection between handle and cartridge.

The basic function of cutting hair is by far the most coupled one where most other functions "pay in", followed by the trimming blade (auxiliary function) We can observe that there is something different about the handle, its basic function namely for holding the razor, but this function is not highly coupled with various other functions. Table 6 more specifically illustrates these functions associated with joint claiming (including many auxiliary functions as well). Joint claiming occurs both within and throughout the different components of the razor. Hence, it is not only the case that technical parameters have been claimed across different technical components, they are also linked to different technical functions.

Moreover, Figure 3 in conjunction with Table 6 reveals that these functions are to be primarily associated with multiple flows coming in or, in other words, those which are highly coupled. For instance, the "cut difficult-to-reach-hair" function is associated with human force and electrical contact seeing that energy flows as well as water and hair as material flows. One exemption is the interface function associated solely with human force, for which intense joint claiming can be additionally found. I propose:

P3: The more coupled functions there are (being associated with more material, energy or signal flows), the higher the potential for creating jointly claimed limitations.

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insert Table 6 about here

4.5 Appropriability and joint claiming

So far, the analyses have concentrated on joint claiming. The question now remains: how did the patents that were filed assist Gillette in appropriating value for their Fusion razor? With this in mind, I will proceed to study competing products introduced after the Fusion in addition to their relative pricing and performance.

In Table 7, I have built on the razor test report and, in addition to the razors investigated above added three competing models that followed next in overall performance. The Fusion received an overall performance grade of 1.7 (on a scale of 1-5, with 1 equaling very good) and an average selling price of 14 EUR. The closest competitor model is the Schick/Wilkinson-Sword Hydro 5 with a performance grade of 2.2 and a selling price of about 10 EUR. Two further razors received an overall performance rating of 2.3 each with the average selling prices between 5 and 6 EUR.[13] The Quattro models come next. This means that a) Gillette has maintained a premium price for its products even four years after first introducing the Fusion razor, as the product comparison reveals, and b) to this day, the razor still outperforms the models when one considers its competitors.

[13] It is the dm/Balea Revolution 5.1 and the Rossmann Cerrus/Isana men Pace 6, private labels of European drug store chains, supposedly manufactured by a subsidiary of Energizer Holdings (which also owns Schick/ Wilkinson-Sword) and Dorco from South Korea.

Overall, the competitors appear to have invented around the Fusion. While they sometimes match the number of blades, they have neither employed flexible blades nor a blade distance that allows for the effortless cleaning of the blades. The Schick/Wilkinson-Sword razors have received good grades for blade cleaning, but have performed worse in terms of skin protection (being associated with flexible blades). As it is, the Revolution 5.1 and the Quattro II even have a trimming blade but one with an entirely different design which, according to the authors' self-test, underperforms. The blade guards of the competitors have fewer and shorter fins, which might also contribute to the lower performance of the competing shavers. Overall, the patenting strategy of Gillette appears to have successfully kept competition at bay; they have neither replicated key product features, nor have they been able to achieve the performance of the Fusion.

This suggests that Gillette has been able to better prevent spillovers to others than Schick/Wilkinson-Sword. Hence, I propose:

P4: Jointly claimed limitations help in the appropriating of value.

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insert Table 7 about here

4.6 Robustness check

In a robustness check, I analyzed granted patents for the Fusion razor from both the US and the European Patent Office (EPO) with respect to joint claiming. Overall, results remain essentially the same.[14] For assessing value appropriation, I additionally built on

[14] Some patent families were granted both in the US and Europe, some in only one of these jurisdictions, and only one family in none of them. Overall, within the applications in Table 3, 77 jointly claimed limitations (double-counting included when relating to different patent family pairs) were mentioned. Within the granted US patents, 32 of the jointly claimed limitations were found, 18 were not found therein, and 27 drop out as no comparison could be performed as at least one patent from the document pair was not granted. When looking at European patents, 40 jointly claimed limitations were found, 5 were not contained in the granted patents, and 32 drop out. These findings not only imply that joint claiming appears to have been more successful at the EPO in comparison to the USPTO. It seems that the joint claiming was hardly the reason for not granting the patent and it does not prevent patentees from claiming joint limitations, meaning that the findings from Table 4 appear to be robust.

With respect to the function analysis, highly-coupled functions (such as the blades) are mentioned relatively frequently in patent applications, but with the results being somewhat mixed with granted patents (see also Table 6). US patents mention the number of blades only twice (in contrast to 5 occurrences in applications), while EPO patents mention them still five times.

citation-based measures which strongly support the prior results. The Appendix provides the specific details.

5. Discussion

The findings and their implications for theory and patent policy will now be discussed in light of the research questions, starting with interlocking patent creation, which includes a definition of interlocking patents as well. The relationship in regards to overlapping patents and value appropriation will come next, finally ending with implications for patenting practice.

5.1 Interlocking patent creation

The content analysis of the Gillette patents has demonstrated that the company has claimed certain limitations across multiple patents (as nicely demonstrated in Table 5). This joint claiming sometimes occurred in a straightforward manner (e.g. with the number of blades), in other cases more subtly (defining blade width from cleaning perspective, requiring a sufficiently *large* distance between them, and from a smooth shaving perspective, calling for a *narrow* blade distance). According to Table 5, the number of limitations jointly claimed across multiple patents is much smaller than the total number of limitations claimed per patent, while most joint claiming has taken place via dependent claims. As the jointly claimed limitations constitute only a small amount of all limitations mentioned in the patents' claims, inventing around may be easier than expected from the combinatorial approach mentioned in section 2.4. However, in practice, the effect may be less severe than it appears, seeing that many independent patent claims contain quite common limitations, in this case "razor", "blades", "housing", etc., which can hardly be invented around when making a razor. Table 8 summarizes these findings, whereas independent claims contain general limitations plus few jointly claimed ones, and few dependent claims comprise jointly claimed limitations as well. This leads to the following definition:

P5: Interlocking patents are patents containing some jointly claimed limitations, which are usually relatively small in number, and mainly comprised in dependent patent claims.

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insert Table 8 about here

Overall, the propositions so far show a relationship where function coupling induces joint claiming/interlocking patents (P3), which also depends on modular boundaries (P1), and this in turn leads to a further hypothesis:

P5: Modular boundaries moderate the relationship between function coupling and joint claiming/interlocking patents.

In order to successfully implement interlocking patents, product development and IP expertise have to closely collaborate. In this light, this work complements the literature on interactions between these two functions [47, 48], even supporting the work from Ernst and Fischer who have shown on the macro level that close collaboration enhances new product performance [49]. In addition, my findings will additionally contribute to the engineering literature on finding ways to invent around patents by means of function analysis [39, 50] [40], as the approaches used therein may help firms generate similar patents which may then be turned into interlocking ones via a claim drafting as outlined in this work.

5.2 Interlocking and overlapping patents

Table 5 illustrates that the Gillette patents are not overlapping though more joint claiming would be necessary.. In this light, overlapping patents are a special case for interlocking patents insomuch as there are extreme cases in which the amount of jointly claimed limitations needs to be much larger. The policy measures suggested so far to mitigate negative effects of overlapping patents are based on the notion that the property rights belong to different parties, thus leading to the anti-commons effect where the technological potential cannot be fully utilized through mutual blocking [51] [12]. However, once belonging to a single party, the dilemma is resolved as this party may be at liberty to fully exploit the market

potential beyond the inventions based on an extraordinarily broad patent scope. This leads to a monopoly situation with a dominant market player that is free to set high prices [52] and may hinder innovative efforts in the marketplace. This potentially calls for antitrust measures (see the Xerox case [27]) once the limitations on the market for competitors severely affect overall market prices and competition. Measures to take in this case are forcing firms to license out their IP on a non-exclusive base, perhaps in the form of a patent pool where patents are supplied by a single party only. An alternative approach for the market leader would be defensive publishing strategies that would allow for them to secure their freedom to operate, as IBM has done in the past to avoid antitrust measures [53, 54].

On the side of patent prosecution, the first challenge to address is the parallel examination of the relevant patents, preferably by the same examiner, as they represent a "single" piece of invention. This means that patent offices have to employ ex ante filtering mechanisms to recognize interlocking patents. Concerning those being filed on the same day, it is certainly more difficult to find prior art among the interlocking patents, but when filed across a certain time span, patent offices should carefully take prior patent filings of the patentee into account in order to critically assess nonobviousness of jointly claimed limitation combinations in order to prevent overly broad patents.

5.3 Interlocking patents and value appropriation

The data analyzed for Gillette and Schick/Wilkinson-Sword also suggests that the market leader has been able to appropriate value from its strategy. Function coupling influences joint claiming (see P3), which, in turn, impacts value appropriation (see P4). So, there is a chain of activities with interlocking taking a mediating part. This leads to my last proposition:

P6: Joint claiming/interlocking patents mediate(s) the relationship between function coupling and value appropriation.

Overall, the phenomenon of interlocking patents has implications for a number of value appropriation approaches. First, according to Henderson and Clark, product innovation

may consist of changes in components, changes in systems consisting of components (i.e. changes in product architecture), or both [30]. Interlocking patents help appropriate value of both product innovation types seeing that not only the components are protected in isolation (as would occur with protecting modules), but also their functional interplay, protecting the architectural design as well. Second, the findings also expand on our understanding of complex systems. Complexity is an effective isolating mechanism to protect firms' resources [55]. Imitators who wish to copy a product such as the Gillette Fusion shaver not only have to manage the complexity of copying technological coupling of components [26, 35, 56], but they also have to cope with legal claims protecting these technological components and their coupling within multiple patent rights, with the consequence being they will have to invent around such joint claiming. As complexity increases with the number of possible combinations of different elements, these legal issues added to technical ones imply that complexity may increase in scale by filing interlocking patent rights. Third, it is shown that there are more ways to appropriate value from intellectual property than by filing overlapping or e.g. application/use patents around core technology patents. Instead, interlocking patents appear to open up further avenues of protection that have been neglected in the economics and management literature so far.

5.4 Implications for practitioners

The data on Gillette suggests that interlocking patents could very well be a strong measure to better appropriate value from valuable inventions. For the successful creation of interlocking patents, function analysis helps identifying the degree of coupling of components, while modular boundaries point towards boundaries of elements to be used. Given that there is a list of elements to be claimed across various patent filings, one needs to carefully select a claim structure jointly with patent professionals where some generic components are potentially mentioned in the independent claims (in this case: razor, housing, sides of a housing, etc.). Thus further elements that are highly coupled, which stem from the same modular boundaries, and that are considered to be important from the customers'

perspective can be then inserted into dependent and independent claims. Together, they will form interlocking claim limitations that, altogether, will make it more complicated for competitors to find product variations that do not violate any patent claims from the interlocking patents. When being filed on the same day, as Gillette partially did, it becomes more complicated for the patent office to consider own prior patents as prior art, increasing the chances to obtain patent protection.

6. Conclusions

The leader in a patent race is supposed to hinder followers by filing preemptive patents. For the wet shaving market, I have analyzed a situation where the market leader continues to be known for its superior patenting strategy, namely filing interlocking patents. Derived from claim composition theory and combinatorics, I have postulated that claiming various product elements across multiple patents could very well lead to interlocking patents. I have been able to show that the market leader filed such patents (and the follower not), while modular boundaries and function coupling seemed to determine the elements to be claimed. Further, the market leader appears to have prevented competitors from being able to introduce products of similar performance, meaning that this patenting strategy may have rightly paid off.

This paper also has its limitations. First and foremost, I conducted a case study without insights from interviews, omitting the internal perspective of the company whose patent strategy I am studying. However, as I have been observing how patents were designed as they were published (and granted), omitting the observation of specific intents in the process of creating such patents does not change their final IP structure as it exists, and which still allows for the drawing of some important conclusions on how to effectively draft interlocking patents. Second, there may be other bibliometric approaches being suitable as filtering criterion for the subsequent content analysis than has been chosen for this work to better assist in detecting possible interlocking patents, and as such they may have delivered other results. However, it seems unlikely that they would have substantially altered the overall results

obtained in this work as there are already quite a number of jointly claimed elements that could have already been studied. Third, I have analyzed how jointly claimed elements were obtained and I have demonstrated that competitors did not in any way introduce a product of similar performance, which has potentially allowed Gillette to set higher prices than its competitors with fewer spillovers to other companies occurring. While this case has shown how interlocking patents are possibly created, the nature of this work does not allow assessing how well the mechanisms can perform in comparison to other IP strategies, which remains a task for future quantitative research. Such research might replicate these outcomes for other industries as well, and qualitatively test the propositions set forth in this work.

Appendix

Data processing

I studied the drawings, descriptions, and particularly the claims of the patent documents as they define the legal scope's boundaries, searching for the same or similar content across the patent families. US patent *applications* formed the basis for this study, as they fully continue to reflect the intention of the applicants regarding the desired legal scope. For a robustness check, granted US and European patents (as of 2013) from Gillette were further analyzed to evaluate how far the claims from the patent applications were actually granted.[15] 17 out of 22 patent families in each jurisdiction had granted patents, but it was only one family that did not obtain patent protection in the US and Europe simultaneously.

To reduce the amount of documents to be analyzed manually, I utilized two filters and heuristics, reducing the amount of documents pairs to be compared to 36. To arrive at this number, I chose two complimentary [57] approaches to identify similarities between documents: citation analysis of backward citations (a technique which has been frequently employed to study relatedness of patent documents [58, 59]), and co-word analysis [60-62]. The words from the claims were extracted per patent document. Then, stopword lists were

[15] The Espacenet database lists the corresponding patent family members both for the US and Europe.

utilized to assist in filtering out words with very little discriminatory power. [16] Next, the words were standardized by means of a porter stemmer [64], deleting plural endings, etc. Seeing that words with a medium occurrence allow for the best in discriminating documents [65], both remaining words occurring in more than 90 percent of the document as well as the long tail of single-occurring words were erased as well. Document similarity was calculated by an asymmetric matrix (list of words vs. documents in analysis), followed by a symmetric matrix using the inclusion index [57].[17] Here, citation links between the patent documents stem from citation information from the USPTO website.[18]

Based on both the matrix with the citation ties and similarity values, the cells (relating to single patent application documents) within the matrices were grouped according to patent family information from Espacenet. When either a citation link existed between two different patent families or the inclusion-index-based similarity value was higher than 0.5, then the claims of the oldest documents from the patent families were manually compared.[19] This approach yielded the 36 document pairs for the comparison by content analysis. Even though only four (eight with respect to the follow-on model) patent families were filed by Schick/Wilkinson-Sword, the same approach was utilized here, leading to eight detailed content comparisons to perform.

The content analysis of the patents' claims differs between limitations comprising (i) of the components of a razor, such as the handle or cartridge, (ii) subassemblies (such as the blade package), and (iii) design parameters (such as a blade distance between 0.7 and 1.2 mm). Overall, the boundaries between these terms have been somewhat blurry in practice.

[16] For this procedure, three types of stopword lists were employed: First, a general one with words such as "the", "is", etc., a second with patent-specific language (such as "claim", "comprise", etc.), and third a list specific to the field of safety razors. Here, words such as "razor" do not have any discriminative power and are supposed to be deleted [63].

[17] The inclusion index measures the degree of co-occurring words over the amount of words from the larger document per document pair

[18] As the patent applications do not contain any examiner citations in contrast to granted patents (which were used where existent), I additionally extracted full text citations made by Gillette and its attorneys throughout the patent description. Patent citations, of course, are subject to various limitations described in the literature.

[19] When there was one document pair which had both a citation link and a similarity value > 0.5 simultaneously, then this document pair was chosen over the oldest from these patent families.

During content analysis, i.e. when studying the patent claims, the difficulty existed in some cases to clearly assess whether two distinct limitations (i.e. components, subassemblies or design parameters) were actually the same or not. So, to increase the reliability of the results, the decision if (and how) a limitation was claimed in two documents was based on the rating of two persons with degrees in engineering.[20] They independently studied the claims and prepared a document showing for which patent pair the same limitations could be found. This was a challenge as some patent applications comprised of more than a hundred claims, comprising hundreds of limitations mapping hundreds of elements that had to be compared against each other, leading to hundreds of comparisons to be made by the document pair. Discrepancies among the raters emerged from assessing if a limitation was being regarded as background noise (being a general part of a razor), or if it was considered rather unique for the new razor (then it might be relevant for defining joint interlocking patents). The inter-rater agreement (Cohen's kappa) was 0.25, commonly described as a fair value[21]. Next, due to the mentioned complexity of the rating, the raters discussed their findings and every disagreement in view of the product architecture in order to elicit potential misunderstandings and the generality/uniqueness of the limitations. Then, joint claiming was only considered to have existed within a document pair when the two raters agreed upon the joint limitation.

Robustness check for value appropriation

As found in prior research on value appropriation, I similarly employed the share of patent self-citations as a proxy [66] as well as their absolute number (measures I and II). In addition, another forward-citation-based measure was used that stems from the research stream of the anti-commons of scientific research. The scholars active in this field continue to be interested in assessing the impact of patenting of academic research. They have looked at

[20] The author as first rater holds a master's equivalent in engineering and management. The second rater holds a masters' equivalent and a PhD in mechatronics (electrical plus mechanical engineering). Both had filed patents themselves before.

[21] As the dataset analyzed here was already filtered by the similarity analysis, which was supposed to eliminate all comparisons that have no value, the theoretical inter-rater agreement for comparing all documents available should be much higher. In addition, the results are highly sensitive to a specific limitation, namely the connecting structure connecting the handle and the cartridge (being discussed by raters), which alone is responsible for a theoretical delta in kappa of 0.15.

pieces of knowledge that were both patented and published, finding that citations to papers decline once it had become obvious that this research was patented [67]. Other work could not only confirm these effects, but also found that broader patents as well as patent thickets led to less paper citations [68]. In other words, the more protected some piece of knowledge, the fewer knowledge spillovers. Patent citations are a prominent way of measuring spillovers in the technical domain [69]. Hence, if interlocking patents effectively help appropriate value, they should be reducing spillovers, leading to less absolute citations from other companies in comparison to non-interlocking patents, serving as third measure for value appropriation (measure III). For the bibliometric measures, not only were total citations received taken as a basis, but also a 5-year citation window was employed as typically found in the literature.

The results are presented in Table 9. First, the self-citation ratio (share of self-citations received) as well as the absolute number of Gillette's self-citation was compared to that from Schick/Wilkinson-Sword, which patents showed no joint claiming effects, as well as the amount of patent forward citations received by external patentees (i.e. the total forward citations net of self-citations). In all three cases, the results indicate that Gillette might have been able to appropriate value from its strategy: The average self-citation ratio for Gillette is 4 times the ratio of Schick (comparison of means: 59 percent vs. 14 percent). In absolute numbers, Gillette cites itself, on average, three times as much as Schick does (comparison of means: 4.96 times versus 1.57 times). And again, when looking at citations received from third parties, Schick receives about 2.5 times the amount from Gillette (comparison of means: 9 vs. 3.53).

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insert Table 9 about here

Acknowledgements

The author would like to thank Clemens Cepnik and Cord Winkelmann for help with coding the patent documents and developing the function analysis, and participants of the TIE Conference 2012 in Hamburg, the DRUID Conference 2012 in Copenhagen, the Academy of Management Annual Meeting 2012 in Boston, and the EPIP Conference 2014 in Brussels as

well as Christoph Hook, Christoph Schreiter, Bernhard Lohnert, Robert Harrison, Karin Beukel, Jana Thiel and Sascha Walter for comments on prior versions of the manuscript.

References

[1] J. A. Schumpeter, *The theory of economic development*, Cambridge, Mass.: Harvard University Press, 1934.
[2] J. A. Schumpeter, *Capitalism, Socialism and Democracy,* New York: Harper, 1942.
[3] G. C. Loury, "Market structure and innovation," *The Quarterly Journal of Economics,* vol. 93, no. 3, pp. 395-410, 1979.
[4] T. Lee, and L. L. Wilde, "Market structure and innovation: A reformulation," *Quarterly Journal of Economics,* vol. 94, no. 2, pp. 429-436, 1980.
[5] C. Harris, and J. Vickers, "Patent races and the persistence of monopoly," *Journal of Industrial Economics,* vol. 33, no. 4, pp. 461-481, 1985.
[6] C. Harris, and J. Vickers, "Perfect Equilibrium in a Model of a Race," *Review of Economic Studies,* vol. 52, no. 2, pp. 193, 1985.
[7] R. J. Gilbert, and D. M. G. Newbery, "Preemptive patenting and the persistence of monopoly," *American Economic Review,* vol. 72, no. 3, pp. 514-526, 1982.
[8] E. Mansfield, M. Schwartz, and S. Wagner, "Imitation costs and patents: an empirical study," *Economic Journal,* vol. 91, no. 364, pp. 907-918, 1981.
[9] D. J. Teece, "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy," *Research Policy,* vol. 15, no. 6, pp. 285-305, 1986.
[10] J. S. Harrison, M. A. Hitt, R. E. Hoskisson *et al.*, "Resource complementarity in business combinations: Extending the logic to organizational alliances," *Journal of Management,* vol. 27, no. 6, pp. 679-690, 2001.
[11] A. Layne-Farrar, and J. Lerner, "To join or not to join: Examining patent pool participation and rent sharing rules," *International Journal of Industrial Organization,* vol. 29, no. 2, pp. 294-303, 2011.
[12] C. Shapiro, "Navigating the patent thicket: cross licenses, patent pools, and standard setting," *Innovation Policy and the Economy,* vol. 1, pp. 119-150, 2001.
[13] R. J. Gilbert, and M. L. Katz, "Efficient division of profits from complementary innovations," *International Journal of Industrial Organization,* vol. 29, no. 4, pp. 443-454, 2011.
[14] P. C. Grindley, and D. J. Teece, "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics," *California Management Review,* vol. 39, no. 2, pp. 8-41, 1997.
[15] G. Pisano, "Profiting from innovation and the intellectual property revolution," *Research Policy,* vol. 35, no. 8, pp. 1122-1130, 2006.
[16] A. Arundel, G. van de Paal, and L. Soete, *Innovation strategies of Europe's largest industrial firms: results of the survey for information sources, public research, protection of innovations and government programmes,* Maastricht: MERIT, 1995.
[17] W. M. Cohen, R. R. Nelson, and J. Walsh, "Protecting Their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or Not)," *NBER working paper,* 2000.
[18] R. C. Levin, A. K. Klevorick, R. R. Nelson *et al.*, "Appropriating the returns from industrial research and development," *Brookings Papers on Economic Activity,* vol. 3, pp. 783-831, 1987.
[19] O. Granstrand, *The economics and management of intellectual property,* Cheltenham: Edgar Elgar, 1999.
[20] H. J. Knight, *Patent strategy for researchers and research managers,* 2nd ed., Chichester: Wiley, 2001.

[21] K. G. Rivette, and D. Kline, "Discovering New Value in Intellectual Property," *Harvard Business Review,* vol. 78, no. 1, pp. 54-67, 2000.
[22] C. Sternitzke, "An exploratory analysis of patent fencing in pharmaceuticals: The case of PDE5 inhibitors," *Research Policy,* vol. 42, no. 2, pp. 542-551, 2013.
[23] M. Blaxill, and R. Eckardt, *The invisible edge: taking your strategy to the next level using intellectual property,* New York: Portfolio Trade, 2009.
[24] D. M. De Carolis, "Competencies and Imitability in the Pharmaceutical Industry: An Analysis of Their Relationship with Firm Performance," *Journal of Management,* vol. 29, no. 1, pp. 27-50, 2003.
[25] G. D. Markman, M. I. Espina, and P. H. Phan, "Patents as Surrogates for Inimitable and Non-Substitutable Resources," *Journal of Management,* vol. 30, no. 4, pp. 529-544, 2004.
[26] F. K. Pil, and S. S. Cohen, "Modularity: Implications for imitation, innovation, and sustained advantage," *Academy of Management Review,* vol. 31, pp. 995-1011, 2006.
[27] T. F. Bresnahan, "Post-entry competition in the plain paper copier market," *The American Economic Review,* vol. 75, no. 2, pp. 15-19, 1985.
[28] A. A. Bright, *The electric-lamp industry,* New York: Macmillan, 1949.
[29] K. T. Ulrich, "The role of product architecture in the manufacturing firm," *Research Policy,* vol. 24, no. 3, pp. 419-440, 1995.
[30] R. M. Henderson, and K. B. Clark, "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly,* vol. 35, no. 1, pp. 9-30, 1990.
[31] K. T. Ulrich, and D. J. Ellison, "Holistic customer requirements and the design-select decision," *Management Science,* vol. 45, no. 5, pp. 641-658, 1999.
[32] D. Campagnolo, and A. Camuffo, "The concept of modularity in management studies: a literature review," *International Journal of Management Reviews,* vol. 12, no. 3, pp. 259-283, 2010.
[33] F. Salvador, "Toward a product system modularity construct: literature review and reconceptualization," *IEEE Transactions on Engineering Management,* vol. 54, no. 2, pp. 219-240, 2007.
[34] J. K. Gershenson, G. J. Prasad, and Y. Zhang, "Product modularity: definitions and benefits," *Journal of Engineering Design,* vol. 14, no. 3, pp. 295-313, 2003.
[35] S. K. Ethiraj, D. Levinthal, and R. R. Roy, "The dual role of modularity: Innovation and imitation," *Management Science,* vol. 54, no. 5, pp. 939-955, 2008.
[36] C. Y. Baldwin, and K. B. Clark, *Design rules: The power of modularity*, Cambridge, MA: MIT Press, 2000.
[37] C. A. Cotropia, "Patent claim interpretation methodologies and their claim scope paradigms," *William and Mary Law Review,* vol. 47, no. 49, pp. 49-133, 2005.
[38] P. N. Katz, and R. R. Riddle, "Desgning around a United States Patent," *S. Tex. L. Rev.,* vol. 45, pp. 647, 2003.
[39] M. Li, X. Ming, M. Zheng *et al.*, "A framework of product innovative design process based on TRIZ and Patent Circumvention," *Journal of Engineering Design,* vol. 24, no. 12, pp. 830-848, 2013.
[40] M. Li, X. Ming, L. He *et al.*, "A TRIZ-based Trimming method for Patent design around," *Computer-Aided Design,* vol. 62, pp. 20-30, 2015.
[41] S.-J. Wang, "Designing around patents: a guideline," *Nature biotechnology,* vol. 26, no. 5, pp. 519, 2008.
[42] J. Henkel, C. Y. Baldwin, and W. C. Shih, "IP modularity: Profiting from innovation by aligning product architecture with intellectual property," *California Management Review,* vol. 55, no. 4, pp. 65-82, 2013.
[43] K. M. Eisenhardt, "Building theories from case study research," *Academy of Management Review,* vol. 14, no. 4, pp. 532-550, 1989.
[44] A. M. Pettigrew, "Longitudinal field research on change: theory and practice," *Organization Science,* vol. 1, no. 3, pp. 267-292, 1990.

[45] P. Hingley, and W. G. Park, "Patent family data and statistics at the European Patent Office."
[46] G. Pahl, W. Beitz, L. Blessing *et al.*, *Engineering design: a systematic approach*, 3 ed., London: Springer Verlag, 2007.
[47] D. Somaya, I. O. Williamson, and X. Zhang, "Combining Patent Law Expertise with R&D for Patenting Performance," *Organization Science,* vol. 18, no. 6, pp. 922-937, 2007.
[48] M. Reitzig, and P. Puranam, "Value appropriation as an organizational capability: the case of IP protection through patents," *Strategic Management Journal,* vol. 30, no. 7, pp. 765-789, 2009.
[49] H. Ernst, and M. Fischer, "Integrating the R&D and patent functions: implications for new product performance," *Journal of Product Innovation Management,* vol. 31, no. S1, pp. 118-132, 2014.
[50] Y.-C. Hung, and Y.-L. Hsu, "An integrated process for designing around existing patents through the theory of inventive problem-solving," *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* vol. 221, no. 1, pp. 109-122, January 1, 2007, 2007.
[51] M. A. Heller, and R. S. Eisenberg, "Can Patents Deter Innovation? The Anticommons in Biomedical Research," *Science,* vol. 280, no. 5364, pp. 698, 1998.
[52] R. P. Merges, and R. R. Nelson, "On the complex economics of patent scope," *Columbia Law Review,* vol. 90, no. 4, pp. 839-916, 1990.
[53] A. Bhaskarabhatla, and E. Pennings, "Defensive disclosure of patentable inventions under antitrust enforcement," *Industry and Innovation,* vol. 21, no. 7-8, pp. 533-552, 2014.
[54] A. Bhaskarabhatla, and D. Hegde, "An organizational perspective on patenting and open innovation," *Organization Science,* vol. 25, no. 6, pp. 1744-1763, 2014.
[55] S. K. McEvily, and B. Chakravarthy, "The persistence of knowledge-based advantage: an empirical test for product performance and technological knowledge," *Strategic Management Journal,* vol. 23, no. 4, pp. 285-306, 2002.
[56] J. H. Mikkola, and O. Gassmann, "Managing modularity of product architectures: toward an integrated theory," *IEEE Transactions on Engineering Management,* vol. 50, no. 2, pp. 204-218, 2003.
[57] C. Sternitzke, and I. Bergmann, "Similarity measures for document mapping: a comparative study on the level of an individual scientist," *Scientometrics,* vol. 78, no. 1, pp. 113-130, 2009.
[58] G. Clarkson, and D. DeKorte, "The problem of patent thickets in convergent technologies," *Annals of the New York Academy of Sciences,* vol. 1093, pp. 180-200, 2006.
[59] G. von Graevenitz, S. Wagner, and D. Harhoff, "Incidence and growth of patent thickets - The impact of technological opportunities and complexity," *Journal of Industrial Economics,* vol. 61, no. 3, pp. 521-563, 2013.
[60] A. Rip, and J. P. Courtial, "Co-word maps of biotechnology: An example of cognitive scientometrics," *Scientometrics,* vol. 6, no. 6, pp. 381-400, 1984.
[61] M. Callon, J. P. Courtial, and F. Laville, "Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemistry," *Scientometrics,* vol. 22, no. 1, pp. 155-205, 1991.
[62] S. Lee, B. Yoon, and Y. Park, "An approach to discovering new technology opportunities: Keyword-based patent map approach," *Technovation,* vol. 29, no. 6-7, pp. 481-497, 2009.
[63] B. Jarneving, "A comparison of two bibliometric methods for mapping of the research front," *Scientometrics,* vol. 65, no. 2, pp. 245-263, 2005.
[64] M. Porter, "An Algorithm for Suffix Stripping Program," *Program,* vol. 14, no. 3, pp. 130-137, 1980.
[65] A. Blanchard, "Understanding and customizing stopword lists for enhanced patent mapping," *World Patent Information,* vol. 29, no. 4, pp. 308-316, 2007.

[66] M. Trajtenberg, R. Henderson, and A. Jaffe, "University Versus Corporate Patents: A Window on the Basicness of Invention," *Economics of Innovation and New Technology,* vol. 5, no. 1, pp. 19-50, 1997.
[67] F. Murray, and S. Stern, "Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis," *Journal of Economic Behavior & Organization,* vol. 63, no. 4, pp. 648-687, 2007.
[68] K. G. Huang, and F. Murray, "Does Patent Strategy Shape the Long-Run Supply of Public Knowledge? Evidence from Human Genetics," *Academy of Management Journal,* vol. 52, no. 6, pp. 1193-1221, 2009.
[69] A. B. Jaffe, "Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value," *American Economic Review,* vol. 76, no. 5, pp. 984-1001, 1986.

Figure 1: Patent data selection, filtering and processing

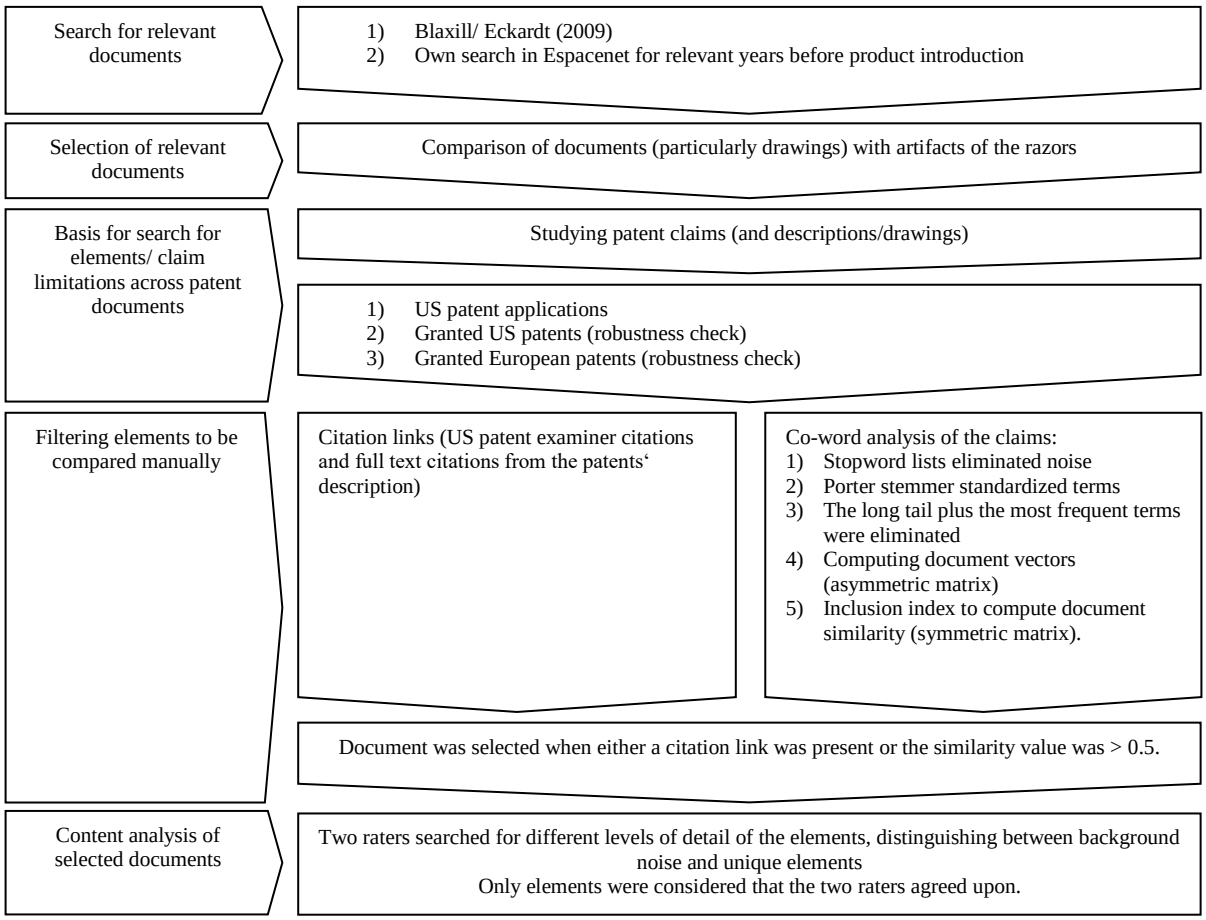

Figure 2: The Gillette Fusion razor – electric version. (a) view from top, (b) cartridge, (c) cross-section of cartridge and cartridge connection.

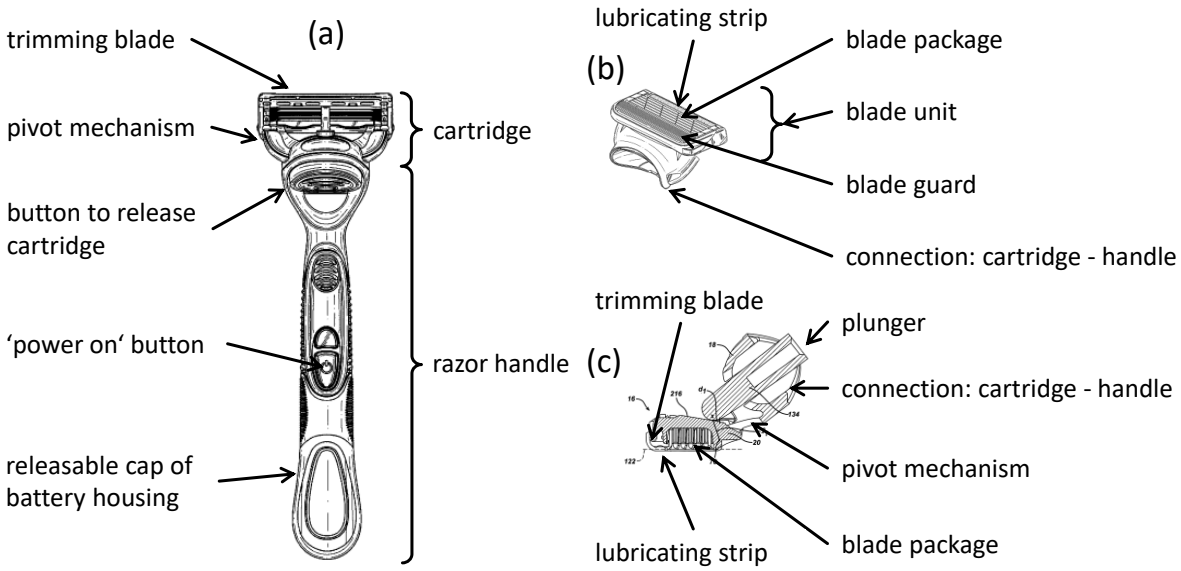

Figure 3: Function analysis of the Gillette Fusion razor (electric version), following Pahl, Beitz, Blessing, Feldhusen, Grote and Wallace [46].
See extra file

Table 1: Patents, components/subassemblies/design parameters and coding: Gillette Fusion

Components/subassemblies	Subassemblies/design parameters	Family ID	DocID	US pat. granted	US pat. no.
Blade design		2	7	Yes	US6629475
			8	Yes	US20040221460
			9		US20050229399
Blade coating	Intermed. layer of Cr-doped C-containing mat.	3	10		US20040172832
			11		US20060265885
Blade coating	intermediate layer of CrN	4	12		US20060277767
Blade package	Blade distance	1	1	-	US20020144404
			2	-	US20040060176
			3	-	US20050108882
			4	-	US20060101647
	Flexible blades		5	-	US20090126196
			6	Yes	US20100269351
Blade package	connector for supporting metal stripe	5	13	Yes	US20050172494
			14	Yes	US20070266565
			15	Yes	US20100005664
Blade package	blade dimensions of supporting metal stripe	6	16	Yes	US20050198828
			17		US20070011880
			18		US20070028450
Blade package	single blade holder	7	19	Yes	US20050172489
Blade package	trimming blade holder, corrosion protection	8	20	Yes	US20050198842
	corrosion protection		21	Yes	US20060174488
	Holder		22	Yes	US20070062044
Trimming blade	Trimming blade + blade package	9	23	Yes	US20050039337
	Trimming blade: canal for rinsing blade		24		US20060196054
			25		US20080172878
	Trimming blade: trimming comb guard		26	Yes	US20090077809
Trimming blade	Trimming blade alignment	10	27	Yes	US20080010833
			28	Yes	US20090205207
Blade guard	distance + force distribution of razor	11	29		US20050198830
			30		US20060179661
Blade guard		12	31	Yes	US20050223568
Pivot mechanism		13	32	Yes	US20050198839
			33		US20060162167
Handle + cartridge connect.	release button	14	34	Yes	US20050198840
			35		US20070193042
Handle + cartridge connect.	Fingerpad	15	36		US20080022529
			37		US20050198829
Handle + cartridge connect.	ejection mechanism	16	38	Yes	US20050198841
Cartridge dispenser		17	39		US20050198825
			40		US20080201957
Circuit + switch	Circuit/switch in wet powered razor	18	41		US20070050981
	Circuit in wet powered razor		42	Yes	US20070050982
	Circuit/switch in wet powered razor		43	Yes	US20080172880
Circuit + switch	Switch housing of wet powered razor	19	44		US20070050996
Battery housing	closing system	20	45	Yes	US20070050983
Battery housing	Battery housing in grip + actuator	21	46		US20070050995
	Battery housing in grip + actuator		47	Yes	US20080110034
	Battery housing in grip + actuator		48		US20100325872
Battery housing	fixture in handle	22	49	Yes	US20070050997

Table 2: Patents, components/subassemblies/design parameters and coding: Schick Quattro (families 1-4) and Quattro II (families 1-3, 4-8)

Components/subassemblies	Subassemblies/design parameters	Family ID	DocID	US pat. granted	US pat. no.
Cartridge	Blade exposure	1	1		US2002157259
			2	Yes	US2004221455
			3		US2006112564
			4	Yes	US2008034593
	Blade span		5	Yes	US2003217469
	Blade span + blade exposure		6		US2005015991
	Blade carrier: platform + cartridge with platform	2	7		US2004255467
	Blade carrier: cartridge with platform		8	Yes	US2007256303
Pivot mechanism		3	9		US2004181954
Handle		4	10		US2004216311
Blades	Titanium and PTFE blade coating	5	11		US2007186424
Cartridge	Trimming blade – trimming guard	6	12		US2008250647
Trimming handle	Trimming handle including various dimensions	7	13		US2009000124
Trimming handle	Trimming handle	8	14		US2009000125

Table 3: Linkage between document pairs and components/subassemblies/design parameters claimed jointly for the Gillette Fusion power razor

document pair doc-doc	patent family fam-fam	links connecting components/subassemblies*	jointly claimed subassemblies/design parameters	USPTO: granted patents	in EPO: granted patent
1-14	1-5	blade distance – blade package: connector for supporting metal stripe	• number of blades	• yes	• yes
1-16	1-6	blade distance – blade package: dimensions of blades welded onto a supporting metal stripe	• number of blades	• no	• yes
			• angle of blade support (direct (1) + supplementary (16))	• no	• no
			• blade distance (direct (1) + distance of blade set (16))	• no	• yes
			• bent blade support	• yes	• yes
1-20	1-8	blade distance – blade package: trimming blade holder, corrosion protection	• design of blade guard	• yes	• yes
			• blade support located movably in slots	• no	• no
1-23	1-9	blade distance – trimming blade + blade package	• number of blades	• yes	• yes
1-31	1-12	blade distance – blade guard	• multiple fins of the elastomeric blade guard	• no	• yes
1-34	1-14	blade distance – handle + connection to cartridge: release button	-		
1-38	1-16	blade distance – handle + connection to cartridge: ejection mechanism	• blade guard with elastomeric material	• no	• no
7-16	2-6	blade design – blade package: dimensions of blades welded onto a supporting metal stripe	• angle of blade support	• no	• yes
			• design of cutting member (blade + blade support)	• yes	• yes
7-23	2-9	blade design – trimming blade + blade package	-		
7-31	2-12	blade design – blade guard	-		
7-34	2-14	blade design – handle + connection to cartridge: release button	-		
7-38	2-16	blade design – handle + connection to cartridge: ejection mechanism	-		
14-16	*5-6*	*blade package: connector for supporting metal stripe – blade package: dimensions of blades welded onto a supporting metal stripe*	• design of cutting member (blade + blade support)	• yes	• yes
			• blades are welded onto blade support	• yes	• yes
14-19	*5-7*	*blade package: connector for supporting metal stripe – blade package: single blade holder*	• connection of longitudinal ends of blades/blade support	• yes	• yes
			• number of blades	• no	• yes
			• cutting edges in a common plane	• no	• yes
			• subassembly has snap-fitting structure for connection to razor housing	• no	• yes
			• housing with a recess to incorporate subassembly	• yes	• yes
			• support of cutting member has longitudinal ends	• yes	• yes
20-32	8-13	blade package: trimming blade holder, corrosion protection – pivot mechanism	• trimming unit	• yes	• yes
20-39	8-17	blade package: trimming blade holder, corrosion protection – cartridge dispenser	• trimming unit	17 not granted	• yes
23-27	*9-10*	*trimming blade + blade package – trimming blade alignment*	• trimming unit:		10 not granted
			○ embedded trimming blade	• yes	
			○ angle indicator of trimming blade	• yes	
			• number of blades	• no	
26-36	9-15	trimming blade: trimming comb guard – handle + connection to cartridge: fingerpad	• number of blades	15 not granted	• yes
			• trimming unit:		• no
			○ stop position for shaving head when trimming blade is used		
29-31	*11-12*	*blade guard: distance + force distribution of razor – blade guard*	• elastomeric member with fins	11 not granted	11 not granted
			• fins longer than blades		
			• elastomeric member extends perpendicular to the blade axis		
			• shore A hardness of fins between 28 and 60		
			• leading portion of elastomeric member is unsupported along its length		
			• leading portion is flexible upon skin contact		
			• leading portion has decreasing thickness to its middle		
			• blade unit can pivot with respect to handle		
			• trimming unit		

29-34	11-14	blade guard: distance + force distribution of razor – handle + connection to cartridge: release button	• blade unit can pivot with respect to handle	11 not granted	11 not granted
29-39	11-17	blade guard: distance + force distribution of razor – cartridge dispenser	-	-	-
31-33	12-13	blade guard – pivot mechanism	• trimming unit • connecting structure • blade unit can pivot with respect to handle • permanent or releasable connection of cartridge and handle	• yes • yes • yes • no	• yes • yes • yes • yes
31-34	12-14	blade guard – handle + connection to cartridge: release button	• blade unit can pivot with respect to handle	• yes	• no
31-39	12-17	blade guard – cartridge dispenser	• connecting structure	• yes	• yes
32-34	13-14	pivot mechanism – handle + connection to cartridge: release button	• connecting structure • pivotal connection • releasable connection	• yes • yes • no	• yes • yes • yes
32-38	13-16	pivot mechanism – handle + connection to cartridge: ejection mechanism	• connecting structure • pivotal connection • releasable connection	• yes • yes • no	• yes • yes • yes
33-39	13-17	pivot mechanism – cartridge dispenser	• trimming unit ○ blade • connecting structure	17 not granted	• yes • yes
34-38	*14-16*	*handle + connection to cartridge: release button – handle + connection to cartridge: ejection mechanism*	• release button	• yes	• yes
34-39	14-17	handle + connection to cartridge: release button – cartridge dispenser	• connecting structure	17 not granted	• yes
34-46	14-21	handle + connection to cartridge: release button – battery housing in grip + actuator	-	-	-
38-39	16-17	handle + connection to cartridge: ejection mechanism – cartridge dispenser	• connecting structure	17 not granted	• yes
44-46	19-21	switch housing of wet powered razor – battery housing in grip + actuator	• grip portion and battery cover form a water-tight unit • all components for battery-powered functionality within grip • subassembly within grip comprising carrier + switch or electronic on carrier • removable mounted battery cover • sealing member between battery cover and grip • battery cover permanently welded to the grip tube	19 not granted	21 not granted
44-49	19-22	switch housing of wet powered razor – battery housing in grip: fixture in handle	• housing comprises grip portion + battery cover + carrier • grip portion + battery cover form water-tight unit • all components for battery-powered functionality within grip • electronics mounted on carrier	19 not granted	• yes • yes • yes • yes
45-46	*20-21*	*battery housing in grip: closing system - battery housing in grip + actuator*	• winding for battery cover and housing • spring element for axial force on battery • electrical connection between battery cover and grip • electronics mounted on carrier • vibration caused by electronics • pair of battery clamp fingers that exert force against battery	• yes • yes • yes • yes • no • yes	20, 21 not granted
45-49	*20-22*	*battery housing in grip: closing system - battery housing in grip: fixture + handle*	• pair of battery clamp fingers that exert force against battery • spring force of clamp fingers is 0.5N @ 9.5mm battery diameter, less than 2.5N when 10.5mm battery diameter • all components for battery-powered functionality within grip • electronics mounted on carrier • removable mounted battery cover	• yes • yes • no • no • yes	20 not granted
47-49	*21-22*	*battery housing in grip+ actuator - battery housing in grip: fixture + handle*	• pair of battery clamp fingers that exert force against battery • all components for battery-powered	• yes • no	21 not granted

*links between documents of the same components/design parameters in italics
Number of blades only mentioned when in separate dependent claim (not as part of a complex main claim), except for family #1 where the number of blades plays a crucial role.
If several documents within one family form a link then only those documents with the lowest ID are compared (i.e. the oldest).
When in one family both word-similarity > 0.5 and a citation link existed, then this pair ceteris paribus was chosen.
For the robustness check, granted patents from the same family were checked.

Table 4: Matrix indicating the links of jointly claimed components/subassemblies that possibly form interlocking patents

Modules or components	**subassemblies**	**ID**	**3**	**4**	**2**	**11**	**12**	**1**	**5**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**18**	**19**
blades	blade coating	3	-																					
	blade coating	4		-																				
	blade design	2			-																			
cartridge	blade guard	11				-																		
	blade guard	12				9	-																	
	blade package	1					1	-																
	blade package	5						1	-															
	blade package	6			2			4	2	-														
	blade package	7							6		-													
	blade package	8						2				-												
	trimming blade	9						1					-											
	trimming blade	10											2	-										
	pivot mechanism	13					4					1			-									
	handle_cartr. connect.	14				1	1								3	-								
	handle_cartr. connect.	15											2				-							
	handle_cartr. connect.	16						2							3	1		-						
	cartridge dispenser	17					1					1			2	1		1	-					
handle	battery housing	20																		-				
	battery housing	21																		6	-			
	battery housing	22																		5	2	-		
	circuit switch	18																					-	
	circuit switch	19																			6	4		-

Table 5: Example of jointly claimed limitations for two document pairs. Joint subassemblies/design parameters appear bold.

Pair	Claims	Claims
31-33	1. A shaving blade unit comprising a plastic housing having a front portion and a rear portion and two side surfaces extending from the front portion to the rear portion, the housing having a length extending from one side surface to the other side surface, one or more shaving blades positioned between the front portion and the rear portion, the one or more blades having a blade length extending along respective one or more parallel blade axes, and a guard at the front portion of the housing, the guard including an elastomeric member that extends along a guard axis that is parallel to the respective one or more blade axes, the elastomeric member having a length along the guard axis that is greater than or equal to the blade length. 31. The shaving blade unit of claim 1, wherein the housing is connected to a **pivoting structure to permit the one or more blades to pivot with respect to a handle**. 32. The shaving blade unit of claim 1 further comprising a **trimming assembly** connected to the housing. 99. A shaving razor comprising: a handle; and a shaving cartridge including **connection structure connecting the cartridge to the handle**, the shaving cartridge comprising a plastic housing having a front portion and a rear portion and two side surfaces extending from the front portion to the rear portion, the housing having a length extending from one side surface to the other side surface, one or more shaving blades positioned between the front portion and the rear portion, the one or more blades having a blade length extending along respective one or more parallel blade axes, and a guard at the front portion of the housing, the guard including an elastomeric member that extends along a guard axis that is parallel to the respective one or more blade axes, the elastomeric member having a length along the guard axis that is greater than or equal to the blade length. 100. The shaving razor of claim 99, wherein the **shaving cartridge is permanently connected to the handle**. 101. The shaving razor of claim 99, wherein the **shaving cartridge is removably connected to the handle** by the connection structure.	1. A shaving cartridge comprising: a housing having a front edge and a rear edge; one or more shaving blades between the front edge and the rear edge; and a **connecting member pivotally connected to the cartridge housing**, the connecting member having a load-bearing surface arranged and configured to contact the housing only when the housing is pivoted beyond a limit angle that is greater than the normal pivot angle. 12. The shaving cartridge of claim 1 further comprising a **trimming assembly** connected to the housing. 24. A shaving razor comprising: a handle; and a shaving cartridge including a **connecting member for connecting the cartridge to the handle**, the shaving cartridge comprising a housing having a front edge and a rear edge; one or more shaving blades between the front edge and the rear edge; and **the connecting member pivotally connected to the cartridge housing**, the connecting member having a load-bearing surface arranged and configured to contact the housing only when the housing is pivoted beyond a limit angle that is greater than the normal pivot angle. 25. The shaving razor of claim 24, wherein the **shaving cartridge is permanently connected to the handle**. 26. The shaving razor of claim 24, wherein the **shaving cartridge is releasably connected to the handle**.
45-49	1. A battery operated razor comprising a housing including a grip portion defining a chamber having an interior wall, and a **battery cover removably mounted on the grip portion**; the housing being configured to contain one or more batteries, and a closing system, including a first component within the battery cover, and a second component secured to the interior wall of the grip portion, the first component being configured to move axially within the battery cover during engagement of the battery cover with the grip portion, and being biased toward a predetermined axial position. 18. The razor of claim 1 further comprising, within the housing, a carrier including a **pair of battery clamp fingers** configured to **exert a clamping force against the battery** when the battery is in place in the housing. 19. The razor of claim 18 wherein each finger exerts a **spring force of about 0.5 N when a battery having a diameter of 9.5** mm is inserted into the housing, and **less than about 2.5 N when a battery having a diameter of 10.5 mm** is inserted into the housing. 8. The razor of claim 1 further comprising **electronic components disposed within the chamber**. 9. The razor of claim 8 wherein the second component extends from a **carrier on which the electronics are mounted within the chamber**.	1. A handle for a razor having a battery-powered functionality, comprising: a housing constructed to hold a battery, and within the housing, a carrier including a **pair of battery clamp fingers** configured to **exert a clamping force against the battery** when the battery is in place in the housing. 4. The razor handle of claim 1 wherein each finger exerts a **spring force of about 0.5 N when a battery having a diameter of 9.5 mm** is inserted into the housing, and **less than about 2.5 N when a battery having a diameter of 10.5 mm** is inserted into the housing. 14. The razor of claim 12 further comprising a plurality of components that provide the battery-powered functionality, wherein **all components of the razor that provide the battery-powered functionality are disposed within the grip portion**. 16. The razor of claim 12 wherein the **battery cover is removably mounted on the grip portion**. 17. The razor of claim 1 further comprising **electronic components, mounted on the carrier**, in electrical communication with the battery.

Table 6: Linking functions to joint claiming of design parameters (if occurring > 1)

		# associated joint claiming			Coupling
Function type	Function name	total	within component	across component	#flows coming in
Basic	Cut hair effectively	6	4	2	7
Auxiliary	Distribute force more uniformly […]	9	7	2	2
Auxiliary	Cut difficult-to-reach hair	7	2	5	3
Auxiliary	Adjust blade unit to face contours […]	6	2	4	2
Auxiliary	Prevent movement of battery	4	4	-	1
Auxiliary	Allow removal of battery, seal from water	3	1	2	1
Auxiliary	Screwed contact with arrestor	2	2	-	1
Adaptive	Connect cartridge + handle incl. release button	15	2	11	1
Special	Protect electronics + battery from water	5	-	5	2

Table 7: Test results of the razors (excerpt).

Characteristics (weight for overall test result)	Gillette Fusion Power	Wilkinson-Sword Hydro5	dm/Balea men Revolution 5.1	Rossmann Cerrus/ Isana men Pace 6	Wilkinson-Sword Quattro II	Wilkinson-Sword Quattro
avrg. price [€]	14.2	9.95	4.95	6.00	10.90	6.05
overall grade*	1.7	2.2	2.3	2.3	2.3	2.4
shaving performance (35%)	1.7	2.3	2.3	2.2	2.2	2.3
i.e. difficult-to-reach parts	good	satisfactory	good	good	good	good
i.e. shaving comfort	good	good	good	good	good	good
skin protection (35%)	1.6	2.0	2.4	2.0	2.2	2.4
durability of blades (10%)	2.0	2.5	2.0	3.5	2.0	3.0
use (20%)	1.8	2.3	2.3	2.3	2.6	2.4
thereof cleaning	good	good	fair	fair	good	good
#blades	5	5	5	6	4	4
trimming blade	yes	no	yes	no	yes	no
pivoting blade unit	yes	yes	yes	yes	yes	yes

Source: TEST 12/2010. Die schärfsten Klingen. Stiftung Warentest, pp. 70-76.
* the lower the better.

Table 8: Structure for formulating interlocking patents.

Claim type	Limitations
Independent claim	General limitations with little discriminatory power Few limitations jointly claimed across several patents
Dependent claim $n_1 \ldots n_i$	Unique elements as typical for claiming
Dependent claim $m_1 \ldots m_j$	Few limitations jointly claimed across several patents

$i = 1, 2, \ldots; j = 1, 2, \ldots$

Table 9: Bibliometric measures for value appropriation: test for unequal variance

Company	Gillette	Schick/Wilkinson-Sword	|t|
N	49	14	
Ratio of self-citations			
total: mean (std. dev.)	0.59 (0.33)	0.14 (0.21)	6.13
5 year citation window: (std. dev.)	0.59 (0.34)	0.23 (0.35)	3.45
Self-citations received			
total: mean (std. dev.)	4.96 (4.75)	1.57 (2.44)	3.60
5 year citation window: (std. dev.)	4.29 (4.16)	1.57 (2.44)	3.08
External citations received			
total: mean (std. dev.)	3.53 (3.83)	9.00 (6.03)	3.22
5 year citation window: (std. dev.)	2.90 (3.04)	7.00 (5.29)	2.77

5 year citation window (publication date of patent application to priority date of citing patent) as a robustness check