April 2001

CO-EVOLUTION IN TECHNOLOGICAL DEVELOPMENT

The role of friction

by

Håkan Håkansson
Department of Marketing
Norwegian School of Management, BI

Alexandra Waluszewski
Department of Business Studies
University of Uppsala

Abstract

The empirical observation that resources which together forms certain technological systems tends to hold together and are difficult to change have been stressed by researchers from several different disciplines, for example by Rosenberg (1982), Hughes (1988), Biejker (1997) and Latour (1997). This was also one of the main observations made in a deep empirical study of how new "green" demands affected the supply and use of high quality printing paper. The focal suppliers of the study were some Swedish and Finnish pulp and paper companies, while the users were large publishers, printers and catalogue produces, such as Axel Springer Verlag and IKEA.

One important observation was that despite really strong intentions to replace resources that was regarded as environmentally unacceptable, rather often these seemed to be "cemented" onto other resources they direct or indirect were interacting with. The most frequently used concept when dealing with such difficulties to change established solutions is "inertia", which connotes an indisposition to motion or change.

However, there where also another main empirical observation made, which appeared as much more difficult to cover with the concept of inertia: Sometimes certain technological solutions building on resource combinations that had hold together for decades, appearing as able to resist almost any intention to create change, suddenly let loose. And then even due to rather weak intentions. Thus, the empirical material revealed that intentions to move non-given resources which features were embedded into each other resulted in a repelling force, which could appear both as a stabiliser and a de-stabiliser of existing resource combinations. In order to pin-point these forces and their effects to concept of *friction* was introduced.

Although the borrowing of concepts over disciplinary borders always is a risky enterprise, the benefit of using the friction metaphor seems to outweigh the risk. Considering its original connotation, the notion of friction have three important features that make it useful dealing with repelling forces. First of all friction is a *relational* concept. Friction is a disposition, which appears when a force is directed towards two interacting bodies. Second, the notion of friction implies that one and the same force can have different effects due to when it is applied, i.e. it is *time dependent*. Through friction a force that at one point of time is not enough to create a movement at another point of time can keep the movement going. Third, and related to the second, together with friction comes not only the *movement* of interacting resources, but also a *transformation* of these, in shape of heat, wearing, deformation etc. Thus, friction is affecting the features of the interacting resources.

The repelling forces that can be captured by the concept of friction seem to strengthen certain aspects of technological development processes. First, friction is a reaction on what has been achieved in earlier interaction. Thus, friction relates present change processes with the past. Second, friction can also connect contemporary processes. Through friction connections to what simultaneously is happening in other interfaces can be created. This activating of historical and contemporary processes strengthens certain aspects of technological change processes. In other words, friction can explain why the outcome of change neither is random nor deterministic.

A central implication is that friction affects the economic outcome of technological change. Friction intervenes as an active force during any attempt to change how embedded non-given economic resources are combined and activated. However, friction is not a force that is entirely negative in relation to the development of new technological solutions, and neither a force that is entirely positive in relation to the development of such. *But, friction is a force that influence technological development processes to take directions that gives a positive economic result – but only in perspective of the existing economic structure. Thus, friction is definitely a force which effects favour existing values*

In the crossroads of forces trying to create change and things that have to work together

Empirical studies of technical development often reveal a picture of companies living rather intriguing lives (see e.g. Håkansson, 1987, 1989, Waluszewski, 1989, Laage-Hellman, 1989, Lundgren, 1991, Håkansson & Waluszewski, 2000). All these studies draw attention to how companies interacting with customers, suppliers, competitors, authorities, non-governmental organisations etc. are constantly exposed to different inquiries. Certainly these inquiries vary both in intensity and direction – there are many questions about existing solutions, suggestions of improvements of varying degree, ideas about how to develop and use new technological solutions and there new rules and regulations that must be followed up. Thus, what all these inquiries have in common is that they most often imply smaller or larger changes of the existing structure.

Along with this flood of stronger or weaker forces trying to create change, many things have to work together. There are production facilities using all sorts of technologies, which have to work – and they have to do it together. There are deliveries of different products that not only have to be on time, but also have to include certain specific features – which have to be stable from one delivery to another. Thus, all these features of resources, which are developed in relation to each other, and activated in certain interfaces, create a need for a co-ordinated activation of resources. The interfaces have to fit together – which means that certain features activated in relation to each other must remain the same over certain activity cycles.

In the crossroads of forces trying to create change and interfaces that must be held together are people. Their role in representing the interfaces, sometimes as advocates of certain change and sometimes as protectors of existing solutions, becomes visible in all the meetings and discussions within or outside their own business unit. Thus, handling interfaces is the same as being familiar with the tricky task of how to cope with something new without destroying what has been achieved. Certainly many inquiries can be fulfilled easily – such building on how features are already activated. However, there are also countless trials to cope with something new that just seems to create unintended – both positive and negative - domino effects in different places in the activated structure. And, certainly any attempt to create change in related interfaces is a delicate issue. The features activated in an interface are the result of interaction processes over time, where resources have been systematically related and where a solution of how to combine them has been gradually chiselled out. Thus, it is the interaction processes that develop and establish the interfaces where resources are activated. And, the interfaces determine the features of the involved resources. In other words, the interfaces determine the use and the value of resources. In this view the appearance of all these forces that are almost constantly directed towards interfaces seems fairly understandable, along with the difficulties involved in changing them.

Resource interfaces and reasons for stability and change

A central implication is that interfaces are essential for the understanding of resource utilisation, particularly for the development of new technological and commercial solutions. As has been illustrated in several empirical studies, our own included, such changes do not come in from the "outside" into a closed economic system, putting it out of balance for a while before it reaches a new equilibrium.[1] Instead, our experiences[2] are similar to what van de Ven et al (1999) describes as moving in an "rugged landscape", which is "unique, ambiguous and uncontrollable." [3] In this rugged landscape, the resources involved are exposed to different forces; there are new and often conflicting ideas stemming from both an image structure and an activated structure. There are also many technical and structural problems to handle within the activated structure. Thus, we are dealing with interfaces that always are exposed to certain forces or tensions.[4]

First of all an image structure is neither totally stable nor the same for all people related to it. According to Czarniawska (1998), as soon as an idea is communicated;

1 Loasby, 1999, 7
2 Håkansson, Waluszewski 2000.
3 van de Ven et al, 1999, p. 21
4 Håkansson, Waluszewski 2000.

in terms of words, pictures or paintings, it is exposed to changes: "Unknown objects appear, known objects change their appearance, practices becomes transformed".[5] Thus, due to influences of a technical, social or structural nature, the image structure is in continuous movement. This implies that an interface can always be exposed to tensions, in terms of actors striving to create stability or change.

Second, an activated structure is never optimal. As Penrose (1959) reminds us: "If we consider the *full* range of resources used in any firm of even moderate size, including its various grades of management personnel, its engineers and other technical specialists, the minimum sales force needed to reach its markets and sell its products, its financial specialist, and even its research personnel, it is clear that this 'least common multiple' may call for an enormously large and varied output." [6] And, if the activated structure, even within a small firm, can never be in what Penrose (1959) labels as a "full balance of processes", how can a technological system involving a large amount of different resources, activated by several business units, belonging to different companies, ever be? In accordance with Penrose's observation, our empirical experiences illustrate how companies constantly struggle with solving imbalances, old and well known as well as new ones, of both technical and structural nature. Thus, it is easy to agree with Penrose's (1959) argument that no matter how much consideration we put into "putting together of the jig-saw puzzle", we still may find that "a number of awkward corners persist in sticking out."[7]

The creation of a perfect "jig-saw puzzle" seems even more beyond reach when we consider how features of resources are built into each other, activated not only within but also across the borders of different companies. Thus, the effects of the features created in a certain interface are not local, but carry over to other interfaces. Although some of the resources activated in an interface can appear to be perfectly adapted to each other, they cannot, per definition, be perfectly adapted in relation to all resources activated in all related interfaces related. The degree of difficulty

[5] Czarniawska, 1998, p. 204.
[6] Penrose, 1959, p. 68
[7] Penrose, 1959, p. 69.

becomes visible if we consider that certain features of certain resources have to fit into different activity structures carried out by different companies – perhaps with different technology, different suppliers/customers and different ambitions.

Thus, interaction between resources creates tensions within the structure where they are activated. These tensions are expressed through the people handling the interfaces, but they stem from the interaction between resources: physical as well as social. The tensions an interface is exposed to can be described *as forces that create movements of resources in relation to each other.* And such movements of resources that are related to different interfaces, activated by different actors, preceding different physical and image structures, are seldom carried out without complications. As van de Ven (1999) illustrates it: "While tilling the garden, the discovery of a huge stone that requires extensive excavation may lead us to wonder about the wisdom of the partner who wanted the garden in this spot as easily as it leads us to speculate about the vagaries of nature."[8]

How to cope with forces holding interfaces together

The many and intriguing forces that can act as a hindrance to change have been observed before, certainly by the people in the industry and also by academics.
In traditional economics it has been dealt with as "imperfections", while von Hippel's (1996) concept of "stickiness" is increasingly adopted within applied economics. However, the concept most frequently used in social science seems to be "inertia". Borrowed from physics, inertia connotes, according to Webster's, an "indisposition to motion, exertion or change".[9] The concept of inertia is used in several disciplines of the social sciences: by historians, such as Hughes (199x), by sociologists, like Scott (1992), and by organisation theorists, new institutionalists included, like DiMaggio & Powell (1991). The concept of inertia has also been applied within the imp/network tradition. Ford et al (1998) use it to explain how an extensive, long-lasting relationship between two companies "dealing with each other

8 van de Ven, 1999, p. 84
9 Webster's Ninth New Collegiate Dictionary

on a continuing base", can hinder both parties' development. "There is likely to be quite a lot of *inertia* in this situation for both the customer and supplier."[10]

Although the concept of inertia is used metaphorically, it can be of interest to consider its original meaning in the context of classical mechanics. One of the heritages from Galileo Galilei (1564-1642) and Issac Newton (1642-1727), the law of inertia, often referred to as the first of Newton's three laws of motion, originally describes a body subjected to no external influence at all. [11] In "Elementary Classical Physics", Wiedner and Sells (1965) use the example of an air-suspended disc in order to illustrate the law of inertia. "We can well imagine that if external disturbances, or forces, were altogether absent, the disc would continue its motion indefinitely, moving in a straight line at constant speed. In fact, *if a body is subject to no net external influence, it has a constant velocity, either zero or nonzero;* that is, *as long as there is no horizontal force acting on the disc to change its speed or direction of motion, it continues in uniform motion – along a straight line covering equal distances in equal time intervals.* This is the *law of inertia"* If such a body once changes its speed or direction of motion, it has been acted upon by an "unbalanced" external force. [12]

In its physical meaning inertia is a concept that connotes the properties of a single body that is not exposed to any external forces at all. [13] However, a main characteristic of the "bodies" that are objects for economic exchange is interaction – which implies always being exposed to external forces. So, if we ever want to borrow a concept from physics to illustrate the forces to which the interacting bodies are exposed, the concept of inertia is probably not the most fruitful. What is needed is a tool that can not only capture external forces, but also how they can appear in rather different shapes.

---

10 Ford et al, 1998, p. 33
11 Weidner & Sells, 1965, 117
12 Weidner & Sells, 1965, 117

13 As Weidner & Sells put it: "What is required to keep a body at rest? *Nothing.* What is required to keep a body in motion? Said Galileo: *nothing.* This is the essence of the *law of inertia.*" Weidner & Sells, 1965, 116-117.

Therefore, if we continue with physics for a while, we need a concept that describes the fact that whenever two bodies interact with one another, each body influences the other. As Wiedner and Sells' (1965) put it, "we can describe this influence in terms of a force acting upon each body by virtue of the presence of the other." [14]

The concept of friction

The concept we are borrowing from physics in order to reach a deeper understanding of forces created through the movement of related resources is that of *friction*. Why we are borrowing this concept is rather straightforward – it seems to enable us to capture several different aspects of these forces. In this case the benefit from crossing borders seems to outweigh the risk. As Burke (1992) argues, if we for whatever reason avoid a certain term that enables a finer distinction and a more rigorous analysis, "we may fail to notice a particular aspect of social reality".[15]

Considering its original connotation, the concept of friction has three important features that appear useful in our struggle with certain "aspects of social reality". First of all friction is a *relational* concept. In "*Elementary Physics"* (1965), Weidner and Sells illustrate the creation of friction as follows: "Consider a hockey puck on a smooth horizontal surface of ice. Friction between the puck and the surface is small, but not entirely negligible. If the puck is initially at rest, it remains at rest, unless pushed; if the puck is set into motion, but then left undisturbed, it coasts in a straight line for a considerable distance before coming finally to rest. The puck comes to rest because friction has not been entirely eliminated." Thus, friction is a disposition that appears when a force is directed towards two interacting surfaces. As Harré (1993) puts it: "Whenever two surfaces are in contact and one surface is moved in relation to the other, the friction forces are quite noticeable."[16]

---

14 Weidner & Sells, 1965, p. 160

15 Burke, 1992, p. 44.
16 Weidner & Sells, 1965, p. 194.

Second, the concept of friction implies that the same force can have different effects depending on when it is applied, i.e. it is *time dependent*. Wiedner & Sells (1965) describe this aspect of friction in the following way: "Consider a block resting on a horizontal surface. What happens when we apply a horizontal force to the block? We find that if the external force is not too large, the block remains at rest. By Newton's second law this implies that there is an equal and opposite force acting on the block to maintain its state of equilibrium. This force, called the *static-friction force, fs,* is produced by the surface on which the block rests… We find, however, that once the block moves, the retarding force of friction is less than *fs.* The friction force now acting is called the *kinetic-friction force, fk.*" [17] Thus, through friction a force that at one point in time is not enough to create a movement, at another point in time can keep the movement going.

Third, and related to the second, along with friction comes not only the *movement* of interacting resources, but also a *transformation* or deformation in shape of heat, wear etc. Thus, friction also affect the features of the interacting resources.

To sum up, in its original connotation friction is a force that only appears between related surfaces and only as a reaction to another force. As Harre (1993) emphasises: "There is no frictional force between two contacting surfaces unless some outside force 'tries' to move them over one another." Thus, friction deals with the *distribution and transformation of forces applied to interacting bodies.* However, what makes friction such a peculiar force is that can appear as both a *stabiliser* and a *de-stabiliser* of the interface between interacting bodies. Harre (1993) states: "A pair of surfaces in contact can be said to have a tendency or disposition to resist relative motion. That tendency is displayed as an actual friction force whenever something tries to push them along." [18] Thus, friction is, to use Nowotny's (1993) formulation, a "janus-faced" phenomenon, since it "dissipates energy which can stabilize or disstabilize the interaction."[19]

17 Weidner & Sells, 1965, p. 194-195.
18 Harre, 1993, p. 62
19 Nowtny, 1993, p. 40.

Although we will use the concept of friction metaphorically, its original meaning is close to the aspects we want to capture in the economic world: *How an alteration force applied to one resource is transferred to resources it interacts with and how this friction can act both as a stabiliser and a de-stabiliser of existing resource interfaces.* However, as Nowotny (1993) stresses, even if it is easy to make simple analogiss between the forces appearing in the physical and social world, this is not enough to make a fruitful tool out of a borrowed term. There must be something more to it: "a new embedding into a certain approach." [20]

The concept of friction in an economic world: what aspects can be captured and what are put aside?

What aspects can then be captured by introducing the concept of friction into an economic world? And, of equal importance, what aspects cannot be covered using this tool?

First of all, it has to be emphasised that the interacting bodies we are trying to understand in one central aspect are completely different as compared to those in the physical world. The concept of friction were developed in the context of classical mechanics, where physical properties were thought to be absolute. As Harré (1993) explains this view of physical bodies: "they would be unaffected by the presence or absence of other material things."[21] However, we are dealing with resources that can only be understood in *relative* terms. Since the features of resources activated in an industrial setting are developed in interaction, or as Harré (1993) says, as "relations between and among material things", they cannot be attributes of isolated material things. "But a flower would have no colour if there were no people (or bees) to see it, nor could we make sense of the idea of our cat as hunter unless there were mice to track down." [22]

20 Nowotny, 1993, p. 38
21 Harré, 1993, p. 62
22 Harré (1993), p. 62

Thus, the only way we can use the concept of friction is as a *tool to capture the interplay between resources whose features are relational*. However, even in this restricted application there is a severe limitation. The concept of friction will leave us with one of the basic aspects of this interaction unanswered - it will say nothing about the origin of the forces creating friction. In Weidner & Sell's (1965) illustration of friction between the ice and the puck, it is the hockey player who triggers the alteration force. Certainly there are - and must be - "players" also in an industrial setting: individuals and organisational units that are responsible for creating the primary force. However, we will not focus on what triggers these actions. That there are already a large number of studies discussing intentional change, and more importantly, using the concept of friction makes these intentions less meaningful to study. Even if it is possible to find a pattern in these reasons, our empirical experiences have indicated that there seems to be a rather loose coupling between the intention that triggers a force and its effects. This is also what the notion of friction implies. *If an external force is directed towards a resource interacting with other resources, the effect will never be local. It will be distributed through friction, creating some kind of reaction within a number of related resources – changing some and perhaps even destroying some interfaces.*

What we can capture by using the concept of friction, is how a force applied to a certain resource creates a repelling force. Any force trying to move a resource embedded into some other resources creates a reaction that affects both the resource exposed to the original force and the other resources interfaces. Embedded into an economic world, friction is a process within the dynamic sphere - producing a reaction when any attempt is made to create change that is distributed among resources that interfaces with the focal resource. And, like physical friction, this distribution of energy to related resources may change their features. So, the concept of friction focuses on the following aspects:

Any force directed towards a resource interacting with other resources will through friction, produce a reaction that will:

a) be distributed to all resources that interface with the focal resource

b) create tensions in the interfaces between these resources, which in turn can transform the resources in relation to each other – and sometimes even create new resources
c) have different effects over time, given the way the resources already move in relation to each other – i.e. the effect is time dependent

The effect described in the first point is perhaps the most obvious one, and is also frequently illustrated in empirical studies, how a force directed towards a certain resource through friction creates a reaction which is distributed among embedded resources:

Friction produces a co-ordinated movement and a co-ordinated transformation of interacting resources. This implies that friction is an important ingredient in the creation of resources. However, there is the janus-face of friction, suggesting that it is never clear what new patterns will be created. A process that for a certain period of time appears as a co-ordinated movement and transformation of resources can, due to the interdependencies between interfaces, take another direction, releasing one or more resources to develop in disparate directions. And, once a resource is breaking loose from its interfaces, it becomes an isolated entity with no economic value. In this case being free is nothing positive at all – at least as long as no new interfaces are created with other resources.

Consequently, although it is possible to stipulate that friction distributes and transforms energy directed towards interacting resources, the effects are unforeseeable in terms of what will happen to each resource. It is never obvious if the interacting bodies will develop together, or if one or more of them will break loose. This pattern is further complicated by the fact the effect of a certain force can change over time. Thus, friction is a force that undermines both linearity and rationality, or the view of development that Latour (1993) characterises as "everything is possible without being limited to anything".[23]

[23] Latour, 1993, p. 32

This is not to say that friction produces totally haphazard effects. Instead, friction makes it possible to foresee some important ingredients in development processes. A first such ingredient is that *friction always has a stabilising effect on the interfaces exposed to a changing force*. Thus, through friction an alteration force directed towards certain resource will always create a co-ordinated reaction, in terms of movement and or transformation of the interfaces into which it is embedded. A second ingredient is that *friction can simultaneously have a de-stabilising effect - on one or more interfaces*. Sometimes the movement and transformation of related resources becomes so extensive that one or more interfaces break up, freeing one or more resources - while a stabilising effect is produced on other interfaces.

It is these two aspects of friction: how it always produces a stabilising effect on resources' interfaces and how its de-stabilising effects appear simultaneously in various degrees, that we will discuss in the next section. We will start by considering how resources are transformed due to tensions in existing interdependencies and then discuss transformations due to the creation of new interdependencies.

Friction as transformer of resources due to connections over time

The type of empirical experiences that friction may help us to articulate, is that whenever resources interact, changes or movements of a focal resource imply some kind of transformation of its interfaces with other resources. One basic reason seems to be that the use of any resource involves a number of interdependencies. Thus, friction is a reaction based on what was achieved in earlier interactions. It is a force that relates what happens today with what has happened earlier. In this form friction is clearly a stabiliser – advocating earlier results and defending what has been achieved towards new solutions.

However, for specific resources or specific interfaces, this basic stabilising effect can still create quite de-stabilising consequences. A conclusion from the previous section was that when a force is directed towards a certain resource, the friction force distributes the reactions. Thus, a number of interfaces are put under tension. Through these tensions the history, or better, parts of the history, of each interface are evoked. As we described earlier, any resource interface is the result of a previous interaction, not only of its own interaction processes, but also of how it has been related to other interfaces. Thus, there is a history embedded in every interface: It is expressed in an image structure, such as the memories of people who have been involved, and/or in a physical structure, in terms of different resource features. Some of these features are used in the existing interface, while others can be dormant. This implies that the history of an interface is never clear-cut. When an interface includes resources that have been used over a long time, and in many different combinations, its history can be so rich and intricate that it is impossible to uncover in detail. Thus, the features that have been activated over time can only be captured as fragments. However, such fragments can be evoked through friction. The tensions created in an interface can activate dormant features - relate them to the on-going process and put them on trial in new resource combinations.

This relating of an interface to a number of historical fragments creates increased variety in the on-going process. This is also one explanation of why it is so difficult ever to forecast a development process. The increased variety makes it not only hard to predict what direction the process will take and what results will be produced, it can even be difficult to interpret what is in progress. Since friction activates the history of several interfaces, the emerging result can be impossible to identify for those who not directly involved. Furthermore, since emerging results often only exist as test-solutions, which can be problematic to describe in words or formulas, it can be hard to communicate them to others. Almost all more detailed stories about technological development shows how projects are closed down or delayed due to difficulties in communicating results. This pattern is hard to ascribe to the ignorance of those who have to be convinced. Instead, such communication problems appear as an indication of how difficult it is to estimate how well a new solution can be fitted into established interfaces. Changing an established solution that has been embedded into many interfaces and about which no has total knowledge (including their history) implies dealing with the unknown. There is never a complete and true picture of the totality to draw from – only some fragmentary views of the history of certain interfaces, and likewise vague views of how a certain change will affect related interfaces.

It is often challenging enough to map out the effect in a focal interface. If we consider two resources that are going to be activated in an interface, this process will probably include a thorough examination of what features have been used before in which setting. Further, there will probably also be a trial-and-error like investigation of which features can be activated in the new interface, how, and especially, they can be fitted into related interfaces. Thus, when two resources are activated in a new interface, we are faced with a process where two histories are brought together. The outcome of this process – of how well the two histories can be integrated is never given. The outcome will be due in part to the work carried out in the interface. However, since there are so many different ways two focal resources and their histories can be brought together, the outcome can not be regarded as the "best", but rather as a combination that was possible to activate. Further, the outcome will also be a function of how the new interface can be integrated with related interfaces. In particular it will depend on the history of these interfaces – if there are some dormant features that can be evoked in one or several of them.

Sometimes the introduction of a new solution can, comfortably, be fitted into a local interface – as long as the connection to other interfaces are blocked out, for example by treating it as a test-solution, or a special adaptation. If such a solution is to be transferred to a more established one, it has to be incorporated with all related interfaces and their histories. During this process the compatibility of the new solution will be put on trial. This is a risky process. Familiarity with how painful such processes can be, can explain better than conservatism why new solutions are so often meet with scepticism.

To sum up, the history of earlier interaction is embedded in any resource interface, along with a large number of interdependencies. These historical interdependencies can be activated, to a lesser or larger degree through friction. However, this activating also includes "peculiarities" or "unevenness" in the established interfaces – which that can create surprises and/or difficulties. The resources activated in established interfaces are seldom simple in terms of their histories and therefore do not move smooth and easy in relation to each other. Instead they include “hooks” or “peaks”, which have to be evened out – or taken care of. When they are of a technical nature, these “peaks” might be easy to grasp and accept. When they are due to structural and/or relational conditions, they can be more difficult to deal with.

Friction as a transformer of resources due to contemporary connections

The conclusion of the previous section was that friction activates a large number of resource interfaces that are interdependent due to long time interaction. However, friction can connect interdependencies in contemporary processes - something that interferes in any attempt to create change. Connections to what is simultaneously happening in other interfaces – both closely related and more distant – can be created through friction. Thus, friction makes it possible to take advantage of interdependencies in contemporary processes. It is a force that can create connections in such processes and enable co-evolution of certain aspects of them.

Friction can connect contemporary processes due to technical, structural and relational interdependencies. Thus, through friction, a co-ordination of how to recombine resources and relate certain interdependent features, activated in several different interfaces, can be created. In this way, an emerging solution can be developed in close relation to the already activated structure of these actors.

Thus, friction can relate changes appearing simultaneously in parallel alteration processes. It allows the same interface to be activated in several of them. And, if a certain solution fits several of these processes, they will co-evolve. Such a solution will have an additional effect on all the related changing processes, as they will become part of a larger process. As a consequence, the outcome of these changes will as a consequence be larger than it would have been if they had been completed in isolation.

One important consequence is that friction, by activating other interfaces, can have a strengthening effect on certain aspects in a process of change. Thus, friction is entirely negative for change only when the environment is in a fixed state. However, this is something that is not found in a world characterised by interaction. In an interactive context there are always trials to change related resources in one way or another. Due to the interdependence of resources, such processes can influence each other in different ways. When processes are connected new interdependencies can be created and existing interdependencies can grow stronger, but they can also decrease or even dissolve.

There is a certain characteristic of changes in resource combinations that increase the importance of co-evolution – that the outgrowing solutions are not totally random. Although there certainly can be elements of chance, processes combining resource are related to the development of certain technologies, of certain companies or to other structuring forces. Thus, the development of new resource combinations is related to identities. The existence of technologies and of companies are two examples. Furthermore, there are interdependencies among these identities and how they are related. There are interdependent changes in more or less interdependent resource elements. The existence of co-evolution is a self-organising process that can be influenced. It can be a conscious effort to co-ordinate changes or it can be changes occurring.

To sum up, an important empirical observation that can be captured by the notion of friction is the reaction created by any alteration force directed towards one or more resources. This reaction is due to interdependencies between interfaces, which in turn are the result of historical and contemporary interaction processes. When an alteration force is focused on a resource embedded in such an interdependent interface, the outcome is not in harmony with the reason for the primary force. The outcome will instead be related to the interdependent interfaces, including what fragments of their histories and what contemporary processes are activated. This implies that the greatest consequences of an alteration force might appear in rather distant interfaces, and/or in a rather unexpected form. Thus, friction is a reaction that:

a) *disconnects the effects from the original force*
b) creates tension between a resource exposed to a force and the history of the resources it interfaces with
c) creates tension between a resource exposed to a force and the contemporary processes of the resources it interfaces with.

Factors affecting the degree of friction

Physical friction is affected by the interplay between the molecules on the surfaces of the interacting bodies', which in turn is related to the amount of pressure exerted on the two bodies and the roughness of the surfaces (friction coefficient). In the same way, economic friction is affected by the characteristics of the interfaces. These interfaces are the results of earlier interactions. Every interface has its own history in terms of how the two resources have been combined and adapted to each other, i.e. how they have been embedded into each other. However, a major difference seems to be that economic friction is not primarily related to the interface where the two resources are moving, but to the other interfaces of the two resources. It seems reasonable to expect that economic friction is more or less directly proportional to the degree to which the two resources, moving in relation to each other, are *embedded into other resources.*

This implies that when a certain resource is exposed to an external force, the reaction in terms of economic friction will appear in these interfaces due to the degree the resource is embedded into other resources. The more the features of the focal resource are embedded into other resources, the more total resources will be affected. One obvious effect is that more interfaces will be affected. This means that the more embedded a resource is, the more power is needed in order to change it in any substantial way. Consequently, the more developed the interfaces are, the more the resources will hold together when exposed to an alteration force. For example, changing such an embedded technological solution as “QWERTY” would require a really strong alteration force, in order to transform all concerned interfaces. A changing of a new technical artefact used in a new mobile system would probably be easier to accomplish, despite the fact that the latter will be regarded as more technologically advanced than QWERTY.

The QWERTY example implies that there are reasons to discuss some aspects the resources involved when we try to identify the friction force. A first such aspect is the economic “heaviness” of the involved resources. As QUERTY or any other established technological solution illustrates, the investments in behind are often huge. There are investments in material resources such as equipment, plants and products. Furthermore, there are other large investments in more immaterial resources such as knowledge and business relationships, and they are forming another related part of the basic structure. There are large investments in single resource elements, but there are even larger ones in how they have been built together. Resources are systematically combined by all involved actors and the result is a total economic substance consisting of a very extensive set of interrelated resources.

The consequences are vital for how this economic world will work. The heaviness is an important force pressing or forging surfaces together. Thus, every interface can be characterised by the degree to which it is under pressure. Heaviness is related to a certain direction. In physics heaviness due to gravity is an important factor influencing friction. In the economic world there exists a similar force, at least in our capitalistic part of the world. There exist a number of specific points where the economic result is recorded and thereby measured and evaluated. The use of the words “investments” and “systematic” also indicates the existence of economic actors or centres. Certainly companies are important here, but in a network setting economic actors can appear in several different ways: as groups of individuals or webs of companies.

The effect of heaviness on single resource items is first that they become more or less locked into a specific position in relation to some other resources. Second, the fact that the resources are pressed together increases the importance of their relative appearance. Even small unevenness in the interfaces is significant. Heaviness increases the importance of the features that are also determined by the interfaces. It is through the interfaces that a specific resource is activated, which gives it economic substance and thereby heaviness. Thus, there is an interesting double-faced "power" situation. The heaviness locks in the resource while giving its features an increased importance - a countervailing power - in relation to the environment. The heaviness will multiply the effects of any specific feature. There is less freedom in terms of alternative uses but there is an increased importance due to a deepened influence in the setting.

An important consequence is that certain movements are made more difficult. It will take time to change the direction of resource items situated in places where the heaviness is great. It is like changing the course of a super tanker. But, in relation to the existing direction there is a very strong living force in those places. It increases the possibilities and the reasons for taking advantage of specific interactive effects between the resources.

The second intervening aspect when trying to identify the friction force is variety. Variety can appear when one resource causes different effects because it is used in different contexts. Another type of variety is where one resource can be adapted different ways – in principle becoming a large number of different resources. A third one is that several different combinations of resources can produce the same output. All these examples show that variety is a combined effect of the characteristics of the resource and its interfaces with other resources. In other words the variety is the result of interactive effects. One important conclusion is that variety is very much an effect of how a resource is used. For example, variety has often been seen as a problem in industrial setting, such as in large-scale production facilities. Standardisation has been used as a tool to reduce variety in those cases. However, variety also has a large economic potential – especially in situations where the economic heaviness is large. As every resource gets its features from the interfaces with other resources, the variety is directly dependent on the resource constellations it is part of.

Above, we concluded that variety is not given, but neither is the way variety is used in the resource constellation. How the variety is used depends on how the use of the resources is embedded into the composition of the resource constellation in terms of number of interfaces and thereby its activated features. Basically we have two different situations from an economic point of view. One is to be able to use a certain resource despite the variety. The question is how a certain resource constellation can accept variety in a certain resource. There are very big differences between resource constellations in this dimension. Sometimes even large variations in a resource can be accepted and absorbed in a resource constellation. Just by changing the composition of the total resource constellation a little, and with no need to make major adaptations, a wide variety in certain dimensions can be handled. However, in these cases the variety is not used, only tolerated. In other constellations even a small variety can create large consequences. In order to tolerate the variety, both the "design" and "content" of the constellation must be changed.

The second situation regards how to benefit from a certain variety in a specific resource. This situation becomes almost the opposite of the first one. The reason is that the more we want to take advantage of the variety in a certain resource, the more we have to make use of a certain "fixed position" of another. We have to find a number of combinations where we systematically relate different interfaces to each other given different values of one resource. For each value we have to try to adapt all other interfaces to this specific value. The more we can adapt to the specific position, the more we can gain from it. This must be done for several "positions" in order to make the most of the variety. So, in order to benefit from variety we need several different resource constellations.

The existence of variety as well as the capacity to take advantage of it in a specific resource is directly related to the total set of resources it belongs to and how other resources have been related to it. In one situation we can have a production process that has been designed in such a way that the input can vary without affecting the output. In another situation there is a production facility where the input is precisely defined but where wide variety is possible in the output. In a third situation the resource is used in several different resource constellations where different features are used. Thus, the composition of resource elements, i.e. the way the interfaces have been related to each other, can be more or less open for variety or changes in certain specific dimensions. Consequently, different constellations are more or less sensitive to variety depending on the dimension in which it appears. This is clearly a factor influencing the degree to which friction appears in relation to a change.

In this section we have argued that economic friction in general is affected by the degree to which the two resources being moved in relation to each other are embedded into other resources. Secondly, we have identified two intervening aspects that complicate this general picture. One has to do with economic heaviness, which is related to the importance of certain resource interfaces for relevant economic centres. Friction is both increased and becomes more directed due to the existence of heaviness. The other has to do with variety. It is about the interplay between a certain resource and the total resource constellation. Every constellation seems to have a built-in sensitivity to variety in some specific dimension. Friction is greatest in a situation where both resources being moved in relation to each other are highly embedded into other resources; when the heaviness is high and when no variety is accepted.

Another important conclusion is that both heaviness, variety and embeddedness can be influenced. Even if they can be regarded as given in the short run, they can be changed over time: Heaviness can be affected if the economic centres are moved; variety can be increased through changes in the resource constellation and so also the embeddedness.

Friction effects

We started out with a description of companies being the midst of a flood of suggestions for change, and at the same time struggling with how to get things to work together. We argued that friction is an important element in these processes. In almost any deeper empirical study of technological development in an industrial setting, it is possible to find examples of how companies are wrestling with this friction, while at the same time actively supporting it. [24] Stability is always looked

[24] For a more thoroughly empirical illustration of friction, see Håkansson, Waluszewski, 2000.

for and at the same time always questioned. This is especially apparent in the investments, and in how to relate to others. The companies are all struggling with their investments, as well as with their counterparts. In both these areas they have certain discretion - they can make decisions. But the friction gives limitations as well as unexpected outcomes.

A central implication is that friction affects the economic outcome of technological change. Friction intervenes as an active force during any attempt to change how embedded non-given economic resources are combined. However, friction is not a force that is entirely negative in relation to the development of new technological solutions, and neither a force that is entirely positive in relation to the development of such. *But, it is definitely a force that influence technological development processes to take directions that gives a positive economic result – but only in perspective of the existing economic structure. Thus, friction is a force which effects favour existing values.*

Friction effects occur as a reaction – a countervailing force – to any attempt to change established resource combinations. Through friction, historical and contemporary processes are activated, creating a pattern where the initial attempt to create change is systematically related to the established economic structure. This implies that the initial change is forced to be "economical" – from the established structures' point of view.

This reaction becomes obvious if we consider the development of new features of single resources. If a new resource introduced just takes over from an established one, activating the same features of related resources, this change would be very costly. However, if the new resource introduced can activate some new features of existing resources, the value of both the new and the established resources would increase. As we have seen, such process in general requires a transformation of both how established resources are embedded into each other, as well as an embedding of the new resource. It is such reaction that is created through friction and it is possible to identify three different aspects in this process.

First, friction creates a reaction in the interface where a change is initiated. Instead of just changing the interface in perspective of the initial intention, friction will create activities to keep or restore the established solution. For example, through combining the established resources in new ways and/or through improving these. Second, friction will distribute the tension also to other interfaces. Consequently, there will be a number of combinations questioned and thereby also put under pressure to develop. Third, the tension in the other interfaces will be reacted upon in the same way as the initial change was in the first affected interface. Thus, friction will question how resources are combined in related interfaces. These interfaces will be put under pressure to develop – and so on. This distribution of tensions over several interfaces directs a development process towards solutions that are compatible in several dimensions. Thus, friction creates a pressure for a technological development processes that takes advantage of established economic values.

This process of reactions implies that friction will influence the direction of knowledge processes going on within economic structures. There are single individuals and there are business units that have to learn more about the interfaces that are put under pressure. Furthermore, there is a need for joint learning about the effects of combining resources in new ways. Thus, there is a need for teaching; individuals and business units have to teach each others about what is happening with their resources and interfaces when the counterparts change, and not least, about the possibility to make compatible changes. Instead of a traditional transfer of knowledge a more interactive process is created which includes a transformation of knowledge. In these processes different intentions and knowledge pieces are brought out of their context to new surroundings. Through friction, these contemporary processes are related to each other – or better, they are intervening in each other.

Thus, friction seems to have at least two important effects on knowledge development. One is that friction effects seem to force transfer of knowledge to become more of creation of knowledge. Co-ordination of different knowledge pieces is not enough – these have to be moulded together into new forms. The second effect is that through the distribution of tensions to several interfaces the possibility increases to find “weak links", i.e. areas where it is fairly easy to develop new knowledge. In other words, development does not have to take place exactly at the point as the initial change.

An important consequence of the last mentioned effect is that friction makes forecasting of development extremely difficult. Due to friction, any forecast for a new solution – i.e. a new product – will be uncertain. As friction expands the affected interface – where the primary effect normally has been estimated and on which the forecast has been done – the uncertainty increases due to an increased complexity. Suddenly, there are so many other directions the process can take. However, this does not mean that friction makes the world safe for all established resources – just for the main part of them. As friction distributes tensions there will always be processes going that question established resources. Thus, friction effects can explain why it suddenly can become possible to replace resources that traditionally have been regarded as impossible to be without. Certainly the development of such new resource combinations will be local, carried out in a specific interface. However, as the transformed resources are related to other resources – how many depends on how embedded they are – this will affect larger economic conditions. And a small change in one part can have severe effects in other parts. Again, this makes forecasting difficult.

If it is more or less impossible for companies to rely on traditional forecasting, experimentation must be of great importance. The only reasonable way to deal with movements of embedded resources seems to be trial and error. When any resource can be developed through changes in existing interfaces or development of new ones, a systematic experimentation with resource combinations can result in the development of new features. This can increase the economic value of a certain resource – but only of it is possible to build in these features in the established economic structure.

A common strike in the experimentation process is that the changes of the individual resources are often rather restricted. Instead it is the way the resources are used in relation to other resources that are developed in a more dramatic way. Sometimes the experimentation is concentrated to a single interface – but then under the severe restriction that the outcome may not affect related resource interfaces. However, most often a change of an interface have effects on related interfaces – and then the development of these have to be co-ordinated. Sometimes such co-ordination is facilitated by the fact that all the affected interfaces are located within an individual company. However, most often interdependent interfaces cross the borders of several companies, thus making the co-ordination process much more tricky; different logic and different ways of utilising resource features have to be considered.

Regardless if an initial change creates effects in a single interface, in several interfaces and if these are located within one or several companies, an important effect of friction is that the transformation of resources are forced to take care of earlier investments. *Thus, friction is an extremely conservative force: it directs any development process in an economic context to a route that favours, not all – but the main part – of established resources.*

Friction as a non-linear but still conservative force

Nowotny (1993) claims that the metaphor of friction is useful in on order to pin-point the doubled-faced forces that always are present as soon as there is interaction. "In the macroscopic world frictionless interaction is a rare exception. Nowhere in the universe, neither in the cosmos, nor in our social world, can anything happen without interaction and often interaction entailing friction. …There can hardly be a social world, however atomic it may appear, without interaction and friction." [25] According to Nowotny (1993), friction can appear both as "effective control mechanisms of social tension and conflicts", but also as "dissipative": "potentially destructive and yet at the same time constructive".[26] Thus, friction is a force that dashes our hope for both an atomistic and linear behaviour. Or, as Åkerman (1993) puts it: "Friction is what keeps you from realizing your goals. It is what compromises all your plans, sometimes making them unrecognizable. It constitutes the divide between dream and reality". [27]

Both Nowotny (1993) and Åkerman (1993) gives illustrating examples of why development processes characterised by interaction and friction also are non-linear.

---

[25] Nowotny, 1993, p. 35
[26] Nowotny, 1993, p. 48
[27] Åkerman, 1993, p. 8

However, both these authors underlines the conflicts that friction creates. We have discussed a somewhat different pattern: *The friction effects are basically due to the complex pattern of how established resources are embedded into each other*. *Friction is certainly a consequence of interaction and a force that creates a non-linear development pattern. However, it is at the same time a force that guides technological development to build on established solutions. And, although friction seems to facilitate the development of new resource combinations, these are definitely forced to be in favour of the main part of the established economic structure.*

References

Åkerman , R., 1993. A free-falling society? Six introductory notes. In Åkerman, ed., The Necessity of Friction, pp. 6-30. Physica-Verlag, Heidelberg, New York.

Burke, P.,1992. History & Social Science. Polity Press, Cambridge.

Czarniawska, B., 1996. Translating Organisational Change. In Czarniawska, B., Sevon, G., eds. *Translating Organisational Change.* De Gruyter, Berlin. NY.

DiMaggio, P.J., Powell, W.W., 1991. Introduction. In W.W. Powell and P.J. DiMaggio, eds. *The New Insitutionalism in Organisational Analysis.* Pp. 232-236.

Ford, D., Gadde, L-E., Håkansson, H., Lundgren, A., Snehota, I., Turnbull, P., Wilson, D., 1998, *Managing Business Relationships*. Chichester: John Wiley & Sons

Harré, R., 1993. An exemplary physical disposition. In *The Necessity of Friction.* Åkerman, 1993, ed. pp. 61-76. Physica-Verlag, Heidelberg, New York.

Håkansson, H., 1987. *Industrial Technological Development. A Network Approach.* Croom Helm, London.

Håkansson, H., 1989. *Corporate Technological Behavior. Co-operation and Networks.* Routledge, London.

Hughes, T.P. 1983, *Network of Power: Electrification in Western Society, 1880-1930.* John Hopkins University Press, Baltimore.

Laage-Hellman, J., 1989. *Technological Development in Industrial Networks.* Acta Universitatis Upsaliensis. Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences. No 16. Uppsala University.

Latour, B., 1993, *We Have Never Been Modern*, Cambrige: Harvard University Press
Loasby, B.J.1999. Knowledge, Institutions and Evolution in Economics. Routledge, London.
Lundgren, A., 1994. Technological Innovation and Network Evolution. Routledge, London.
Nowotny, H., 1993. Re-discovering friction: all that solid does not melt in air. In *The Necessity of Friction,* Åkerman, ed, 1993, pp. 31-60. Physica Verlag, Heidelberg, New York.
Penrose, E., 1959, *The Theory of the Growth of the Firm*, Oxford: Basil Blackwell
Scott, R.W., 1992, *Organizations: Rational, Natural, and Open Systems.* Englewood Cliffs, N.J.: Prentice-Hall
van de Ven, A., Polley, D., Garud, R., Venkataram, S., 1999, *The Innovation Journey*, New York: Oxford University Press
von Hippel, E.,1996 The Dominant Role of Users in the Scientific Instrumentation Innovation Process. *Research Policy,* Vol. 5, pp. 213-239.
Waluszewski, A., 1990. Framväxten av en ny massateknik. The emergence of a new mechanical pulping technique – a development story. Acta Universitatis Upsaliensis. Studia Oeconomiae Negotiorum. Uppsala University.
Waluszewski, A., Håkansson, H., 2000, Managing Development in Interaction or How White Paper was made Green. (Manuscript)
Wiedner & Sells 1965