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*Abstract**:** Product liability bears significant risks for a manufacturer: litigation, damages and negative market reactions. After identifying the components of such risks as well as discussing microeconomic adjustment strategies, an approach for the appraisal of investments into product safety under the (in reality given) imperfect market conditions is developed. Since such investments affect production, the payments required for a financial valuation have to be derived from production planning. Employing duality theory of linear programming shows that the highest price an individual manufacturer can afford (the investment´s price ceiling) can be interpreted as a sum of (sometimes corrected) net present values NPVs. These corrected NPVs are a generalization of the well-known NPVs from perfect markets and consider the scarcity of capacities/resources. Surprisingly, all the partial processes of a chosen process have the same nonnegative corrected NPV as the whole process. Hence, they are not value additive.*
By applying sensitivity analyses, one can prove that higher risks for product liability sometimes discourage investments into product safety. This unexpected result is of utmost importance for policy makers and courts: awarding high compensations for faulty products may lead to less consumer protection – and that at even higher cost for the society. In the same way, policies allowing for high punitive elements in the awarded compensation may not be helpful for ensuring product safety. Furthermore, awarding such high punitive elements to the aggrieved party, may encourage litigation even when there is only little chance for success, leading to often incalculable risks for the manufacturer. Instead, in the interest of both sides, it might make more sense to consider stricter product license procedures.

Abstract: Control, a fundamental component of alliance relationships, improves performance. Alliance control mechanisms can be the formal result of the negotiation phase or can develop through the collaboration process. Literature therefore distinguishes formal and informal control, usually respectively understood as contract and trust. Partner firms also develop control mechanisms (autonomous resource control mechanisms) within the firm, such as appropriability mechanisms, which play an enabling and facilitating role in collaborative activities. The purpose of this paper is to explore how contract, trust and appropriability mechanisms combine to foster alliance performance.

Abstract: Between 2012 and 2015, increases in bandwidth in South Africa and implementation of the International <IR>Framework created incentives for corporate website disclosure behaviour to change.

N. Delener, Editor-in-Chief

EDITORIAL

After a short introduction into product liability risks, identifying their components and discussing microeconomic adjustment strategies, Heinz Eckart Klingelhofer developed a general approach to assess investments into product safety with particular regard to the effects of product liability in the 1st article. Since such investments affect production, the payments required for a financial valuation have been derived from production planning: Product liability modifies the contribution margins and the constraint system. At this stage it becomes visible, that strict liability may be understood as a borderline case of negligence liability.

Unfortunately, the usually applied approaches for investment appraisal, which implicitly require that the conditions of perfect markets are fulfilled, cannot be employed to determine the individual profitability of such an investment. Instead, one has to use more generalized approaches that are also applicable under imperfect market conditions and additionally consider

- the mentioned interdependencies between production and investments as well as
- that some payments may depend on the activity level of production, while others do not, and
- that a technology investment is usually indivisible (either it will be undertaken entirely or not).

Applying duality theory allows for identifying and quantifying the determinants of the manufacturer´s individual price ceiling for such an investment. On imperfect markets, this maximum price, which an individual investor is able to afford, may be interpreted as a sum of (sometimes corrected) net present values. Although dealing with uncertainty, information on probabilities, means or variances is not necessary. The corrected net present values are a generalization of the well-known net present values from perfect markets and consider the scarcity of capacities/resources. Surprisingly, if more than one partial process h of a process β is chosen, then all these partial processes have the same nonnegative corrected net present value, which is also the one of the whole process β. (Thus, the corrected net present values of the partial processes are *not value additive*.)

Because on imperfect markets the use of restricted capacities may lead to interdependencies, (over-)compensation effects between the various determinants of the maximum payable price for such an investment may be possible. Therefore, changes in the product liability risks may lead to much more complex, even unexpected and undesired reactions of this price ceiling than the straightforward ones that an investor would usually consider on perfect markets. Employing sensitivity analysis, it is possible to demonstrate that a higher product liability risk does not always encourage investments into product safety. In particular cases, it may even lead to the paradoxical situation that: 1. it is *unprofitable* to invest into product safety; 2. the marginal incentive to invest is *negative*; *and 3. the expected damages even increase.*

Obviously, this finding is of utmost importance for policy makers and courts: In their desire to protect consumers from and to compensate them for damages resulting from faulty products, they will have to consider that, instead, their decisions and judgements may be counterproductive for increased consumer protection. Hence, they have to carefully look at the individually given situation to prevent a generalized reaction by the manufacturers which, in the end, may lead to less consumer protection – and that at even higher cost for the society.

In the same way, policies which allow for high punitive elements in the awarded compensation may not really be helpful for ensuring product safety. This point is gaining even more importance when the punitive amount is paid to the aggrieved party: Firstly, in the same way as people may be motivated to invest into lottery tickets, high punitive elements encourage litigation (sometimes with incalculable risks for the manufacturer) even when there is only little chance for success. Secondly, this may lead to overprotective behavior by the manufacturers – allowing for the described paradoxical effects of less product safety at even higher cost for the society. Therefore, since consumer protection is still a noble objective, this raises the question whether it is not better to have stricter product license procedures in place which make it more difficult to bring a product into the market, but indemnify the manufacturer as long as no better knowledge is available. Of course, it should be possible to recall such licenses, and criminal law would still need to protect against criminal behaviour.

Control, a fundamental component of alliance relationships, improves performance. Alliance control mechanisms can be the formal result of the negotiation phase or can develop through the collaboration process. Literature therefore distinguishes formal and informal control, usually respectively understood as formal contract and trust. A formal contract is designed to control behavior in order to minimize the costs and performance losses that arise from hazards. There is no consensus in the literature regarding the effect of contracts on alliance performance. Some authors find that contractual governance does not affect alliance performance, showing for instance that a contract has no effect on knowledge leakage. Other studies show that formal contractual governance improves alliance performance by reducing collaboration cost. On the other hand, studies show that performance depends on the level of trust. Inter-organisational trust hinges on close interactions and developing personal relationships. No consensus has been reached regarding the interplay between contractual and trust-based governance. Some authors consider that firms simultaneously use both contractual and trust-based governance, since both are at play in alliance performance. Other authors argue that the two types of governance substitute each other in explaining alliance performance.

In addition, an alliance is embedded in each partner's particular management context. Alliances enable firms to access complementary resources and know-how and their performance may depend on the firms' specific endogenous capabilities, like appropriability capabilities. Appropriability capabilities are the mechanisms that firms implement to appropriate their return on investment. These mechanisms are classified in two groups: legal protection measures (e.g., patents) and informal mechanisms (e.g., secrecy and lead time). Several combinations of formal and informal mechanisms can create positive synergy for the innovative product's performance. The purpose of the 2nd paper by Helene Delerue is to explore how autonomous instruments of control, like appropriability mechanisms, and alliance control mechanisms, like contract and trust, combine to foster alliance performance. Based on set theory, the author therefore examines a sample of 68 Australian SMEs in the biopharmaceutical R&D sector and applied fuzzy set qualitative comparative analysis (fsQCA). The conceptual model therefore relies on the configurational and complementarity approach to understand the bundles of control mechanisms leading to high alliance performance. The configurational approach considers the possibility of interaction among control mechanisms and incorporates the assumption of equifinality. It posits that multiple, unique configurations of the relevant factors can lead to the same outcome.

The findings highlight the effectiveness of a thoughtfully developed and implemented control system in alliance relationships. They also show that effective control is dependent on the manner in which the various mechanisms are combined, or bundled.

Communications via corporate websites forms part of voluntary disclosures that companies make to their various stakeholders. As opposed to financial statements, which content is regulated by various standards, acts and codes, the use of corporate websites is not regulated in South African. Intuitively, one would expect a continual increase over time in companies' use of corporate websites as communication channel for a number of reasons: decreased cost, non-textual communication via video and audio (enabled by increased bandwidth), increased expectations from users that information will be available via WWW and an increased demand and supply of information following regulatory changes (e.g., International Integrated Reporting Framework). The purpose of 3rd study by George Nel and Leana Esterhuyse was therefore to examine whether there is evidence that Johannesburg Stock Exchange (JSE)-listed companies have improved the usage of their corporate website as a stakeholder communication channel between 2012 and 2015. The study sample consisted of fifty-eight companies listed on the JSE in South Africa. For each company in the study sample, a disclosure score consisting of 25 attributes was calculated following a content analysis of corporate websites in both 2012 (pre-test) and 2015 (post-test). As the authors anticipated that technology and regulatory stimulants might affect the availability of information on corporate websites differently, the total disclosure score was composed of an annual reporting (AR), extra content (EC) and technology (T) score.

The results of a paired t-test showed that the increase in the mean total disclosure score was statistically significant at the 1% level. It therefore seems that for the study sample, significant improvements were made overall in the usage of their websites over the three-year period. This can probably be ascribed to the increase in bandwidth as well as improved application of integrated reporting principles. The mean AR score decreased, but this was not statistically significant. Based on an analysis of the attributes measured to compile the AR score, it is evident that the decrease in the AR score is caused by the decrease in the number of companies who are providing their annual reports in alternative formats such as HTML and Excel. On the other hand, both the mean EC and T scores increased statistically significant at the 1% level. It seems that the change in disclosure behaviour centres on providing extra content, video and audio features, as well as improved symmetrical communication features. Finally, the potential of five company characteristics to explain the use of the corporate website as communication channel were tested, i.e. industry membership, company size (market capitalisation), leverage (debt to assets), dual listing status and dispersed shareholding. Only company size and dual listing status were found significant in explaining the use of the corporate website as communication channel in both 2012 and 2015.

The study contributes to the institutional isomorphic theory of voluntary disclosure behaviour by showing that over time companies can decide to reduce their disclosure effort. Previously, it was usually assumed that disclosure behaviour would always increase or at least remain stagnant over time. Comparing for the first-time website communication practices over two periods for the same sample, the study seems to indicate that JSE-listed companies in their sample are exhibiting mimetic isomorphism in that they follow the lead of other companies that reduces the availability of HTML reports.

With sharpened digitization and business transformation strategy, the resulting changes from the accelerated rate of technological adoption, and the performance outcome from the exploitation of technology trends such as robotic process automation (RPA), social media, mobile, analytics, cloud computing, and internet of things (SMACIT) which significantly influence processes, products, and services are all the more evident. The extent to which information technologies are applied to realize efficiency, business effectiveness and innovation is, expectedly, exponentially more significant in the future. As a result, IT leaders are acknowledging digital transformation for what it has become - a business opportunity than a buzzword.

However, even when the potentials for business value generation through digital transformation and the return on investment (ROI) is promising, they do not come cheap, and worse still, digital transformation initiatives are failing at a time of quantum leap in technological innovation and abundance of knowledge in change management. The failures in transforming businesses digitally could be attributed to the existing gap in the understanding of the mechanism through which firms attain business value from technology. There has been overly emphasis on technology artefact than the transformation dimension which stretches beyond the technology component. More than technology, organizational readiness accounts for digital transformation success. Organization readiness refers to an organization’s ability to harness and orchestrate core organizational capabilities namely; resource capability, process capability, and cultural capability in an integrated manner. Hence, even with available innovative technology solutions, digital transformations are lagging or even failing for several reasons ranging from lack of agreement on the meaning of digital transformation to lack of organizational readiness for change.

This suggests that digital transformation failures are a function of mostly organizational factors. On the aggregate, it has been traced to a wide range of organizational factors ranging from poor planning and delivery, organizational culture, and lack of exploitation of the potentials offered by IT. Lack of organizational readiness for change is a classical definition of the underlying causes of digitization failure over time. So that as it stands today, digital business transformation is already failing for reasons which are apparent but often ignored, historically. Digital business transformation is much more than SMACIT, chatbots and artificial intelligence (AI) and big data. It entails technology adoption, but beyond that it also entails process alignment and cultural transformation that the organizations require to meet their agility demands. Digital transformation refers to a fundamental change in productivity which information technology happens to be a part.

An integrated capability approach, a framework proffered in the 4th paper by Chiene Ike Orji, provides businesses with a practical tool for aggregate understanding and holistic analysis of three dimensions of organizational capabilities that together explicate how (1) resources, (2) processes, and (3) contextual factors lead to the generation of value from information technology. These are the critical factors on which successful digital transformation and business value generation hinges. This view is anchored on the theorem that the combined and complementary use of distinct sets of resources produces an aggregate higher total return than the sum of returns that could have been achieved otherwise if each set of resources were understood, planned and utilized independently. This theory is based on the premise that when organizational capabilities are orchestrated and aligned in an integrated manner, it enhances the organization's ability to create and realize the anticipated business benefits from investments, especially IT investments, and by extension improves its performance objective.

Contrary to the current digital business transformation theory and practice which is technology driven bereft of organizational and digitization readiness, Chiene Ike Orji's paper intended to generate theoretical insights that can enrich the understanding of IT value creation and provide practical implications that are helpful to firms wanting to digitally transform their business and realize benefits from IT investments. It is recommended that managers prior to full-scale immersion in the transformation, evaluate not only the technology but also the organizations cultural and structural disposition to the anticipated transformation, and ensure a level of readiness which transforming the business digitally requires.

Current and near future organizational strategies are placing great emphasis on automation, robots and AI – with the aim of improving efficiency and maximizing profitability. The overall quest for continued cost reductions, in not only monotonous tasks but in more complex professional tasks requiring elaborate analysis, calculations and certain levels of tacit knowledge, are not only being pursued across reduced labour costs, but also across productivity improvements via increased speeds and efficiencies. The modus operandi continues to be doing more with less.

In the 5th paper, W. David Wolford deconstructs certain popular discourses on AI capabilities. An examination of AI vs human decision making abilities in the face of uncertainty, complexity and ambiguity show that humans are still better than AI in situations of uncertainty and ambiguity, while AI has an edge in situations of defined complexity. When Holford critically examines some of the latest successes in AI such as IBM's Watson and Google DeepMind's AlphaGo, which beat human champions at Jeopardy and Go, he acknowledges superhuman performances in very specific and well defined spheres of activity – yet to say is a sign of intelligence in the sense of imitating human sentience is an inaccurate anthropomorphism.

Evolutive algorithms, such as IBM's Watson, have repeatedly failed the Turing Test, in that it demands being able to maintain a fluent and meaningful conversation – in itself, an exercise of successfully navigating undefined complexities, uncertainties and ambiguities. This is because natural language conversation not only involves arbitrarily defined syntactic aspects, but the infinitely more complex and contextual semantic and pragmatic dimensions.

Similar challenges of undefined complexities, uncertainties and ambiguities exist within organizational contexts. As such, and more specifically in regards to organizational decision-making, machines are not capable to address dimensions of uncertainty and ambiguity. Humans, on the other hand, have the potential capability to do so across a unique type of knowledge known as *mètis*. It is a form of knowledge that is lived out, acquired and renewed across human practice and experience, and called upon in situations which do not lend themselves to precise measurement, exact calculation, or rigorous logic. *Mètis* cannot be simplified into deductive principles found in book learning alone, because the contextual environments in which it is exercised are too complex, non-repeatable and non-predictable in which general formal procedures are impossible to apply. Contemporary examples of *mètis* include surgeons, aircraft pilots and engineers, whereby all of these technical domains involve both uncertainty and ambiguity.

Management can help enable *mètis* by encouraging individual and social practice in various contextual settings, as well as dialogue within the workplace. Finally, Holford recommends that organizations implement organizational configurations which partner human decision makers with AI when facing the mutually inter-dependent aspects of uncertainty, complexity and ambiguity, in which humans maintain overall control and oversight.

N. Delener, Ph.D.
Editor-in-Chief

NOTE FROM THE EDITORS

As an interdisciplinary indexed journal, *The Journal of Global Business and Technology (JGBAT)* serves academicians and practitioners in the fields of global business and technology management and their related areas. JGBAT is also an appropriate outlet for manuscripts designed to be of interest, concern, and applied value to its audience of professionals and scholars.

Readers will note that our attempt to bridge the gap between theory and practice has been successful. We cannot thank our reviewers enough for having been so professional and effective in reiterating to contributors the need to provide managerial applications of their research. As is now obvious, the majority of the articles include a section on managerial implications of research. We wish to reiterate once again our sincere thanks to JGBAT reviewers for having induced contributors to answer the "so what?" question that every *Journal of Global Business and Technology* article is required to address.

Thank you for your interest in the journal and we are looking forward to receiving your submissions. For submissions guidelines and requirements, please refer to the Manuscript Guidelines at the end of this publication.

N. Delener, Ph.D., Editor-in-Chief
F. Victor Lu, Ph.D., Managing Editor

REVIEWERS

PRODUCT LIABILITY AS A CATALYST FOR INVESTMENTS INTO PRODUCT SAFETY?

Heinz Eckart Klingelhöfer

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ABSTRACT

Product liability bears significant risks for a manufacturer: litigation, damages and negative market reactions. After identifying the components of such risks as well as discussing microeconomic adjustment strategies, an approach for the appraisal of investments into product safety under the (in reality given) imperfect market conditions is developed. Since such investments affect production, the payments required for a financial valuation have to be derived from production planning. Employing duality theory of linear programming shows that the highest price an individual manufacturer can afford (the investment´s price ceiling) can be interpreted as a sum of (sometimes corrected) net present values NPVs. These corrected NPVs are a generalization of the well-known NPVs from perfect markets and consider the scarcity of capacities/resources. Surprisingly, all the partial processes of a chosen process have the same nonnegative corrected NPV as the whole process. Hence, they are not value additive. By applying sensitivity analyses, one can prove that higher risks for product liability sometimes discourage investments into product safety. This unexpected result is of utmost importance for policy makers and courts: awarding high compensations for faulty products may lead to less consumer protection – and that at even higher cost for the society. In the same way, policies allowing for high punitive elements in the awarded compensation may not be helpful for ensuring product safety. Furthermore, awarding such high punitive elements to the aggrieved party, may encourage litigation even when there is only little chance for success, leading to often incalculable risks for the manufacturer. Instead, in the interest of both sides, it might make more sense to consider stricter product license procedures.

Keywords: Product liability, investments, corrected net present values, imperfect markets, price ceiling

INTRODUCTION

Product liability – a term one finds repeatedly in international media resulting from class actions with exorbitant compensations for damages, often in connection with punitive elements. However, both science as well as practice usually take a qualitative point of view, mostly from a risk management perspective. This takes only partially into account that product liability may lead to a lot of *financial* consequences as well (Klingelhöfer, Kurz & Kurz, 2011: 243): besides and on top of insurance premiums and litigation cost, a manufacturer may still have to pay for (non-covered) compensations; the need to recall products and/or change critical components may arise; negative perceptions by clients and the

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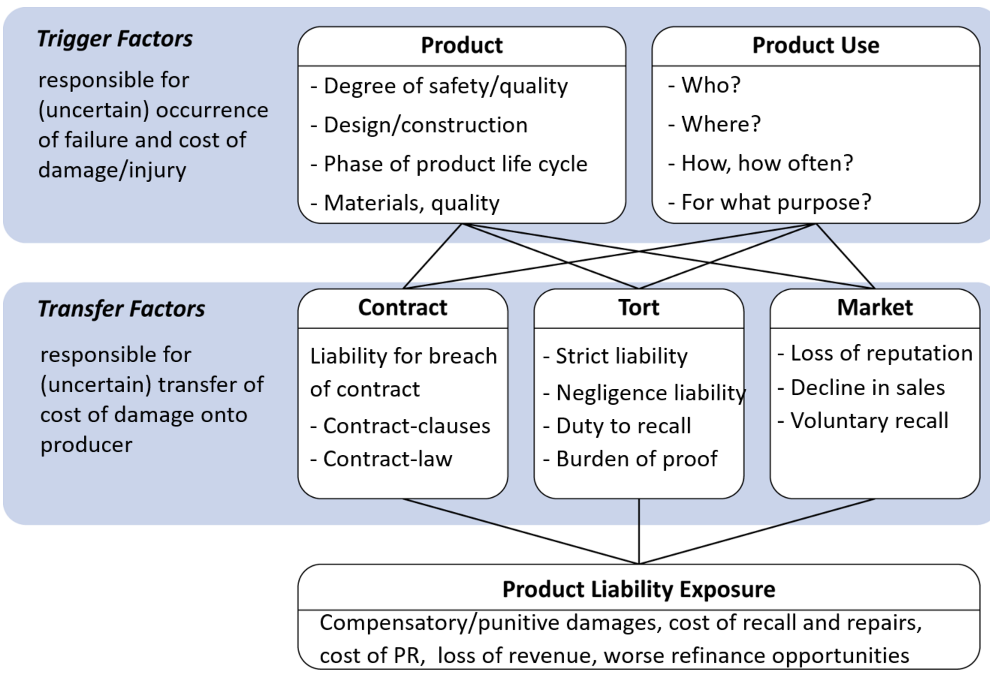
public can lead to a loss of market shares not only for the relevant product, but also affect other products and services; additional image and advertisement campaigns to restore confidence may become necessary. Often, even small issues may trigger severe financial losses. Therefore, dealing with product liability cannot be restricted to the optimization of insurance covers.

Alternatively to insurance and financing of liability risks, the manufacturer can only resort to *risk avoidance* by additional safety, disclaimers or production reductions until abandonment and divestment. However, such decreased liability exposure concurs with increasing prevention cost on the other hand: higher production cost, rebates to be granted, forfeited earnings and/or insurance premiums. A prevention decision has to take all of them into account.

Figure 1: Components of product liability risk



Source: Klingelhöfer, Kurz & Kurz (2011): 244, based on Wischermann (1991).

Therefore, this paper tries to investigate how product liability may affect decisions on investments into product safety. Under perfect market conditions, transferring the results of *Pigou* (1932: 172, 174, 183, 224) for the effects of taxes and subsidies, one would expect an increasing need for such a mitigation the higher the perceived risk is. However, in reality, markets are not perfect, but imperfect. In particular with respect to product safety, constraints resulting from production and restricted capacities (and also from limited financial opportunities) must be taken into account. This means, that in theory (over-)compensation effects may be possible. Hence, this paper presents an approach to assess investments into product safety and to examine the determinants of their price ceiling in imperfect markets. On this basis, it shall also investigate whether such overcompensation effects may indeed exist. If so, then this is for utmost importance for policy makers and courts since their decisions and judgements to compensate consumers for faulty products may lead to adverse effects with respect to increased consumer protection.

MANIFESTATION OF PRODUCT LIABILITY FOR THE MANUFACTURER

Components of product liability risk

In principle, one can divide the components of product liability risk in *trigger* und *transfer factors* (Klingelhöfer, Kurz & Kurz, 2011; Wischermann, 1991). While the product and its use fall under the former, only the latter, i.e. contracts, tort or the market situation, lead to a responsibility transfer to the manufacturer (fig. 1):

Obviously, the manufacturer´s influence on these components of product liability is limited: Regarding the *trigger factors*, he will only have little influence on the product use. However, product development and design (incl. the chosen materials, construction, complexity and testability) as well as the realized quality level, allow him to affect some risk parameters as well as the kind of usage, the height of a possible damage and the point in the product life cycle when it may occur (Klingelhöfer, Kurz & Kurz, 2011: 243-245; Wischermann, 1991: 76-78; Masing, 1994: 27). Also, the product presentation, warnings and a good instruction manual may reduce usage damages and limit the resulting liability, while the marketing instruments allow for interaction with the user on safety issues and the necessary level of care (Rogler, 2002: 378; Eisenberg et al., 2008: 173-175).

With respect to the *transfer factors*, the manufacturer may hardly do anything regarding the existing liability scheme and the market environment, but often he will be able to impact the contract conditions:

Usually, he will have to deliver free from defects and at the agreed quality, which will allow for a usage according to the contract. Otherwise the buyer might insist on supplementary performance, require a reduction of the purchase price or even withdraw from the contract; the seller may be liable for faults (Klingelhöfer, Kurz & Kurz 2011: 244; Wischermann 1991: 83 f.). Further claims may be the consequence of guarantees and secondary obligations like duties of disclosure, to advise (inform, instruct, or warn) or to care – and, finally, legally from tort law, in particular in its facets of strict liability and negligence liability. While strict liability results from a failure in manufacturing, design or information, negligence refers to a failure in exercising reasonable care in design, construction, manufacturing, information, surveillance (Klingelhöfer, Kurz & Kurz 2011: 246).

Microeconomic adjustment to product liability

Since, according to the previous, the user normally only has a limited opportunity to judge the product´s safety and, therefore, usually is not able to influence the occurrence of a product damage, his behaviour can be seen as a datum for the manufacturer. This allows for assuming a *unilateral* view. Then, the manufacturer´s *cost* C resulting from product liability consist of the expected cost of a damage/loss ECD and his cost for damage prevention CDP (for the following cp. analogously Klingelhöfer 2000: 205-209; 2013: 12-13):

(1) $C = CDP + ECD$

ECD[2] will decline and CDP increase with the level of his precaution pre (standard of care):

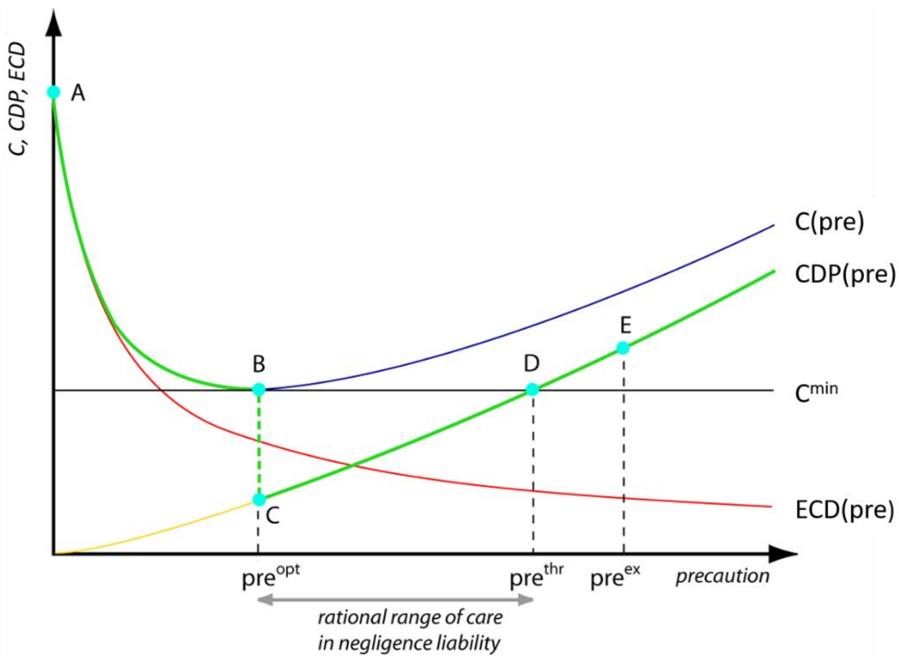
(2) $\partial ECD/\partial pre \leq 0$,

(3) $\partial CDP/\partial pre \geq 0$

Punitive elements (as according to US laws) and compensations for immaterial damage, pain or suffering can be included via a factor or a summand to the amount of damage. Thus, taking the preventative activities into account, one can write instead of (1) (figure 2):

(4) $C(pre) = CDP(pre) + ECD(pre)$

Figure 2: The (slightly expanded) basic liability model



Source: own, based on Klingelhöfer (2000): 205-209, and Endres (2001): 23-33, 41-51.

According to fig. 2, the total cost of product liability C reach their minimum C^{min} in point B. In case of *strict liability*, this point would also represent the manufacturer´s optimal level of precaution pre^{opt}, while in case of *negligence liability*, depending on the level of his standard of care, the cost incurred by the manufacturer may be even lower than the sum of ECD and CDP: exercising the precaution pre^{nec} demanded by the courts, the manufacturer is no longer liable for the damage, so that only prevention cost CDP occur. Thus, the cost function C(pre) will have a jump discontinuity in pre^{nec} (cp. the jump from point B to C in fig. 2):

[2] While in the following trees of future states will be used to model uncertain future, the probability of a damage in a particular state (depending on the level of precaution) is considered via the ECD in this state.

(5) $$C(pre) = \begin{cases} CDP(pre) + ECD(pre) & \text{for } pre < pre^{nec} \\ CDP(pre) & \text{for } pre \geq pre^{nec} \end{cases}$$

In the end, this is true for all the necessary precaution levels which are smaller than the threshold level pre^{thr} in fig. 2: $pre^{nec} \leq pre^{thr}$. However, if the courts demand a higher level of precaution than pre^{thr} (i.e. $pre^{nec} > pre^{thr}$) like the excessively high one pre^{ex} in fig. 2, it would not make sense to follow this demand from a cost perspective. Instead, one would just realize the optimal level pre^{opt}: on this level pre^{opt} one would reach point B again, while the excessively high level pre^{ex} would lead to point E with much higher cost just for damage prevention in comparison to the relatively small total cost in B for precaution and expected damages.

ASSESSMENT OF INVESTMENTS INTO PRODUCT SAFETY

Background: Investment assessment on imperfect markets under uncertainty

Assessing an investment into product safety to reduce product liability needs to consider the decision maker´s individual objectives and decision field, i.e. in particular the production situation (of the potentially harmful products). Therefore, a valuation employing cost-based approaches, discounted cash flow (DCF) models or real options analyses is no longer appropriate (Klingelhöfer 2010: 33 f.): their underlying condition of perfect markets does not concur with the existence of such decision relevant market imperfections. This may result already from restricted or differing borrowing and lending conditions, as shown for two points in time by Hirshleifer (1958). Furthermore, manufacturing companies may have other opportunities than the financial market – like investing in other technologies or increasing/reducing production. Then, both ordinary (net) present values calculated by discounting expected cash flows with exogenous interest rates (even if adjusted to uncertainty) as well as real options values are inadequate for the financial valuation of technology investments. This becomes even more significant as other requisites for the application of real option pricing models usually are not fulfilled by the characteristics of investments into product safety either.[3]

Therefore, instead of calculating the investment´s value solely by discounting cash flows with a single market interest rate, a theoretically correct (partial) appraisal demands the endogenous marginal rates of return of the best alternatives (compare for this and the following Klingelhöfer 2017: 3). Likewise, a mere calculation of the net present value NPV of an additional object does not say much regarding its profitability, because such an NPV does not account for capacity shortages resulting from the realization of this additional object, which, subsequently, may also alter the decision relevance of other objects or capacities (i.e. binding restrictions of the manufacturer´s investment and production program may change). Consequently, assessing the degree of profitability of an additional single investment or activity within imperfect markets means a comparison of the situation after investing [i.e.

[3] In many cases, markets containing real investments are not complete (Klingelhöfer 2010: 33 f.): Short selling of (installed) machines or production lines is generally not possible. Also, the underlying asset (the investment) is normally neither divisible (it is realized entirely or not at all) nor traded continuously, nor following a distinct (stochastic) price process. Additionally, the effects of technology investments and the consequences of interdependencies on the entire production are individually different. Thus, both alternatives – the construction of a replicating portfolio with production plants as well as finding a twin asset that is perfectly correlated with the underlying – are likely to fail. However, in case their underlying assumptions are fulfilled, certain discrete option pricing models, such as the binomial model of Cox, Ross & Rubinstein (1979) and Rendleman & Bartter (1979) (and therefore several real options based approaches), result as specifications of the presented model (Klingelhöfer 2006: 76–77).

the valuation program (VP)] to the one before investing [i.e. the basic program (BP)] (Hering 2014: 60-62; Jaensch 1966: 664–665; Klingelhöfer 2006: 59–91; Matschke 1975: 253–257, 387–390). By doing so, a sensible approach implicitly considers (differently from neoclassical approaches) that such a technology investment is usually indivisible – it is either undertaken entirely or not at all. In case of a greater maximum value in the VP than in the BP, investing becomes reasonable. Ensuring this by means of a minimum withdrawal constraint, the VP computes the *price ceiling* p_I^{opt}*, that is, the highest possible price p the manufacturer could afford for investing into product safety*. Employing duality theory of linear programming then allows for examining its determinants and delivers information for the theoretically correct calculation of the (corrected) net present values of possible activities, and sensitivity analyses reveal the impact of parameter changes on the investment´s profitability.

Uncertainty may be taken into account by using trees of future states (Klingelhöfer 2017: 3 with reference to Magee 1964a, 1964b; Mao 1969; Klingelhöfer 2006: 59-83; Laux 1971: 19-22, 39-44): Starting with s = 0 for the already realized and, therefore, known state in t = 0, the set $\boldsymbol{S} = \{0; 1; \ldots; S\}$ also includes the S possible future states s until the time horizon t = T. Although presenting itself graphically in a (two-dimensional) tree structure, this set may still be easily treated as a one-dimensional mathematical structure by consecutively numbering the states from s = 0 to s = S. Hence, mathematically, the valuation under uncertainty does not differ from the one under certainty (where each point in time t would be represented by exactly one state s). However, in the economical interpretation, this means that *all* payments in *all* possible states are considered. At least, because of the given mathematical structure, the decision maker does not need to know probabilities, means or variances, so that the restrictive assumptions of the *Bernoulli* principle together with its axioms are no longer required. Instead, the decision maker only depends on information on which states may occur with positive probability, as simple dominance considerations are sufficient.

Basic considerations to formalize product liability

While the manufacturer has only limited possibilities to influence the product use, he can indeed determine which products he wants to manufacture for which kind of usage and in which production environment, the product development and design as well as the realized quality level. This still allows him to affect several risk parameters, the point in the product life cycle of a possible damage and its height. Hence, an appraisal of an investment into product safety should take these factors into account. For this reason, activity analysis shall be employed (Koopmans, 1957: 71-83; 1959; Debreu, 1959: 37-49; Nikaido, 1968: 180-185; Klingelhöfer 2000: 222-252, 417-442): every technically possible (joint) production $\underline{\varphi} = (\underline{r}'; \underline{x}')' = (r_1, \ldots, r_m; x_1, \ldots, x_n)' \geq \underline{0}$ with the m inputs r_μ (e.g., fuel, material, labour) and the n wanted and undesired outputs x_ν (i.e. besides the products also waste and emissions) results as a linear combination of the q basic activities $\underline{\varphi}^{B,\beta}$ with non-negative coefficients λ^β describing their levels (underlining a variable denotes a vector and the added prime, i.e. the symbol ´, the transposition of a vector):

$$(6) \qquad \underline{\varphi} = \sum_{\beta=1}^{q} \underline{\varphi}^{B,\beta} \cdot \lambda^{\beta} \qquad \text{with } \lambda^{\beta} \geq 0, \ \beta = 1, \ldots, q$$

Valuing the m+n resources and products φ_ε with (positive or negative) prices p_ε delivers the *contribution margin* $CM(\underline{\varphi})$ as a sum of the process specific contribution margins:

(7) $$CM(\underline{\varphi}) = \underline{p}' \cdot \underline{\varphi} = \underline{p}' \cdot \sum_{\beta=1}^{q} \underline{\varphi}^{B,\beta} \cdot \lambda^{\beta} = \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} p_{\varepsilon} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda^{\beta} = CM(\underline{\lambda})$$

On this basis it is possible to integrate the *cost of a liability scheme* according to (4) for strict liability or (5) for negligence liability. Since the manufacturer´s liability depends (amongst others) on the quantity of products sold, one may rewrite (2) as:

(8) $$\partial ECD/\partial\varphi_{\varepsilon} \geq 0$$

Nonetheless, with respect to product liability, this seems to be thought too easily: c.p. the manufacturer´s rational adaption to an increasing liability risk would be just to reduce sales until the product disappears from his program. This concern gets aggravated by the fact that (2) refers to products, while according to the definition of φ_{ε} (8) includes resources. However, since the vectors $\underline{\varphi}^{B,\beta}$ represent joint production, x_{ν} may also stand for potentially dangerous product *components*.[4] Indeed, *their reduction leads to increasing precaution*. Furthermore, as potentially dangerous components often result from a certain production input (component),[5] the generalization to φ_{ε} appears to be reasonable. Since the expected cost of damages ECD reduce the earnings from production, (7) needs to be adjusted:

(9) $$CM(\underline{\varphi}) = \underline{p}' \cdot \underline{\varphi} - \sum_{\varepsilon=1}^{m+n} ECD(\varphi_{\varepsilon})$$

In doing so, the liability-free maximum quantity $\varphi_{\varepsilon}^{max,old} \geq 0$ of the potentially harmful substances can be extended by the (maximum) *excess* $\varphi_{\varepsilon}^{max,exc}$, allowing for the new upper bound $\varphi_{\varepsilon}^{max,new}$:

(10) $$\varphi_{\varepsilon} \leq \varphi_{\varepsilon}^{max,old} + \varphi_{\varepsilon}^{max,exc} = \varphi_{\varepsilon}^{max,new} \qquad \forall\varepsilon$$

Subject to the chosen excess $\varphi_{\varepsilon}^{max,exc}$ (e.g. as a quantity where negligence will become criminally relevant as well), new maximum levels may even no longer exist. On the other hand, with respect to varying degrees of the severity of consequences, one may also model several levels of excessive production $\varphi_{\varepsilon}^{max,exc1}$, $\varphi_{\varepsilon}^{max,exc2}$ etc. in the same way – leading to additional intervals of increased production, restricted by $\varphi_{\varepsilon}^{max,new1}$, $\varphi_{\varepsilon}^{max,new2}$ etc.

In case of non-linear ECD and CM, (9) and (10) may be substituted by (11) and (12) employing partial amounts $\varphi_{\varepsilon h}$ of φ_{ε} with a *constant rate of expected cost of damages* $ecd_{\varepsilon h}$ in the H intervals h. Thus, ECD($\varphi_{\varepsilon h}$) = ECD(λ_h^{β}) will be linearly dependent on $\varphi_{\varepsilon h}$ and, therefore, on λ_h^{β} in each interval h.

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4 If one interprets a product formally as a *bundle of its components*, differences in its composition result from varying quantities of its components (Klingelhöfer 2000: 232-246, 426-430, generalising an idea of Souren 1996). With respect to product liability, this allows to look at the potentially dangerous components in a product as well as at the (total) quantity in the potentially dangerous products in the market.

5 Also an input can be interpreted as a bundle of its components. In particular the explanation in the text becomes understandable, if input and output are defined via their mass balances (e.g. in medicine or recipes). However, in a more general way, the explanations in the text also cover diverging dimensions of objects and components as they may be found in bills of materials (Klingelhöfer 2000: 236-240).

(11) $$CM(\underline{\varphi}) = \underline{p}' \cdot \underline{\varphi} - \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H} ECD(\varphi_{\varepsilon h}) = \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H} \left(p_\varepsilon - ecd_{\varepsilon h}\right) \cdot \varphi_\varepsilon^{B,\beta} \cdot \lambda_h^\beta$$

(12) $$\varphi_\varepsilon = \sum_{h=1}^{H} \varphi_{\varepsilon h} = \sum_{\beta=1}^{q} \sum_{h=1}^{H} \varphi_\varepsilon^{B,\beta} \cdot \lambda_h^\beta \quad \leq \quad \varphi_\varepsilon^{max,old} + \varphi_\varepsilon^{max,exc} = \varphi_\varepsilon^{max,new} \qquad \forall \varepsilon$$

Additionally, quantity constraints in the H partial intervals h have to be considered:

(13) $$0 \leq \varphi_{\varepsilon h} = \sum_{\beta=1}^{q} \varphi_\varepsilon^{B,\beta} \cdot \lambda_h^\beta \leq \varphi_{\varepsilon h}^{max} \qquad \forall \varepsilon \quad \forall h$$

where

(14) $$\sum_h \varphi_{\varepsilon h}^{max} = \varphi_\varepsilon^{max,new} \qquad \forall \varepsilon$$

However, since the potentially dangerous substances $\varphi_\varepsilon^\beta$ of different processes β may compensate each other, one will usually fail to derive *other* restrictions $\lambda_h^{\beta,max}$ than $\lambda^{\beta,max}$ for increasing the (partial) production levels λ_h^β: higher quantities $\varphi_\varepsilon^{\beta*}$ from process β* leave less space for production with process β in intervals h with low $ecd_{\varepsilon h}$.

(15) $$\sum_{h=1}^{H} \lambda_h^\beta \leq \lambda^{\beta,max} \qquad \forall \beta \in \{1; 2; \ldots; q\}$$

With respect to investment appraisal in the next sections, this entails implications for the corrected net present values NPV^{corr} of the partial processes h: in each state s, the adjusted constraint (15) leads to a *common* dual variable ζ_s^β – and, therefore, (after division by the dual variable l_0 for the liquidity constraint in s = 0) to the *same* upper limit for *all* the NPV^{corr} of the H_s partial processes h. However, this is understandable because it is still the very same process β – just split for mathematical reasons.

Moreover, for *convex* ECD (i.e. the rates $ecd_{\varepsilon h}$ of the expected cost of damages are not falling with increasing amounts of potentially dangerous substances φ_ε), special order conditions for the intervals h remain unnecessary, and one only needs the conditions (11), (13), and (15). Hence, both strict liability and negligence liability are modelled:

- For **strict liability**, where the manufacturer is liable for a damage, irrespectively of the standard of care he kept, one has to set $\varphi_\varepsilon^{max,old} = 0$ and $ecd_{\varepsilon h} > 0$ ∀h.

- In a scheme of **negligence liability**, the manufacturer only has to compensate if the dangerous substances exceed $\varphi_\varepsilon^{max,old} > 0$. Then $ECD(\varphi_\varepsilon) = 0$ and, thus, $ecd_{\varepsilon h} = 0$ for $\varphi_\varepsilon \leq \varphi_\varepsilon^{max,old}$. (Therefore, usually $\varphi_{\varepsilon 1}^{max} = \varphi_\varepsilon^{max,old}$.) Violation of $\varphi_\varepsilon^{max,old}$ leads to $ecd_{\varepsilon h} > 0$. As a result, $ecd_{\varepsilon h}$ can be interpreted as the *rate of punitive cost* when the production/input of the potentially harmful substances exceeds given limits. Hence, it becomes evident that *product liability may lead to similar effects as a tax system*. Furthermore, varying the limits $\varphi_\varepsilon^{max,old}$ shows that one can interpret *strict liability as a borderline case of negligence liability*.

In case of a product liability insurance, additional insurance premiums $ipr_{\varepsilon h}$ have to be considered in (11), while the rate for the manufacturer´s remaining expected cost of damages $ecd^*_{\varepsilon h}$ will decrease: $0 \leq ecd^*_{\varepsilon h} < ecd_{\varepsilon h}$:[6]

$$(16) \qquad CM(\underline{\varphi}) = \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H} \left(p_\varepsilon - ecd^*_{\varepsilon h} - ipr_{\varepsilon h}\right) \cdot \varphi_\varepsilon^{B,\beta} \cdot \lambda_h^\beta$$

Depending on the fact, whether $ecd^*_{\varepsilon h}$ is 0 in a certain interval h or not, this presentation covers both the cases that the insurance pays for the whole damage or only for a part. If the manufacturer has to pay an excess or in case the insurance only covers up to a maximum claim, then $ecd^*_{\varepsilon h} > 0$ in the respective intervals h. However, in the next sections, the indexing of $ecd^*_{\varepsilon hs}$ with an asterisk will no longer be necessary since it then follows from the individual specification of the liquidity constraint in state s whether $ecd_{\varepsilon hs}$ refers to the (remaining) expected cost of damages with or without insurance.

Different to ECD, the *cost of damage prevention* CDP are already considered model immanently:

- as opportunity cost of production if, as a consequence of product liability,
  - the otherwise possible production can no longer be run to full potential, and/or
  - potentially dangerous substances are substituted by safer ones, and/or by the fact that
- the investment to be assessed will be realized exactly for this reason, i.e. to reduce the inherent risks.

Model for the Financial Valuation of Investments into Product Safety

As already discussed, assessing investments on imperfect markets under uncertainty means to compare the situation after investing (i.e. the VP) to the one before doing so (the BP). An operationalization of the highest value to be calculated by the BP may be the maximization of the sum SWW of weighted withdrawals $w_s \cdot W_s$ subject to the constraints of investment and production – with $s \in \{0; 1; 2; \ldots; S\}$ denoting the S + 1 states from today (s = 0 in t = 0) to time horizon t = T and the weights w_s expressing to which degree the decision maker prefers payments in the regarded states relative to payments in the other states.[7] Considering that investments into product safety affect production, the constraint system needs to integrate contribution margins, the relevant limits of production and the payments related to product liability. Of these, the production limits go directly into the BP, while the

[6] This implies that the insurance premiums depend on the quantities $\varphi_{\varepsilon h}$ of the potentially dangerous substances in the relevant intervals h. Otherwise they can be seen as fix cost, independent from the production program.

[7] Cp. for this and the following analogously Klingelhöfer (2006): 271-277 together with 71-91; (2010): 36-38; (2013): 15-16 and further Hering (2017): 150-164, 276-279, for decisions under risk Laux (1971): 46 ff. The weights w_s need not sum up to 1. They are just a measure for individual preference and not necessarily expressing probabilities. Thus, although similar at first sight, SWW is normally not an expected value.

contribution margins CM (16)[8] modify its liquidity constraints: to avoid insolvency, the manufacturer has to guarantee liquidity with respect to all the payments from production and product liability, z_{js} from the other investment or finance projects inv_j (including credits and loans), uz_s which are independent of production quantities and the investment program (like additional individual deposits, fixed rents, taxes or payments determined in former periods), and the withdrawals W_s. Hence, the following linear programming problem can be derived as the BP:

(17) **Max. SWW**, where $SWW := \sum_{s=0}^{S} w_s \cdot W_s$

Subject to:

a) Liquidity constraints (capital budget constraints) for the S+1 states s (cp. (16)):

$$-\sum_{j=1}^{J} z_{js} \cdot inv_j - \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} \left(p_{\varepsilon s} - ecd_{\varepsilon hs} - ipr_{\varepsilon hs}\right) \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} + W_s \le uz_s \qquad \forall s \in \boldsymbol{S}$$

b) Γ_s production limits γ for the S+1 states s (employing restriction coefficients $a_{\varepsilon\gamma s}$):

$$\sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} a_{\varepsilon\gamma s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} \le b_{\gamma s} \qquad \forall \gamma \in \{1; 2; ...; \Gamma_s\} \qquad \forall s \in \boldsymbol{S}$$

c) Production constraints resulting from product liability (cp. (13)):

$$\sum_{\beta=1}^{q} \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} \le \varphi_{\varepsilon hs}^{max} \qquad \forall \varepsilon \in \{1;2;\ldots;m+n\} \qquad \forall h \{1; 2; ...; H_s\} \qquad \forall s \in \boldsymbol{S}$$

d) q activity level constraints, which also consider the partial processes, for the S+1 states s (cp. (15)):

$$\sum_{h=1}^{H_s} \lambda_{hs}^{\beta} \le \lambda_{s}^{\beta,max} \qquad \forall \beta \in \{1; 2; ..., q\} \qquad \forall s \in \boldsymbol{S}$$

e) Quantity restrictions of the J other investment or finance projects:

$$inv_j \le inv_j^{max} \qquad \forall j \in \{1, ..., J\}$$

f) Non-negativity conditions:

[8] For reason of simplicity ECD_s shall be assumed as a monotonously increasing and convex function of $\varphi_{\varepsilon s}$ (i.e. $ecd_{\varepsilon hs} \ge 0$ does not decrease with growing $\varphi_{\varepsilon s}$), so that special order conditions for the intervals h are not necessary. Otherwise they can be integrated analogously to Klingelhöfer (2000): 427-438. Indexing of $ecd_{\varepsilon hs}$ with β for the processes is not necessary, because a damage usually results from the products, irrespectively in which process they have been manufactured. However, $ecd_{\varepsilon hs}$ (and the subdivision into intervals h of partial amounts) can differ between the states s.

$$\lambda_{hs}^{\beta},\ inv_j,\ W_s \ \geq\ 0 \qquad \forall \beta \in \{1; ...; q\} \quad \forall h\ \{1; 2; ...;\ H_s\} \quad \forall j \in \{ j = 1; ...; J\} \quad \forall s \in \boldsymbol{S}.$$

Its optimal solution SWW^{opt} serves as a profitability benchmark for investing into product safety for process q (w.l.o.g.). Only if the manufacturer receives at least the same sum of weighted withdrawals again (minimum withdrawal constraint), the investment I becomes financially interesting. Then, surplus money can either be consumed or used to pay the investment´s price p_I. Thus, the VP calculates the decision maker´s highest affordable price for carrying out this investment: its *price ceiling* p_I^{opt}. Besides this different objective function VAL and the minimum withdrawal constraint, the VP resembles structurally the BP. However, it also includes all the activity level-dependent and -independent payments caused by this investment. In particular, the liquidity constraints will not only consider the new contribution margins according to (16), but also the investment´s price p_I and other investment related payments z_{Is} which are independent from the activity levels of production (e.g. for implementing the safety measures).

(18) **Max. VAL;** VAL := p_I

Subject to:

a) Liquidity constraints (capital budget constraints) for the S+1 states s (cp. (17a)):

$$-\sum_{j=1}^{J} z_{j0} \cdot inv_j - \sum_{\beta=1}^{q-1} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_0} \left(p_{\varepsilon 0} - ecd_{\varepsilon h0} - ipr_{\varepsilon h0}\right) \cdot \ \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{h0}^{\beta} + W_0 + p_I$$
$$\leq uz_0 + z_{I0} + \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_0} \left(p_{\varepsilon 0} - ecd_{\varepsilon h0} - ipr_{\varepsilon h0}\right) \cdot \ \varphi_{\varepsilon}^{B,I} \cdot \lambda_{h0}^{I}$$

$$-\sum_{j=1}^{J} z_{js} \cdot inv_j - \sum_{\beta=1}^{q-1} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} \left(p_{\varepsilon s} - ecd_{\varepsilon hs} - ipr_{\varepsilon hs}\right) \cdot \ \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} + W_s$$
$$\leq uz_s + z_{Is} + \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} \left(p_{\varepsilon s} - ecd_{\varepsilon hs} - ipr_{\varepsilon hs}\right) \cdot \ \varphi_{\varepsilon}^{B,I} \cdot \lambda_{hs}^{I} \qquad \forall s \in \boldsymbol{S} \setminus \{0\}$$

b) Γ_S production limits γ for the S+1 states s (employing restriction coefficients $a_{\varepsilon\gamma S}$):

$$\sum_{\beta=1}^{q-1} \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} a_{\varepsilon\gamma s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} + \sum_{\varepsilon=1}^{m+n} \sum_{h=1}^{H_s} a_{\varepsilon\gamma s} \cdot \varphi_{\varepsilon}^{B,I} \cdot \lambda_{hs}^{I} \leq b_{\gamma s} \qquad \forall \gamma \in \{1;\ ...;\ \Gamma_s\} \qquad \forall s \in \boldsymbol{S}$$

c) Production constraints resulting from product liability (cp. (13)):

$$\sum_{\beta=1}^{q-1} \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_{hs}^{\beta} + \varphi_{\varepsilon}^{B,I} \cdot \lambda_{hs}^{I} \leq \varphi_{\varepsilon hs}^{max} \qquad \forall \varepsilon \in \{1;2;\ldots;m+n\} \qquad \forall h\ \{1; 2; ...;\ H_s\} \qquad \forall s \in \boldsymbol{S}$$

d) q activity level constraints, which also consider the partial processes, for the S+1 states s (cp. (15)):

$$\sum_{h=1}^{H_s} \lambda_{hs}^{\beta} \leq \lambda_s^{\beta,\max} \qquad \forall \beta \in \{1; 2; ...; q-1; I\} \qquad \forall s \in \boldsymbol{S}$$

e) Quantity restrictions of the J other investment or finance projects:

$$inv_j \leq inv_j^{\max} \qquad \forall j \in \{1, ..., J\}$$

f) Minimum withdrawal constraint (ensuring that the utility is not less than before):

$$-\sum_{s=0}^{S} w_s \cdot W_s \leq -SWW^{opt}$$

g) Non-negativity conditions:

$$\lambda_{hs}^{\beta}, inv_j, W_s \geq 0 \quad \forall \beta \in \{1; ...; q-1; I\} \ \forall h \{1; 2; ...; H_s\} \ \forall j \in \{j = 1; ...; J\} \ \forall s \in \boldsymbol{S}$$

$$p_I \in \mathbb{R}$$

Besides the investment´s price p_I and the activity levels λ_{hs}^{I} of the partial processes of the now safer process I (instead of q before), the BP and the VP contain the same decision variables: the activity levels λ_{hs}^{β} of the partial processes h of the q – 1 old processes □, the quantities inv_j of the other projects j, and the withdrawals W_s. In both programs, the contribution margins (16) modify the liquidity constraints, while (13) and (15) are constraints.

PRODUCT LIABILITY AND THE WILLINGNESS TO INVEST INTO PRODUCT SAFETY

(Corrected) Net Present Values and the Price Ceiling for the Investment

If both the BP and the VP have a finite and positive optimal solution, applying duality theory of linear programming allows for obtaining information about the determinants of the price ceiling (the maximum payable price). In order to interpret them economically, at first (corrected) net present values shall be derived:

By introducing the dual variables

- l_s for the liquidity constraints (and the resulting discount factors $\rho_{s,0} = l_s/l_0$),
- $\pi_{\gamma s}$ for the restrictions of production,
- $\zeta_{\varepsilon hs}^{PLL}$ for the interval boundaries h with constant rates of expected cost for damages resulting from product liability and with constant insurance premiums,
- ζ_s^{β} for the activity level constraints,
- ξ_j for the limits of the other investment or finance projects;

and dividing the dual constraints by l_0, one obtains the *(corrected) net present values* $NPV^{(corr)}$ of:[9]

- using the partial processes h of the processes $\beta \in \{1; 2; \ldots; q\}$ in the BP or $\beta \in \{1; 2; \ldots; q-1; I\}$ in the VP in the states s:

$$(19)\quad NPV^{corr}_{\lambda h,\beta s} := \underbrace{\sum_{\varepsilon=1}^{m+n} \left(p_{\varepsilon s} - ecd_{\varepsilon hs} - ipr_{\varepsilon hs}\right) \cdot \varphi^{B,\beta}_{\varepsilon} \cdot \frac{l_s}{l_0}}_{NPV_{\lambda h,\beta s}} - \underbrace{\left(\sum_{\gamma=1}^{\Gamma_s} \sum_{\varepsilon=1}^{m+n} a_{\varepsilon\gamma s} \cdot \varphi^{B,\beta}_{\varepsilon} \cdot \frac{\pi_{\gamma s}}{l_0} + \sum_{\varepsilon=1}^{m+n} \varphi^{B,\beta}_{\varepsilon} \cdot \frac{\zeta^{PLL}_{\varepsilon hs}}{l_0} \right)}_{Correction} \le \frac{\zeta^{\beta}_{s}}{l_0}$$

$NPV^{corr}_{\lambda h,\beta s} :=$ discounted contribution margin (incl. the expected cost of damages and insurance premiums)

– discounted monetary equivalent of the required capacity of the production constraints (including the relevant limits resulting from product liability)

- the realization of the J other investment or finance projects j:

$$(20)\quad NPV_{inv,j} := \sum_{s=0}^{S} z_{js} \cdot \frac{l_s}{l_0} = \sum_{s=0}^{S} z_{js} \cdot \rho_{s,0} \le \frac{\xi_j}{l_0}$$

$NPV_{inv,j}$:= discounted payments

Because of the complementary slackness conditions between primal decision variables and corresponding dual constraints, the known decision rules for NPVs on perfect markets can only be applied to these (corrected) NPVs (19) and (20) on imperfect markets:[10] It only makes sense to employ a process β in state s ($\lambda^{\beta}_{s} > 0$) or to realize another financial project j ($inv_j > 0$) if the corresponding inequality (19) resp. (20) is satisfied as an equation greater 0 or (for boundary objects) equal 0. This is intuitively understandable: using limited capacities reduces the space for employing other profitable processes. Therefore, besides the discounted contribution margins, the NPVs of the (partial) processes have to value the required capacities as well. Furthermore, deriving these corrected net present values shows that product liability exerts *three, partly opposing effects* on employing the (partial) production processes:

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9 While the following $NPV^{(corr)}$ can be derived from both the BP (17) and the VP (18), the dual variables and, consequently, the factors $\rho_{s,0} = l_s/l_0$ are normally not the same. Especially, in case of an existing finite positive solution $p_I > 0$ of both the primal and dual VP, one can deduce $l_0 = 1$ and, therefore, $\rho_{s,0} = l_s$ from the complementary slackness condition $p_I \cdot (1 - l_0) = 0$ for *all* the (corrected) NPVs derived from the VP.

10 The dual variables ζ^{β}_{s} and ξ_j on the right hand side of (19) and (20) can only be positive, if (17) d resp. e in case of the BP or (18) d resp. e in case of the VP are satisfied as equations. Since for positive activity levels $\lambda^{\beta}_{s} = \sum_{h=1}^{H_s} \lambda^{\beta}_{hs}$ and realizations inv_j of the financial projects the corresponding dual restriction – and, therefore, (19) resp. (20) – becomes an equation, the (corrected) NPV of maximum production employing process β / maximum realization of a financial project j is positive (0 in case of degeneration). Equally, it is 0 for (the only partially chosen) boundary productions / financial projects and even negative for non-realized processes/financial projects (0 in case of degeneration).

1. The expected cost of damages diminish the contribution margin.

2. The discounted monetary equivalents of the required capacity intervals h resulting from product liability reduce the NPVs via higher correction terms.

3. Violation of constraints resulting from product liability allows for employing further (partial) processes, leading to additional positive NPV^{corr}.

Thus, ceteris paribus, higher product liability risks diminish the profitability of a process. Nevertheless, caused by interdependencies, structural changes of production may be required. Since this may alter the dual variables as well, previously disadvantageous processes may gain profitability because of comparatively lower penalties. This will be examined further in the next section by employing sensitivity analyses.

Furthermore, according to (19) the NPV^{corr} of *all* the partial processes h of one process β are restricted by the *same* dual variable ζ_s^β. It is independent of the intervals h and can only be positive if the corresponding primal constraint $\sum_{h=1}^{H_s} \lambda_{hs}^\beta \le \lambda_s^{\beta,max}$ is satisfied as an equation. Hence, one can derive for the partial processes employed in the optimal solution:

- *Either only one* partial process h of process β has an $NPV^{corr} > 0$ (meaning that $ecd_{\varepsilon S}$ remains constant while process β is fully employed on its maximum activity level $\lambda_s^{\beta,max}$ and *not* divided into partial processes)
- *or* – in the case of more than one partial process with $NPV_{\lambda h,\beta s}^{corr} > 0$ – *all* partial processes h have the *same positive corrected net present value which is also the corrected net present value of the entire process β*. This implies that all H_S intervals h are exhausted, i.e. process β is employed on its maximum activity level $\lambda_s^{\beta,max}$.

As a result of these considerations, one can write in both cases:

(21) $$NPV_{\lambda,\beta s}^{corr} = NPV_{\lambda h,\beta s}^{corr} = \zeta_s^\beta \qquad \forall\ NPV_{\lambda h,\beta s}^{corr} > 0$$

Employing the $NPV^{(corr)}$ (19) and (20) under consideration of (21) allows for identifying the determinants of the maximum payable price p_I^{opt} for investing into product safety: If positive and finite solutions exists to both the primal and the dual problem, duality theory of linear programming demands that they are the *same* optimal solution. Hence, information on p_I^{opt} can be gained from the optimal solution to the VP's dual problem. Moreover, via the withdrawal constraint in the VP, even effects caused by the one (SWW^{opt}) of the BP are considered. Since this optimal solution SWW^{opt} of the BP in the VP´s minimum withdrawal constraint can also be substituted by the equal one to its dual, the equation for p_I^{opt} contains a variety of corresponding dual variables of both programs.

Yet, by resorting to the $NPV^{(corr)}$ (19)-(21), it is still possible to interpret this equation economically: For positive primal variables λ_{hs}^{β} of the activity levels or inv_j of the other investment or finance projects, the *complementary slackness conditions* force the corresponding inequality (19) or (20) to be satisfied as an equation. Thus, all the *positive* dual variables ζ_s^{β} and ξ_j of the VP and the BP can be substituted by the corresponding $NPV^{(corr)}$.[11] Introducing the dual variable δ of the withdrawal constraint and indexing the otherwise ambiguous dual variables and $NPV^{(corr)}$ according to their origin either with BP or with VP, leads to an equation for the *maximum price* p_I^{opt} an investor can afford to invest into product safety as a sum of several (partly corrected) NPVs:[12]

$$(22)\quad p_I^{opt} = \underbrace{\sum_{s=0}^{S} z_{Is}\cdot\rho_{s,0}^{VP}}_{I} + \underbrace{\sum_{NPV_{\lambda,Is}^{corr,VP}>0} \lambda_s^{I,max}\cdot NPV_{\lambda,Is}^{corr,VP}}_{II}$$

$$+\underbrace{\sum_{NPV_{\lambda,\beta s}^{corr,VP}>0} \lambda_s^{\beta,max}\cdot NPV_{\lambda,\beta s}^{corr,VP} - \delta\cdot \sum_{NPV_{\lambda,\beta s}^{corr,BP}>0} \lambda_s^{\beta,max}\cdot l_0^{BP}\cdot NPV_{\lambda,\beta s}^{corr,BP}}_{III}$$

$$+\underbrace{\sum_{NPV_{inv,j}^{VP}>0} inv_j^{max}\cdot NPV_{inv,j}^{VP} - \delta\cdot \sum_{NPV_{inv,j}^{BP}>0} inv_j^{max}\cdot l_0^{BP}\cdot NPV_{inv,j}^{BP}}_{IV} + \underbrace{\sum_{s=0}^{S} uz_s\cdot\left(\rho_{s,0}^{VP} - \delta\cdot l_s^{BP}\right)}_{V}$$

$$+\underbrace{\sum_{s=0}^{S}\left(\sum_{\gamma=1}^{\Gamma_s^{VP}} b_{\gamma s}^{VP}\cdot\pi_{\gamma s}^{VP} - \delta\cdot\sum_{\gamma=1}^{\Gamma_s^{BP}} b_{\gamma s}^{BP}\cdot\pi_{\gamma s}^{BP}\right)}_{VI} + \underbrace{\sum_{s=0}^{S}\left(\sum_{\varepsilon=1}^{m+n}\sum_{h=1}^{H_s^{VP}} \varphi_{\varepsilon hs}^{max,VP}\cdot\zeta_{\varepsilon hs}^{PLL,VP} - \delta\cdot\sum_{\varepsilon=1}^{m+n}\sum_{h=1}^{H_s^{BP}} \varphi_{\varepsilon hs}^{max,BP}\cdot\zeta_{\varepsilon hs}^{PLL,BP}\right)}_{VII}$$

p_I^{opt} = NPV of all activity level-independent payments of the investment into product safety (e.g. for its installation, but besides p_I^{opt}) (I)

\+ NPV^{corr} of operating the profitable safer new processes at their maximum activity levels $\lambda_s^{I,max}$ (II)

\+ NPV^{corr} of the changes between VP and BP regarding the use of the other q – 1 profitable production processes β and the former process q in the BP (if it was profitable before the investment) at their maximum activity levels $\lambda_s^{\beta,max}$ (III)

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[11] As explained in footnote 9, l_0 = 1 in the VP, but not necessarily in the BP. Hence, to substitute the dual variables of the BP by the corresponding $NPV^{(corr)}$, the latter have to be multiplied by l_0^{BP} .

[12] The dual variable δ of the withdrawal constraint calculates the value of a marginal increase in SWW^{opt} referring to the objective function of the VP (the price ceiling).

+ NPV of the changes between VP and BP regarding the inv_j^{max} realized other financial projects j (IV)

+ NPV of the changes between VP and BP regarding the valuation of the payments that are independent of activity levels and the investment program (V)

+ NPV of the changes between VP and BP regarding the monetary equivalents of the production constraints (VI)

+ NPV of the changes between VP and BP regarding the monetary equivalents of the exhausted production intervals h resulting from product liability (VII)

This price ceiling p_I^{opt} for investing into product safety is determined by the (corrected) NPVs of its payments and of the interdependencies resulting from adjusting the optimal investment program. Under uncertainty, the *discounted payments in all the states s are included* – even if, in fact, they may not occur.

At first sight, this economic interpretation (22) of p_I^{opt} resembles the known one from perfect markets (cp. analogously Klingelhöfer 2017:15): Especially, the (partly corrected) net present values $NPV^{(corr)}$, which were derived from the dual constraints of the two primal problems, represent the equivalents to the ordinary NPVs on perfect markets. Hence, writing p_I^{opt} as a sum of (partially corrected) net present values allows for an interpretation which may be of particular importance for management accounting and financial planning: Once the optimal solution is known and as long as its structure does not change, one can easily estimate *the monetary consequences (in today´s money)* of varying price determinants (e.g. of the expected cost of damages or the insurance premiums). Nonetheless, one has to recognize that on imperfect markets these $NPV^{(corr)}$ are *usually not* calculated by discounting with capital market interest rates, but with the correct *endogenous* interest rates of their respective optimization problem BP or VP (expressing the *individually different* opportunity cost of capital), and that they are corrected for using restricted capacities. Furthermore, on imperfect markets, also the effects of restricted resources/capacities (which would not be considered on perfect markets) are valued in monetary terms as price determinants. These discounted monetary equivalents have the same monetary interpretation as net present values. Thus, one can see that the maximum payable price for investing into product safety is calculated in a much more complicated way than on perfect markets, but, in the end, may be expressed in a similar way. However, being corrected for using restricted capacities and considering the interdependencies occurring from: (1) imperfect market conditions and (2) changes between the situations before and after realising the investment, it gives already an indication for possible *overcompensations* between the various determinants. And in fact, this is the reason that under the conditions of imperfect markets one can get to much more complex, even unexpected and undesired, reactions of the maximum payable price on changes (e.g. in the product liability risk) than the straightforward ones on perfect markets. The next section is going to examine them closer.

Increasing Product Liability Risk and the Willingness to Invest Into Product Safety

The economic interpretation of the terms (II), (III) and (VII) of (22) demonstrates the effect of product liability on the *price ceiling* p_I^{opt} for investments into product safety resulting from

- changes in the expected cost of damages and the necessary insurance premiums as well as
- the usage of potentially harmful substances in the liability relevant intervals h.

In particular, the affected NPV^{corr} (19) and (21) seem to confirm the expected economical results for single investments because the safer new processes are charged less than the more dangerous old ones (most visible if one compares the new ones I to the former ones q). However, sensitivity analysis of the left hand side coefficients of both the BP and the VP reveals that higher liability risks are *not always helpful for investing into product safety*. p_I^{opt} may indeed grow, but also stay constant or even decline. Mathematically, there are three reasons for this:

- Both the rates $ecd_{\varepsilon hs}$ of the expected cost of damages and the insurance premiums $ipr_{\varepsilon hs}$ are coefficients for decision variables which can be basis or non-basis variables. This may differ between the BP and the VP.
- The optimal solution of the VP considers the one of the BP via the minimum withdrawal constraint.
- In both programs, negative $NPV^{(corr)}$ cannot be part of the optimal solution.

Hence, while the (positive) terms II of (22) resulting from continuous production with the safer new processes and, consequently, perhaps some of the positive terms VII of (22) are still decreasing, some of the other processes, which contribute to the negative terms III, and perhaps also some of the negative terms of VII of (22), may lose their profitability earlier. Therefore, no longer being part of the optimal solution, they can neither diminish the absolute value of some of the negative terms (III) and (VII) (which result from the BP) – causing a possible (over-) compensation of the effects of higher $ecd_{\varepsilon hs}$ and/or $ipr_{\varepsilon hs}$. With other words: the optimal solution SWW^{opt} of the BP is no longer equally affected as the one of the VP, so that p_I^{opt} may decline. In the end, this proves that a higher risk of product liability may lead to the **paradoxical situation** that: 1. an investment into product safety is *no longer attractive*; 2. the *marginal incentive to invest is negative*; and 3. the *expected damages are even higher*. Clearly, this finding is of utmost importance for policy makers and courts: In their desire to protect consumers from and compensate them for damages from faulty products, they will have to consider that their decisions and judgements may be counterproductive instead. Obviously, this refers in particular to high punitive elements in the awarded compensation. This point is gaining even more importance when the punitive amount is payed to the aggrieved party: in the same way as people may be motivated to invest into lottery tickets, high punitive elements encourage litigation (sometimes with incalculable risks for the manufacturer) even when there is only little chance for success. Hence, policy makers and courts have to carefully analyze the individually given situation to prevent a generalized reaction by the manufacturers which, in the end, may lead to less consumer protection – and that at higher cost for the society.

In order to underline the importance of this – perhaps unexpected – outcome for practical decisions, it should be stated that it does not result from employing “just” a linear programming approach but rather from the interdependencies between (constrained) production and investments on imperfect markets. In order to demonstrate these findings, a small example shall be employed. Focussing on the main results as stated above and allowing for easier recalculations, it is kept as simple as possible. Therefore, some of its assumptions may seem to be unrealistic. Nevertheless, similar results can be derived on the basis of different quantities, a longer time horizon and and future states to consider uncertainty, other withdrawal preferences, and additional opportunities for obtaining finance.

EXAMPLE – INCREASING PRODUCT LIABILITY RISK AND THE WILLINGNESS TO INVEST INTO PRODUCT SAFETY

The manufacturer of a product x_P wants to maximize his withdrawals in t = 1. Currently, he has uz_0 = 150 [$] available in t = 0. Additional borrowing is not possible, but he can lend money at the interest rate i_L = 50% (investment project inv_L), hence, the market is imperfect. To manufacture x_P, he needs two resources r_1 and r_2, i.e. he employs the basic activity $\underline{\varphi}^{B,old} = \left(r_1^{B,old}, r_2^{B,old}; x_P^{B,old}, x_C^{B,old}\right)' =$ (4, 5; 8, 10). Unfortunately, one of the product components x_C tends to be faulty and may cause damages during usage (for reason of simplicity, no other components shall be considered). Therefore, the manufacturer thinks about investing into a modification I which allows for reduction of the potentially dangerous component x_C by 3 [QU] (quantity units), if input r_1 increases by 1 [QU]. This leads to the modified basis activity $\underline{\varphi}^{B,I} = \left(r_1^{B,I}, r_2^{B,I}; x_P^{B,I}, x_C^{B,I}\right)'$ = (5, 5; 8, 7)′. Before and after investing, the process can be operated at the same maximum activity levels $\lambda^{old,max} = \lambda^{I,max} = 10$ with prices $\underline{p} = (p_{r1}; p_{r2}; p_{xP}; p_{xC})' = (-12; -6; 30; 0)'$, but for the installation the manufacturer has to spend $z_{I,0}$ = –150 [$] in t = 0. Hence, performing the basic activities once (i.e. $\lambda^{old} = \lambda^I = 1$), leads to the following contribution margins CM if no damage occurs:

(23) $CM(\lambda^{alt} = 1) = \underline{p}' \cdot \underline{\varphi}^{B,old} \cdot 1 = -12 \cdot 4 - 6 \cdot 5 + 30 \cdot 8 + 0 \cdot 10 = 162$ [$]

(24) $CM(\lambda^{I} = 1) = \underline{p}' \cdot \underline{\varphi}^{B,I} \cdot 1 = -12 \cdot 5 - 6 \cdot 5 + 30 \cdot 8 + 0 \cdot 7 = 150$ [$]

With respect to product liability, the manufacturer calculates with the following rates of the expected cost of damages ecd_{xC} for both points in time, leading to 3 intervals h for the partial processes λ_h^{old} and λ_h^I:

Table 1: Expected cost of damages and resulting partial activity levels of the old and the modified production

h	$ecd_{xC,h}$	For amounts x_C		Partial activity level λ_h^{old}		Partial activity level λ_h^I
1	0	$0 \le x_C \le 30$		$0 \le \lambda_1^{old} \le \lambda_1^{old,o} = 3$		$0 \le \lambda_1^I \le \lambda_1^{I,o} = \frac{30}{7}$
2	3	$30 < x_C \le 60$		$0 < \lambda_2^{old} \le \lambda_2^{old,o} = 3$		$0 < \lambda_2^I \le \lambda_2^{I,o} = \frac{30}{7}$
3	6	$60 < x_C$		$0 < \lambda_3^{old} \le \lambda_3^{old,o} = 4$		$0 < \lambda_3^I \le \lambda_3^{I,o} = \frac{10}{7}$

As one can see from table 1, the same rates of the expected cost of damages before and after the investment lead to different productions, because the reduction of the potentially dangerous component x_C allows for higher sales until the same expected damage occurs. Hence, depending on the rates of expected cost of damages $ecd_{xC,h} = ecd_{xC,h0} = ecd_{xC,h1}$ the optimal solutions SWW^{opt} of the BP and p_I^{opt} of the VP result as given in table 2.

Table 2: Optimal solutions of BP and VP with respect to product liability

$ecd_{xC,h}$ (with h = 1; 2; 3)	SWW^{opt}	p_I^{opt}	Expected cost of damages $ECD(x_C)$ before investment	after investment
0; 0; 0	4,275	–350	0	0
0; 3; 6	3,450	-50	330	150
1; 4; 7	3,200	0	430	220
3; 6; 9	2,700	100	630	360
6; 9; 12	1,950	250	930	570
9; 12; 15	1,200	400	1,230	780
10.2; 13.2; 16.2	900	460	702	864
12; 15; 18	630	430	810	990
13.2; 16.2; 19.2	450	410	396	1,074
15; 18; 21	315	290	450	1,200
15 3/7; 18 3/7; 21 3/7	282 6/7	261 3/7	462 6/7	1,015 5/7
16.2; 19.2; 22.2	225	222 6/7	0	1,062
18; 21; 24	225	42 6/7	0	1,170
18 3/7; 21 3/7; 24 3/7	225	0	0	552 6/7
21; 24; 27	225	–128 4/7	0	630
21 3/7; 24 3/7; 27 3/7	225	–150	0	0
24; 27; 30	225	–150	0	0

According to table 2, no or only small product liability risks do not encourage an investment into product safety: at both points in time, one would only realize a contribution margin of 10 · 150 [$] instead of 10 · 162 [$], but lose the initial amount of cash (plus interest) for implementing the modification. Hence, the price ceiling p_I^{opt} = –350 [$] for carrying out the investment is negative. This means, the manufacturer would only invest if somebody else pays.

However, as expected, higher liability risks affect the price ceiling for investments into product safety. As soon as ecd_{xC} becomes positive, production with the safer process I leads to less expected damages than before. Hence, although both the contribution margins CM of production in the BP as well as in the VP start to fall, the one of the safer process does not decline as fast. Therefore, the *investment becomes increasingly profitable*. At $\underline{ecd}_{xC}$ = (1; 4; 7)´ [$/QU], it even reaches its break-even point: Now, the manufacturer is willing to pay for it. Since this *advantage is growing* up to $\underline{ecd}_{xC}$ = (10.2; 13.2; 16.2)´ [$/QU], he is able to pay increasing prices while still obtaining, at the least, the same sum of weighted withdrawals as without investing.

For ecd_{xC} > 16.2 [$/QU], producing with the old process does no longer cover the expected cost of damages ECD. Thus, for $\underline{ecd}_{xC}$ > (10.2; 13.2; 16.2)´ [$/QU], the manufacturer will no longer employ the old process in the 3rd interval, but just concentrate on the first two intervals. In the VP, however, it is still worthwhile to produce in all 3 intervals, resulting in *greater ECD after investing than before*. Accordingly, the high rate $ecd_{xC,3}$ only diminishes the contribution margins CM of production employing process I, while $ecd_{xC,1}$ and $ecd_{xC,2}$ charge the first two partial processes in both programmes equally. Consequently, p_I^{opt} *begins to fall*.

These effects get even stronger for $\underline{ecd}_{xC}$ > (13.2; 16.2; 19.2)´ [$/QU], because the old process will no longer be profitable in the 2nd interval either – until, beyond $\underline{ecd}_{xC}$ = (15 3/7; 18 3/7; 21 3/7)´ [$/QU], employing the safer process becomes disadvantageous in the 3rd interval as well. However, with $\underline{ecd}_{xC}$ > (16.2; 19.2; 22.2)´ [$/QU], it does no longer make sense at all to produce with old, so that the sum of weighted withdrawals stays constant at SWW^{opt} = 225 [$], (still, the initial amount of cash uz_0 = 150 [$/QU] can be invested into the lending opportunity inv_L at i_L = 50%). Therefore, only the safer process I may cause damages. Consequently, constant withdrawals in the BP, but decreasing CMs after investing, cause p_I^{opt} *to continue to decline.*

Finally, $\underline{ecd}_{xC}$ > (18 3/7; 21 3/7; 24 3/7)´ [$/QU] stops the investment from being profitable: though one will still employ process I because its CMs remain positive at least in the 1st interval, these CMs do no longer cover the activity level-independent payments $z_{I,0}$ = –150 [$] for (un)installing the processes in t = 0. If, at last, $\underline{ecd}_{xC}$ > (21 3/7; 24 3/7; 27 3/7)´ [$/QU], there will not be any production in the VP either. For this reason, the manufacturer *will lose* $z_{I,0}$ *= –150 [$] overall.*

Nevertheless, though higher product liability risks may cause the investment into product safety to become unprofitable, one could argue that – in the interest of the society – safety sometimes costs money. But even this *argument can be wrong*: Starting at $\underline{ecd}_{xC}$ = (10.2; 13.2; 16.2)´ [$/QU], higher rates of expected cost of damages lead to *higher* expected damages *although* the manufacturer invests in product safety (cp. upper light shading in table 2), and for (18 3/7; 21 3/7; 24 3/7)´ [$/QU] < $\underline{ecd}_{xC}$ < (21 3/7; 24 3/7; 27 3/7)´ [$/QU], investing into product safety is *wrong in terms of profitability and increases the expected damages* (cp. dark shading in table 2). Taking into account that table 2 “only” furnishes information on the highest price, which is individually affordable for the investment, while the manufacturer will usually have to pay more than just 0 [$] (with the difference between the price ceiling and the actual price delivering the investment´s profitability), this dark shaded area displaying the investment´s disadvantage in terms of both its profitability as well as the resulting level of expected damages will be even larger.

CONCLUSION AND RECOMMENDATIONS

After a short introduction into product liability risks, identifying their components and discussing microeconomic adjustment strategies, a general approach to assess investments into product safety with particular regard to the effects of product liability has been developed. Since such investments affect production, the payments required for a financial valuation have been derived from production planning: Product liability modifies the contribution margins and the constraint system. At this stage it becomes visible, that strict liability may be understood as a borderline case of negligence liability.

Unfortunately, the usually applied approaches for investment appraisal, which implicitly require that the conditions of perfect markets are fulfilled, cannot be employed to determine the individual profitability of such an investment. Instead, one has to use more generalized approaches that are also applicable under imperfect market conditions and additionally consider

- the mentioned interdependencies between production and investments as well as
- that some payments may depend on the activity level of production, while others do not, and
- that a technology investment is usually indivisible (either it will be undertaken entirely or not).

Applying duality theory allows for identifying and quantifying the determinants of the manufacturer´s individual price ceiling for such an investment. On imperfect markets, this maximum price, which an individual investor is able to afford, may be interpreted as a sum of (sometimes corrected) net present values. Although dealing with uncertainty, information on probabilities, means or variances is not necessary. The corrected net present values are a generalization of the well-known net present values from perfect markets and consider the scarcity of capacities/resources. Surprisingly, if more than one partial process h of a process β is chosen, then all these partial processes have the same nonnegative corrected net present value, which is also the one of the whole process β. (Thus, the corrected net present values of the partial processes are not value additive.)

Because on imperfect markets the use of restricted capacities may lead to interdependencies, (over-)compensation effects between the various determinants of the maximum payable price for such an investment may be possible. Therefore, changes in the product liability risks may lead to much more complex, even unexpected and undesired reactions of this price ceiling than the straightforward ones that an investor would usually consider on perfect markets. Employing sensitivity analysis, it is possible to demonstrate that a higher product liability risk does not always encourage investments into product safety. In particular cases, it may even lead to the paradoxical situation that: 1. it is unprofitable to invest into product safety; 2. the marginal incentive to invest is negative; and 3. the expected damages even increase.

Obviously, this finding is of utmost importance for policy makers and courts: In their desire to protect consumers from and to compensate them for damages resulting from faulty products, they will have to consider that, instead, their decisions and judgements may be counterproductive for increased consumer protection. Hence, they have to carefully look at the individually given situation to prevent a generalized reaction by the manufacturers which, in the end, may lead to less consumer protection – and that at even higher cost for the society.

In the same way, policies which allow for high punitive elements in the awarded compensation may not really be helpful for ensuring product safety. This point is gaining even more importance when the punitive amount is payed to the aggrieved party: Firstly, in the same way as people may be motivated to invest into lottery tickets, high punitive elements encourage litigation (sometimes with incalculable risks for the manufacturer) even when there is only little chance for success. Secondly, this may lead to overprotective behavior by the manufacturers – allowing for the described paradoxical effects of less product safety at even higher cost for the society. Therefore, since consumer protection is still a noble objective, this raises the question whether it is not better to have stricter product license procedures in place which make it more difficult to bring a product into the market, but indemnify the manufacturer as long as no better knowledge is available. Of course, it should be possible to recall such licenses, and criminal law would still need to protect against criminal behaviour.

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ALLIANCE PERFORMANCE: AUTONOMOUS AND COOPERATIVE INSTRUMENTS OF CONTROL

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ABSTRACT

Control, a fundamental component of alliance relationships, improves performance. Alliance control mechanisms can be the formal result of the negotiation phase or can develop through the collaboration process. Literature therefore distinguishes formal and informal control, usually respectively understood as contract and trust. Partner firms also develop control mechanisms (autonomous resource control mechanisms) within the firm, such as appropriability mechanisms, which play an enabling and facilitating role in collaborative activities. The purpose of this paper is to explore how contract, trust and appropriability mechanisms combine to foster alliance performance.

Keywords: Contract, trust, alliance performance, appropriability mechanisms, fsQCA

INTRODUCTION

Control is a fundamental issue in alliance relationships, which are usually described as risky, dangerous and unstable (Das & Teng, 1996). More specifically, appropriability and leakage risk mitigation is important in any collaborative activity and particularly in the context of R&D alliances (Henttonen et al., 2015; Kale et al., 2000). Control is defined as a set of formal and informal mechanisms that partners can use to favour alliance performance (Kumar & Seth, 1998). Alliance control can apply at the alliance level, but it also depends on firms' alliance management capabilities (Schreiner et al., 2009).

At the alliance level, formal control is based on contractual governance, which helps mitigate potential opportunism (Poppo & Zenger, 2002). In contrast, informal control relies on informal processes that are socio-psychological in origin: relational exchange is based on a social component largely analyzed as trust (e.g., Granovetter, 1985; Kale et al., 2000).

In addition, an alliance is embedded in each partner's particular management context. Alliances enable firms to access complementary resources and know-how and their performance may depend on the firms' specific endogenous capabilities (Schreiner et al., 2009), like appropriability capabilities. Appropriability capabilities are the mechanisms that firms implement to appropriate their return on investment. These mechanisms are classified in two groups: legal protection measures (e.g., patents) and strategic mechanisms (e.g., lead time and secrecy) (Laursen & Salter, 2005), also referred to as informal

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or alternative mechanisms (Nieto & Perez-Cano, 2004). The choice of mechanism is a complex process that leads to positive alliance outcomes (Huang et al. 2013). For example, effective protection through intellectual property rights like patents encourages firms, especially small ones, to collaborate through alliances (Colombo et al., 2006). First, a patent plays a key role in signaling the firm's quality to potential partners (Levitas & McFaden, 2009; Somaya, 2012); however, it is also an appropriability mechanism with safeguards that make it easier to exploit inventions through alliances (Oxley, 1999). The perceived potential for appropriability may motivate firms to commit to and invest in the alliance relationship. The purpose of this paper is to explore how autonomous instruments of control, like appropriability mechanisms, and alliance control mechanisms, like contract and trust, combine to foster alliance performance.

THE COMPLEX LINK BETWEEN CONTROL & PERFORMANCE

Managers can use several instruments of control they can combine in various ways. Some instruments of control result from an entrepreneurial logic and from an autonomous decision. Others are the result of a cooperative behaviour (Delerue, 2005).

Cooperative Control Mechanisms: Contract and Trust

In the context of contractual alliances, two control mechanisms help firms to mitigate opportunism and achieve coordination for improved performance: a formal contract and/or trust. A contract is usually considered the central element of formal control processes in contractual alliances (Poppo & Zenger, 2002; Zollo et al., 2002) because its execution is guaranteed by competent legislation outside the alliance (Lumineau & Malhotra, 2011). A contract is the outcome of a combination of clauses (Delerue et al., 2016) that specify promises, obligations, and processes for dispute resolution (Poppo & Zenger, 2002; Lumineau & Malhotra, 2011). A formal contract is designed to control behavior in order to minimize the costs and performance losses that arise from hazards (e.g., Kalnins & Mayer, 2004; Adler et al., 2016). Control clauses are the more stringent clauses (Parkhe, 1993), exact penalties for noncooperative behavior and reduce opportunism (Deeds & Hill, 1998; Williamson, 1991). These clauses usually deal with audit, confidential information, proprietary technology, alliance termination, and the adjudication of disputes by third parties (Lumineau & Malhotra, 2011; Reuer & Ariño, 2007). A contract is therefore viewed as an important mechanism by which firms protect themselves from a partner's opportunism and as a framework within which cooperation between partners proceeds (Gulati, 1995; Reuer & Arino, 2007). There is no consensus in the literature regarding the effect of contracts on alliance performance. Some authors find that contractual governance does not affect alliance performance (Delerue, 2005; Lee & Cavusgil, 2006), showing for instance that a contract has no effect on knowledge leakage (Jiang et al., 2013). Other studies show that formal contractual governance improves alliance performance by reducing collaboration cost (Parker & Brey, 2015). On the other hand, studies show that performance depends on the level of trust (Delerue, 2005; Krishnan et al., 2006; Jiang et al., 2013). Inter-organisational trust hinges on close interactions and developing personal relationships (Kale et al., 2000). This kind of trust, also called relational capital or goodwill trust, is thus emotional and based on benevolence, integrity, and good faith (Das & Teng, 1998)—essentially, it constitutes trust-based governance. Malhotra and Lumineau, (2011: 982) point out that "Perceptions of goodwill entail attributions regarding the intention of another party to behave in a trustworthy manner." Goodwill trust is anchored in both the shadow of the past, arising from repeated interaction, and the shadow of the future – arising from expectation continuity (Poppo et al., 2008).

Extant literature has shown that firms simultaneously use both contractual and trust-based governance, since both are at play in alliance performance (Poppo & Zenger, 2002; Van der Valk et al., 2016; Jiang et al., 2013). Contracts and relational mechanisms are complementary in relationship governance (Arranz & Arroyabe, 2012; Poppo & Zenger, 2002; Van der Valk et al., 2016; Jiang et al., 2013). Arranz and Arroyabe (2012: 584) conclude that "contracts entail an ex ante way to make explicit both payoff and task coordination in the operative stage of the project, while relational norms and trust complement the contract in the face of conflicts and unforeseen situations."
Nevertheless, no consensus has been reached regarding the interplay between contractual and trust-based governance (Cao & Lumineau, 2015). Other authors argue that the two types of governance substitute each other in explaining alliance performance (e.g., Lui & Ngo, 2004). Yet the complementarity or substitution effect may depend on alliance objectives, i.e., whether the purpose is exploration or exploitation (Arranz & Arroyabe, 2012; Pittino & Mazzurana; 2013), and on partner location (Li et al., 2010). For instance, Arranz and Arroyabe (2012) find that trust has a more positive impact than contract on the performance of joint exploration projects. By analysing buyer-suplier relationship in China, Li et al. (2010) find that formal and social control mechanisms function as substitutes in domestic buyer–supplier relationships in explaining cooperation performance. These works highlight the existence of moderating effects.

Autonomous Control Mechanisms

At the same time, alliance performance relies on management capacity within the firm (Niesten & Jolink, 2015; Schreiner et al., 2009; Shakeri & Radfar, 2017), also referred to as autonomous control mechanisms (Delerue, 2005) or orchestration mechanisms (Hurmelinna-Laukkanen et al., 2012). These mechanisms, when implemented by firms, can explain alliance formation (Duysters & Lokshin, 2011; Henttonen et al., 2015) and improve alliance success (Hurmelinna-Laukkanen et al., 2012). Among these mechanisms, appropriability mechanisms are crucial, particularly in R&D alliances that are based on knowledge beyond the boundaries of any individual organization (Jiang et al., 2013; Hurmelinna-Laukkanen et al., 2012). Appropriability refers to the ability of the owner of an intellectual asset to obtain a return equal to the value generated by that asset (Cohen et al., 2000). At the firm level, Estrada et al. (2016) show that a firm must have internal knowledge-sharing mechanisms and formal knowledge protection mechanisms in order for competitor collaborations to positively impact that firm's performance.

Appropriability mechanisms can be classified into two groups: legal mechanisms provided by the system of intellectual property rights, and informal mechanisms such as secrecy and lead time (Cohen et al., 2000). One of the most studied appropriability mechanisms is the patent (e.g., Somaya, 2012). Some authors suggest that patents give managers the confidence to engage in external relationships (e.g., Baum et al., 2000). According to Henttonen et al. (2016), patents make the rules of the game visible and enable firms to exchange knowledge safely. Nevertheless, such legal protection entails limitations. For instance, in the biopharmaceutical industry, protecting inventions using patents has become more difficult in the last few years "because legal trends have created uncertainty regarding what subject matter is eligible for patent protection. […] For example, courts have invalidated patents covering valuable diagnostic methods for treating Crohn's disease and screening methods for Down's syndrome." (Smith, 2017, p. 74). Several studies therefore show that patents are often used in conjunction with other mechanisms such as secrecy (Arora, 1997; Arundel, 2001; Graham, 2004) and lead time (Laursen & Salter, 2005). For instance, Laursen and Salter (2005) find that firms who tend to use a legal appropriability strategy also tend to use a first mover strategy. However, they conclude that legal mechanisms and lead time are often incompatible because patents require openness and disclosure and first mover mechanisms require secrecy and non-disclosure. Studying knowledge-intensive business services firms, Miozzo et al. (2016) show that the combinations of appropriability mechanisms are often associated with the nature of firms' partners. In the same vein, Henttonen et al. (2016) find that patents, contracts, secrecy, and lead time are usually connected to R&D collaboration with suppliers while contracts and lead time are emphasised as appropriability mechanisms in R&D collaboration with competitors. In addition, Lee et al. (2018) find that when the technology in an industry is complex, several combinations of formal and informal mechanisms (such as multiple formal AMs and a single informal AM or a single formal AM and multiple informal AMs) can create positive synergy for the innovative product's performance, suggesting the possible complementary and substitution effects of different AMs within and between each AM type.

Combination of Control Mechanisms

Our conceptual model relies on the configurational and complementarity approach to understand the bundles of control mechanisms leading to high alliance performance. The configurational approach considers the possibility of interaction among control mechanisms and incorporates the assumption of equifinality. It posits that multiple, unique configurations of the relevant factors can lead to the same outcome (e.g. Miller, 2018). Therefore, there is no one best configuration (Grandori & Furnari, 2008). The notion of complementarity is theorized around the concept of internal fit in the interaction among different organizational attributes. "Complementarities implies that high performance arises only when particular combinations of practices with similar or different attributes interact with each other in a positive way" (Garcia-Castro et al., 2013: 392). For instance, it has been shown that bundles of human resource management practices (e.g. Lai et al., 2017), corporate governance mechanisms (Garcia-Castro et al., 2013), cooperation dimensions (Delerue, 2018) exert a collective influence on organizational outputs. Turning to the field of collaborative projects and alliances, Ning (2017) find that different combinations of formal control (outcome and behavior control) and trust (competence and goodwill trust) would lead to high project performance. Futhermore, some empirical evidence provide a valid interpretation of the existence of complementarities and substitutions. Innovation appropriation can be maintained by contract (Delerue et al., 2016). Nevertheless, several researchers note that contracts do not decrease the likelihood of knowledge leakage (Jiang et al., 2013; Delerue, 2005) due to both contract incompleteness and the nature of the knowledge leakage, which may be intentional and unintentional (Jiang et al., 2013). Instead, trust has been found to diminish risks as perceived by partners (Delerue, 2005), thereby improving innovation appropriability (Kale et al., 2000). Delerue (2005) find that combinations of instruments of control are used to reduce risks perception in alliance relationships and in turn, alliance performance.

METHODOLOGY

We sent a questionnaire to 220 top managers of biopharmaceutical SMEs in Australia. A total of 68 managers agreed to participate, for a participation rate of approximately 31 percent. The Australian biotechnology industry is small by international standards, consisting of about 220 small companies (ausbiotech.org). We use fuzzy set qualitative comparative analysis (fsQCA) to assess the causal conditions and combinations that produce the outcomes, based on set–subset connections using Boolean algebra (Ragin, 2000). This method allows for identification of distinct combinations of causal variables that suggest different theoretical pathways to a given outcome, also known as "multiple conjunctural causation" (Longest & Vaisey, 2008). Rather than attempting to identify the more significant ingredients, fsQCA seeks to understand which ingredients must be combined and in which combinations (Ragin & Fiss, 2008). *Consistency* and *Coverage* values ranging from 0 to 1 determine the sufficient and necessary conditions (Ragin and Fiss, 2008). A configurational perspective allows for the capture of three causal complexities (Hofman et al., 2017): combination, where conditions (instruments of control) may not impact alliance performance in isolation from one another, such that both the presence and the absence of conditions in the combinations can be associated with the related outcome; equifinality, where different, equally effective configurations of conditions may lead to the same outcome (Fiss 2007); and asymmetry, where all combinations of instruments of control associated with a successful alliance differ from those associated with an unsuccessful alliance. Table 1 illustrates the details of the measurement used to operationalize our theoretical construct and the Cronbach alpha reliability value.

Table 1. Items used to measure the variables

Construct	Scale origin
Perceived performance (α = .92)	Parkhe (1993)
1. Many alliance results in "spillover" effects for their parent firms. For example, positive spillover effects may occur when know-how that is gained from alliance activities can be applied profitably to non-alliance operations as well. Negative spillover effects may occur from competition between the alliance and other parent firm operations, such as when geographical markets overlap. In the present alliance, are the net spillover effects for your firm 1 Strongly negative 5. Strongly positive	
2. Using the most significant indicator of profitability in the context of this alliance (such as return on investment, return on sales, or return equity). The profitability of your alliance relative to the profitability of the industry of which the alliance is a part would be 1 far lower 5 far greater	
3. In your overall assessment, how has the alliance performed as compared to your expectations 1 very poorly 5 very well	
Lead time (α = .70)	Delerue & Lejeune (2010)
1. We increase the speed of product delivery for the client faster than the competition.	
2. Our R&D efforts are led by timelines	
Secrecy (α = .71)	Delerue & Lejeune (2010)
1. We maintain secrecy regarding product and process technology.	
2. We use confidentiality clauses in all our contracts (clients, suppliers, and partners).	
3. It is important to limit publicity about new inventions to a restricted circle until the patent application has been filed	
Patent (α= .84)	Delerue & Lejeune (2010)
1. We protect our knowledge by patents.	
2. Our patents ensure total protection of knowledge and know-how.	
Contract (α= .85)	Delerue (2005)
1. The contract should not include clauses of exclusiveness	
2. We think that a contract is essential	
3. The clauses the partners insert in the contract allow us to understand its objectives	
4. The contract enables us to define the alliance performance	
5. The contract enables us to limit the effect of a defection from	

our partner
6. The contract allows us to go to court

Goodwill Trust (α =.83) 1. There is close, personal interaction between the partner at multiple levels 2. The alliance is characterized by mutual respect between the partner at multiple levels 3. The alliance is characterized by mutual trust between the partner at multiple levels 4. The alliance is characterized by personal friendship between the partner at multiple levels 5. The alliance is characterized by high reciprocity among the partners	Kale et al. (2000)

As a first step, measures for the outcome and the conditions were calibrated into set membership scores. All calibrations were performed using the *stdrank* function in Stata proposed by Longest and Vaisey (2008). Table 2 presents the necessity and sufficiency matrix. The necessity–sufficiency matrix is equivalent to the correlational matrix in regression analysis (Garcia-Castro and Francoeur, 2016). For instance, *Patent* has a necessity score of 0.710, meaning that investing in patents above the 50th percentile in isolation does not constitute a necessary condition for superior alliance performance. Similarly, *Patent* obtains a sufficiency score of 0.616, meaning that investing in these practices above the 50th percentile in isolation also does not constitute a sufficient condition for superior alliance performance (i.e., it is below the 0.80 benchmark).

Table 2. Sufficiency and necessity matrix[a]

	P	L	V	S	K	G
Alliance performance (P)	1.000	0.647	0.710	0.723	0.738	0.715
Lead Time (L)	0.551	1.000	0.667	0.724	0.595	0.537
Patent (V)	0.616	0.679	1.000	0.777	0.743	0.543
Secrecy (S)	0.602	0.707	0.746	1.000	0.675	0.564
Contract (K)	0.704	0.667	0.818	0.774	1.000	0.594
Goodwill trust (G)	0.770	0.680	0.674	0.730	0.670	1.000

[a] Necessity scores are shown above the matrix diagonal (upper right corner) and sufficiency scores below the diagonal (lower left corner).

The next step involved identifying configurations with *y* consistencies (High alliance performance) greater than .750 (Ragin, 2009) and those significantly greater than their *n* consistencies (Low alliance performance). Logically, these configurations could nonetheless overlap. The Quine–McCluskey algorithm provides a logical reduction of the configurations (Fiss, 2007). Final reduction set results are reported in Table 3. Each column presents a configuration of causal conditions with the corresponding raw coverage, unique coverage, and solution consistency (sufficient condition for the configuration). The solution yields close to 58 percent coverage and 91.6 percent consistency.

Table 3. Configurations of autonomous and cooperative instruments of control sufficient for high and low alliance performance (final reduction set)

		High performance			Low performance	
		C1	C2	C3	C4	C5
Lead Time	C	●			⊗	⊗
Patent	V	●	⊗	●	⊗	●
Secrecy	T	●	●	⊗	⊗	●
Contract	K	●	●	●	●	⊗
Trust	R		●	●	●	⊗
Raw Coverage		0.292	0.261	0.223	0.219	.322
Unique Coverage		0.134	0.038	0.032	0.077	.181
Solution Consistency		0.957	0.976	0.970	0.865	.896
Total Coverage		0.577			.400	
Solution Consistency		.916			.866	

●Measures at above-median level. ⊗ below-median level. Blank spaces indicate "don't care."

The analysis reveals that three configurations for instruments of control (solutions C1, C2, and C3) lead to membership in the set of high-performing alliance. C1 combines patent, secrecy, contract, and lead time. C2 gives an alternative path to alliance success that combines secrecy, contract, and trust with limited or no reliance on patents. Another path is given by C3, which combines patent, contract, and trust with limited or no reliance on secrecy. The unique coverage of C1 is substantially greater than those of C2 and C3, indicating the relatively higher prominence of this configuration.

The analysis also identified two configurations associated with low performance alliances: C4, a configuration that reflects limited reliance on autonomous resource control (patent, lead time, and secrecy) and strong reliance on cooperative instruments of control (contract and trust), and C5, a configuration that reflects strong reliance on secrecy, patent, limited lead time, and limited reliance on contract and trust.

DISCUSSION AND CONCLUSION

The purpose of this research is to understand the alliance performance implications of the appropriability mechanisms implemented by firms and the formal and informal controls implemented within the alliance. Results show that the factors explaining alliance performance can form complex combinations. Contract and trust can substitute or complement each other, depending on the firm's appropriability mechanisms. Appropriability mechanisms are usually associated with innovative performance (e.g., Laursen & Salter, 2005; Cenamor et al., 2019). The results suggest that appropriability mechanisms can also explain R&D alliance performance when combined with contract and trust. It has been shown that appropriability mechanisms combine to improve innovative performance by firms. For instance, according to Laursen and Salter (2005), legal and fast-mover appropriability strategies are complementary in influencing innovative performance. Our findings show that effective combinations of appropriability strategies may differ when combined with formal and informal alliance control mechanisms.

In sum, our results show that:

(1) When alliance governance is based primarily on a contract, appropriability mechanisms and contract serve as complements and both increase alliance performance. Appropriability mechanisms compensate for the incompleteness of contracts. Van Beers and Zand (2014) also suggest that when the level of mutual trust is low, appropriability mechanisms become relevant in protecting assets. Firms are less concerned about appropriation in alliance, when patent protection is significant, when they can keep trade secret and when the first advantage is sufficiently large, (Gulati & Singh, 1998).

(2) When contract and trust are complements, secrecy and patent are substitutes that foster alliance performance. The complexity of the combinations of AMs declines.

(3) In R&D alliances, contract and trust can co-exist without leading to success, especially when the firm has not developed effective appropriability strategies.

(4) Finally, unsurprisingly, appropriability mechanisms alone do not ensure alliance success. In other words, when the autonomous resource control mechanisms (like appropriability mechanisms) replace alliance control mechanisms (contract and trust), alliances do not perform well.

From a managerial point of view, our results emphasize the need to be aware of existing dynamics between systems of alliance control and appropriability mechanisms. Managers must make finely judged decisions: they would be wise to focus on a select efficient combination of control and appropriability mechanisms.

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CORPORATE WEBSITES AS A STAKEHOLDER COMMUNICATION CHANNEL: A COMPARISON OF JSE-LISTED COMPANIES' WEBSITES OVER TIME

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ABSTRACT

Between 2012 and 2015, increases in bandwidth in South Africa and implementation of the International <IR>Framework created incentives for corporate website disclosure behaviour to change. We apply the institutional isomorphism theory to explain the observed behaviour. Using unique longitudinal data, this study examined whether 58 Johannesburg Stock Exchange-listed companies improved their corporate websites as a stakeholder communication channel. A checklist of 25 items, measuring annual report, extra content and technology features was used to complete the content analyses of the corporate websites in 2012 and 2015. Various parametric and non-parametric statistical tests were conducted to ascertain the significance of the changes over the period, as well as potential factors associated with these changes. The results indicate that although the use of technical features improved for the sample companies, and extra content were provided, financial reports were increasingly dominated by PDF formats with a decrease in the provision of HTML reports from prior levels. The study's contribution is that it provides some evidence that technology may be an enabler of general website usability, but not necessarily for financial reports. HTML financial reporting might suffer from 'negative' mimetic isomorphism, where undesirable disclosure behaviour is mimicked. This paper opens up avenues for further research into underlying reasons for temporal changes in corporate disclosure practices.

Keywords: Investor relations, online reporting, internet financial reporting, voluntary disclosure, isomorphism

INTRODUCTION

Just over 30 years ago, the World Wide Web (WWW) was born with the idea of Tim Berners-Lee to create a large hypertext database with typed links. Within ten years since the inception of the WWW, a new body of research emerged – attempting to understand companies' use of their corporate websites as a communication channel with investors. Initially (early 1990s) companies merely established some web presence, primarily aimed at customers (Stage I as described by Hedlin, 1999). According to Hedlin's model, Stage II is characterised by companies beginning to use their corporate websites to communicate financial information, usually by duplicating the hard-copy annual report in an electronic format (PDF)

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that is available on the website. Stage III is when companies start to take advantage of the unique features and possibilities of the medium, e.g. audio and video files (Hedlin, 1999).

Using data from a developing country (South Africa), Loxton (2003) and Esterhuyse and Wingard (2016) used Hedlin's (1999) three-stage model to assess the stage of companies' use of their corporate websites to communicate with stakeholders. According to Loxton (2003), "most companies in SA appear to be in the second stage". Thirteen years later, Esterhuyse and Wingard (2016) stated that "instead of moving towards stage III (HTML, video and audio) of Hedlin's model (1999), JSE-listed companies still seem to find themselves in stage II (paper-equivalent PDFs)". Although it seems that companies listed on the Johannesburg Stock Exchange (JSE) have shown no improvement since the Loxton (2003) study, it should be noted that Loxton (2003) surveyed only the 40 largest companies; whereas Esterhuyse and Wingard (2016) assessed 205 JSE-listed companies of all sizes.

Intuitively one would expect an increase in companies' use of corporate websites as a communication channel in the past decade for a number of reasons: decreased cost (e.g. increased bandwidth and internet access), non-textual communication via video and audio (enabled by increased bandwidth), increased expectation from users that information will be available via the WWW (e.g. Generation Z), and increased demand and supply of information following regulatory changes (e.g. the International Integrated Reporting Framework [IIRC, 2013] and the King III Code of Governance Principles for South Africa [IoD, 2009]).

Esterhuyse and Wingard (2016) argue that companies in developing countries would only fully utilise the benefits of corporate websites as a communication vehicle if bandwidth were increased to international standards[1]. The average South African bandwidth in 2012 was 3.29 Mbps when Esterhuyse and Wingard (2016) conducted their study, compared to an average bandwidth of 6.92 Mbps in March 2015 (Mybroadband, 2015) when Nel, Smit, Brümmer (2017) completed a similar study on website communication by South African companies. Nel et al. (2017) report that on average companies disclosed only 28% of attributes measured, with a significant cross-sectional variation between companies. The results of the Nel study shows that the majority of companies examined in 2015 did not use their corporate websites optimally to communicate with investors. Having two datasets measuring the same phenomenon at distinct periods presented us with an opportunity to study the behaviour of matched pairs. The purpose of this study was therefore to examine whether there is evidence that some JSE companies has improved the usage of their corporate websites as a stakeholder communication channel between 2012 and 2015.

LITERATURE REVIEW AND HYPOTHESES

Communications via the corporate website forms part of the voluntary disclosures that companies make to their various stakeholders. Popular theories offered to explain companies' rationale for engaging in any voluntary disclosures about their activities are agency theory (i.e. gaining the trust of the principals/shareholders [Jensen & Meckling, 1976]) and legitimacy theory (i.e. gaining the approval of societal stakeholders [Suchman, 1995]). While accepting both these theories, we argue that institutional isomorphism is an appropriate theory for our context as this study was based on the premise of technological advancements affecting disclosure behaviour. DiMaggio and Powell (1983) observe that institutions such as companies tend to behave more like one another over time. They identify three institutional isomorphic processes: coercive, mimetic and normative. Coercive isomorphism results from "formal and informal pressures exerted on organizations by other organizations upon which they are

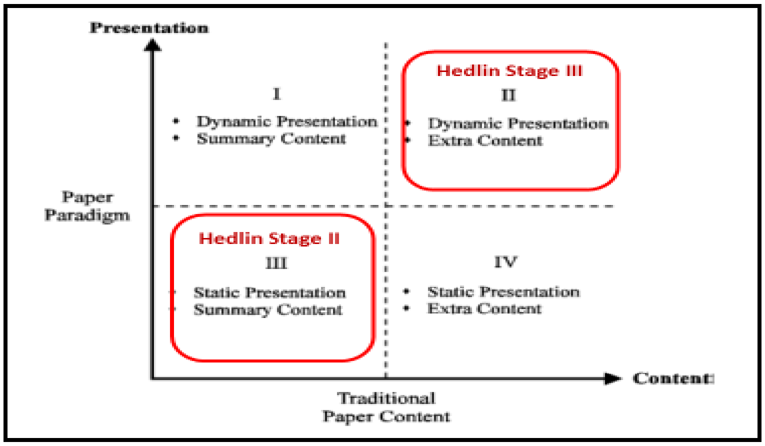
[1] For a comparison of international download speeds during the comparative period, refer to Esterhuyse and Wingard (2016: 223).

dependent and by cultural expectations in the society within which organizations function" (DiMaggio & Powell, 1983). Examples of this are where regulatory changes to disclosure requirements force companies to exhibit similar disclosure behaviour. The mimetic form of isomorphism occurs in the absence of regulation or clear guidelines (uncertainty about what is expected). In such circumstances, companies tend to mimic the behaviour or practices of other companies that are seen as successful leaders (DiMaggio & Powell, 1983). The normative force for isomorphic change in companies relates to the extent to which their personnel are members of professional bodies, for example chartered accountants. The output produced by these employees will look similar to that of other companies that employ the same type of employees, because of professional standards regarding such work (DiMaggio & Powell, 1983). When considering what and how companies use their websites for corporate communication, we would be able to consider which type of institutional isomorphism is prevalent for our sample of companies in South Africa.

Prior studies on disclosure behaviour often distinguish between content and presentation, with content referring to all financial and non-financial information and presentation with the use of presentation technologies to communicate and enhance the information. Marston and Polei (2004) reason that although investors are mainly interested in the extent to which information has been provided (i.e. content), they also need to find this information as quickly and easily as possible (via clear presentation). Usability is defined by ISO 9241-11 as "the extent to which a system can be used by specified users to achieve a specified goal with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1998). Research by the Nielsen Norman Group on the usability of websites found that websites should attract a visitor's attention within ten seconds, otherwise they will leave the site in increasing numbers during the next 20 seconds. The focus of usability guidelines is therefore on getting the users to the right information swiftly and making it easy for them to view and use the information (Nielsen 2011). The Financial Accounting Standards Board (FASB) (2000) proposes four quadrants for corporate website communications (as presented in Figure 1) based on these two dimensions (namely content and presentation).

Figure 1 is overlaid with the stages of website investor communication as proposed by Hedlin (1999) and discussed in the introduction. Movement diagonally on the FASB model corresponds with the progression on the Hedlin model. As can be seen in Figure 1, internet technologies should enable companies to move upward on the vertical axis by improving presentation formats (e.g. beyond text) and usability of websites. Pressure from users and regulators for more financial and non-financial information (e.g. integrated reporting) should move companies to the right on the horizontal axis by providing more content.

Figure 1: The two dimensions of web design attributes – Presentation and content



Source: Authors' composition from FASB (2000) and Hedlin (1999)

The average South African bandwidth in 2012 was 3.29 Mbps (Esterhuyse & Wingard, 2016), compared to the average bandwidth of 6.92 Mbps in March 2015 (Mybroadband, 2015) when Nel et al. (2017) conducted their study. During the intervening period, the Integrated Reporting Framework (IIRC, 2013) was released which calls for more information on strategies and risks and the interrelation with the companies' long-term sustainability and stakeholders. In terms of Figure 1, we conclude that there were technology enablers for dynamic presentations as well as regulatory pressure for increased content provisioning in the South African capital market between 2012 and 2015. We therefore phrase our first hypothesis as follows:

Hypothesis 1: There is a change in companies' use of their corporate websites for communicating with stakeholders as measured by the total disclosure score between 2012 and 2015.

The total disclosure score was a composite of an annual reporting (AR) score, extra content (EC) score and technology (T) score. We anticipate that the technology and regulatory stimulants discussed above might affect the subgroups differently. Utilising the subgroups, we phrase the following sub-hypotheses:

Hypothesis 1(a): There is a change in the AR score between 2012 and 2015.
Hypothesis 1(b): There is a change in the EC score between 2012 and 2015.
Hypothesis 1(c): There is a change in the T score between 2012 and 2015.

Given the voluntary nature of corporate websites as a communication medium, an assortment of empirical research focused on understanding the underlying reasons or determinants for companies' to excel (or not) in using their corporate websites to communicate with investors and stakeholders. Some of the research to date revealed that company industry, size (e.g. market capitalisation), leverage, dual listing status and shareholder dispersion are important determinants of disclosure (Botti, Boubaker, Hamrouni, & Solonandrasana, 2014; Fuertes-Callén, Cuellar-Fernández & Pelayo-Velázquez, 2014; Mendes-Da-Silva & Onusic, 2014; Mohamed & Basuony, 2014; Omran & Ramdhony, 2016; Nel et al. 2017; Esterhuyse, 2018; Kundelienė & Stepanauskaitė, 2018; Zadeh, Salehi & Shabestari, 2018). We were therefore interested in seeing whether these factors were associated with our sample of JSE-listed companies' disclosure behaviour over the two periods. We specify research Hypothesis 2 as follows:

Hypothesis 2(a): Company industry is associated with the use of corporate websites as a stakeholder communication channel in both 2012 and 2015.

Hypothesis 2(b): Company size (market capitalisation) is associated with the use of corporate websites as a stakeholder communication channel in both 2012 and 2015.
Hypothesis 2(c): Company leverage is associated with the use of corporate websites as a stakeholder communication channel in both 2012 and 2015.
Hypothesis 2(d): Company dual listing status is associated with the use of corporate websites as a stakeholder communication channel in both 2012 and 2015.
Hypothesis 2(e): Company shareholder dispersion is associated with the use of corporate websites as a stakeholder communication channel in both 2012 and 2015.

RESEARCH METHODOLOGY

The research methodology employed was quantitative, using a quasi-experimental pre-test post-test design to measure changes over time. Our study made use of secondary data. Hand-collected data measuring corporate website content and features from selected JSE-listed companies were obtained from the Esterhuyse and Wingard (2016) study (pre-test data) and the Nel et al. (2017) study (post-test data). Cross-sectional secondary data about company characteristics were obtained from the JSE, IRESS and Orbis databases for both periods. A variety of statistical tests was used based on the hypothesis tested and the characteristics of the data. In all the tests, the normality of the data was tested based on an examination of the normal p-plots and, where appropriate, the Shapiro-Wilk test. Where applicable, non-parametric tests were used and reported where our data did not meet the normality assumptions for parametric tests.

Study Sample

Although an important research advantage of examining corporate websites as a communication medium is the publicly accessibility thereof (as a data source), a disadvantage is that websites are not automatically archived for posterity. Researchers cannot go ‘back in time’ to see how a website looked at a previous point in time. For this reason, accounting studies on website disclosures and features are usually cross-sectional (Botti et al., 2014; Fuertes-Callén et al., 2014; Mendes-Da-Silva & Onusic, 2014; Mohamed & Basuony, 2014; Omran & Ramdhony, 2016; Kundelienė & Stepanauskaitė, 2018; Zadeh et al., 2018). We were therefore in a unique position to obtain longitudinal data from two independent South African studies conducted on corporate websites as a stakeholder communication channel respectively in 2012 for 205 JSE-listed companies (Esterhuyse & Wingard, 2016) and in 2015 for 85 JSE-listed companies (Nel et al., 2017). Fifty-eight JSE-listed companies were identified as common to both studies.

Measurement Instrument

The 25 attributes that were measured, as well as their average availability in 2012 and 2015, are listed in Table 1 below. The attributes measured were also categorised into three subgroups: annual report (AR), extra content (EC) and technology (T). The disclosure scores were calculated following a content analysis of each company's website in each year. '1' was awarded if the content or attribute was available and '0' if not. Lastly, a total disclosure score was calculated from the three subgroups.

Referring to Figure 1, it is now almost two decades since the FASB (2000) published their two-dimensional model of website communication. Having a *textual* report in HTML format with menus and clickable hyperlinks is no longer considered 'advanced technology'. Furthermore, PDF documents may also have thumbnails and clickable hyperlinks that ease navigation. We therefore adapt the definition of Quadrant III (static presentation and summary content) by incorporating reports in PDF *and HTML* format in that quadrant. Subgroup AR therefore attempts to measure Quadrant III behaviour (i.e. summary content, static and hyperlinked presentation of *textual* financial reports). EC attempts to measure Quadrant II behaviour (dynamic presentation [audio and video] and extra content). The third disclosure score (T) examines the use of technologies to enhance symmetrical communications between the company and its stakeholders.

Table 1: List of attributes

Annual report (AR) (7 attributes)	**2015**	**2012**	**Change**
Financial reports in the IR section (descriptive category)	98%	97%	1%
Annual report – PDF	98%	95%	3%
Archived annual reports	97%	91%	6%
Annual report format – HTML	29%	48%	-19%
Annual report format – downloadable Excel	12%	43%	-31%
Half-year results format – HTML	19%	33%	-14%
Customisation of reports by users for downloading	53%	24%	29%
Extra content (EC) (8 attributes)			
Snapshot/Highlights page	57%	52%	5%
Archived key data (e.g. key ratios)	36%	34%	2%
Comparison with competitors and/or industry	24%	3%	21%
Result announcements format – audio (podcast)	22%	22%	0%
Result announcements format – video	31%	28%	3%
Result announcement format – PowerPoint slides	69%	41%	28%
AGM (audio or video)	7%	12%	-5%
Value proposition investors (e.g. future plans and new products)	88%	60%	18%
Technology (T) (10 attributes)			
Virtual tour (video) of facilities	12%	7%	5%
Social media link – Twitter	34%	19%	16%
Social media link – YouTube	24%	9%	15%
Social media link – Linkedln	29%	7%	22%
Social media link – Facebook	28%	21%	7%
Link to subscribe to e-mail alert service	48%	48%	0%
Link to subscribe to RSS content feed	10%	9%	1%

Availability of generalised email address for investor queries	38%	31%	7%
Availability of personalised email address for investor queries	24%	19%	5%
Availability of a contact form for investor queries	7%	5%	2%

Independent Variables Measurements

As discussed in the literature review section, we identified a few prominent company characteristics associated with voluntary disclosure behaviour of companies. Although the JSE Industry Classification Benchmark (ICB) scheme of ten industries is the most popular classification scheme used in South Africa, it was deemed inappropriate for this study given the relative small sample size of 58 companies, which hindered meaningful statistical analyses.[2] For the purpose of this study, two different industry classification schemes were used to categorise companies. The first scheme was based on the SA Sector classification[3] that groups companies into one of four sectors: resources, financials, industrials and industrials – other. The Two Sector scheme categorises companies in only one of two sectors: primary or consumer.[4] Table 2 shows the other measurements. This data was obtained from the JSE, IRESS and Orbis databases.

Table 1: Independent variable measurements

Variable	Measurement
Size	Market capitalisation in ZAR millions. This was transformed to the natural log during statistical analyses.
Leverage	Debt to total assets.
Dual listing	Dummy variable coded '1' if the company's shares were listed on another stock exchange in addition to the JSE; otherwise '0'.
Dispersed	We used the board independence indicators from the Orbis database of Bureau van Dijk for this measure. Companies classified with an 'A' (no known shareholders holding more than 25% direct or total ownership) were coded '1'; otherwise '0'.

RESULTS AND DISCUSSION

We start the discussion of the results with the univariate statistics presented in Table 3. In Panel A, we see that the mean total disclosure score increased from 8.59 (2012) to 9.97 (2015). To address *Hypothesis 1* (i.e. a change in corporate websites communication practices from 2012 to 2015 is expected), a paired t-test was performed. The 2015 total disclosure score differed significantly from the

[2] The ICB categories for our sample were (number of companies in brackets): Basic material (10), consumer goods (5), consumer services (10), financials (12), healthcare (1), industrials (14), oil and gas (1), technology (3), telecommunications (2) and utilities (0).

[3] In terms of the SA Sector classification, resources consist of companies listed in basic materials and oil and gas; financials of companies listed in financials; industrials of companies listed in industrials; and industrial – other of companies listed in consumer goods, consumer services, technology, telecommunications and healthcare.

[4] Primary industries consist of industrials, basic materials, oil and gas and technology; and consumer industries consist of consumer goods, consumer services, telecommunications, healthcare and financials.

2012 total disclosure score (t = 3.4896, p = 0.0009, two-tailed[5]). Therefore, Hypothesis 1 is accepted. It seems that for our sample of 58 JSE-listed companies, significant improvements were made overall in the usage of their websites over the three-year period. This can probably be ascribed to the increase in bandwidth as well as improved application of integrated reporting principles.

Table 2: Descriptive statistics

Panel A: Continuous variables							
	Mean	**Min**	**Quartile**			**Max**	**Std dev**
			Q1	**Q2**	**Q3**		
TDS (2015)	9.97	2.00	7.00	10.00	13.00	19.00	3.97
TDS (2012)	8.59	2.00	6.00	8.50	11.00	17.00	3.84
AR (2015)	4.07	1.00	3.00	4.00	5.00	7.00	1.30
AR (2012)	4.31	2.00	3.00	4.00	5.00	7.00	1.49
EC (2015)	3.34	0.00	2.00	3.00	4.00	8.00	1.82
EC (2012)	2.53	0.00	1.00	2.00	4.00	7.00	1.78
T (2015)	2.55	0.00	1.00	2.00	4.00	7.00	2.05
T (2012)	1.74	0.00	0.00	1.00	3.00	6.00	1.67
Market cap (2015) (ZAR billions)	70.391	0.051	1.290	11.920	48.618	1 411.045	200.757
Market cap (2012) (ZAR billions)	45.262	0.065	1.410	11.520	30.649	812.411	125.003
Leverage (2015)	0.49985	0.002	0.33	0.47	0.67	1.21	0.26
Leverage (2012)	0.49854	0.03	0.35	0.48	0.64	0.97	0.22

Panel B: Categorical variables				
	Count 2015	**Mean TDS 2015**	**Mean TDS 2012**	**Count 2012**
Dual listed	18	11.83	11.19	16
JSE only	40	9.13	7.6	42
Dispersed shareholding	36	10.17	8.56	34

[5] The result was confirmed with the non-parametric test, Wilcoxon matched pairs (p = 0.0069).

Concentrated shareholding	22	9.64	8.63	24
SA Sector	**Count[6]**	**Mean TDS 2015**	**Mean TDS 2012**	
Industrials	14	9.21	7.07	
Industrials – Other	21	9.95	8.71	
Resources	11	9.27	8.55	
Financials	12	11.5	10.17	
Two Sector				
Primary	28	9.25	7.86	
Consumer	30	10.63	9.27	

To address *Hypotheses 1(a), 1(b) and 1(c)* (i.e. subgroups' scores are different in 2015 and 2012), a paired t-test was performed on the change in the average score of the AR subgroup and Wilcoxon matched pairs on the EC and T subgroups as the latter two subgroups' scores did not resemble a normal distribution. We report two-tailed significance values. From Table 3 Panel 1, we see that the mean AR score decreased from 4.31 to 4.07; however, this was not statistically significant (t = -1.154, p = 0.253283), leading us to reject Hypothesis 1(a). The mean EC score improved from 2.53 in 2012 to 3.34 in 2015; and this increase was significant (Z = 3.269, p = 0.001076). Similarly, the T subgroup mean score improved from 1.74 in 2012 to 2.55 in 2015; and this increase was also significant (Z = 2.889, p = 0.003854). Therefore, Hypotheses 1(b) and 1(c) are accepted. It seems that the change in disclosure behaviour centres around providing extra content and video and audio features, as well as improved symmetrical communication features.

Referring to Table 1, it is suggested that the decrease in the AR score is caused by the decrease in the number of companies providing their annual reports in alternative formats such as HTML (19% decrease) and Excel (31% decrease). This is not surprising given the research conducted by Nel (2004). He found that in all the countries investigated, as in South Africa, the trend was to use more PDFs and less HTML documents. It is also important to note that almost all the companies already supplied their current and archived annual reports in PDF format in 2012, resulting in insignificant increases in 2015. Esterhuyse and Wingard (2016) reported a ratio of 2:1 for the provisioning of PDF vs HTML annual reports in 2012. This ratio was also noticeable for the sample of 58 companies in 2012. In 2015, the ratio deteriorated to 3:1, contributing to the decrease in the AR score. Regarding Excel, Nel (2004) documented an increase in the use of Excel over a two-year period (2002 to 2004). The use of Excel doubled when Esterhuyse and Wingard (2016) reported on their 2012 study. It is alarming that the current study reports a 31% decrease in the number of companies providing downloadable Excel sheets in 2015. The 29% increase in companies that allow the customisation of (mainly PDF) reports by users for downloading further suggests that companies are not willing to provide annual reports in alternative formats, viewing the PDF as sufficient.

The significant increase in the EC scores is mainly attributable to more companies providing downloadable PowerPoint slides that accompany their results announcements. Providing comparative information on their competitors also showed a marked increase. It is very encouraging to see companies expounding on their value proposition by sharing information on their plans for the future, product pipelines, etc. Companies are therefore providing more content, but they could still do better by

[6] Industry membership (i.e. SA Sector or Two Sector) did not change between 2012 and 2015.

improving the availability of audio and video files of results announcements. The improvement in the technology (T) scores centres on the greater social media presence of companies in 2015.

In *Hypothesis 2*, we hypothesised whether specific independent variables are associated with the use of corporate websites as a stakeholder communication medium in both 2012 and 2015. From Table 3 Panel B, we can see that the mean disclosure scores for all the industries increased over the period. As a first step, t-tests were performed to ascertain whether the total disclosure score changed significantly in each industry, using respectively the SA Sector (4 industries) and Two Sector classification schemes. Using the Two Sector scheme, the total disclosure score increased significantly from 2012 to 2015 for both the consumer industries ($p = 0.041$) and the primary industries ($p = 0.007$). The total score increased by 15% for companies categorised in consumer industries compared to 18% for companies categorised in primary industries. Based on a further t-test performed, the higher mean increase for companies in primary industries (18% versus 15%) is not statistically significant ($p = 0.83$). Using the SA Sector scheme, the total disclosure score only increased significantly for industrials ($p = 0.016$), with no statistically significant increase for resources ($p = 0.267$), industrials – other ($p = 0.056$) or financials ($p = 0.239$). Although industrials increased with 30% compared to resources (8%), industrials – other (14%) and financials (13%), based on an ANOVA performed ($F[3,54] = 0.74162$, $p = 0.53$), differences between industries are not statistically significant. We therefore reject Hypothesis 2(a), that industry classification is associated with websites as a stakeholder communication channel.

From Table 3 Panel B, we observe very little change in the dual listing status or the shareholder dispersion independent variables between the two periods. Two companies became dual listed by 2015 and two companies' shareholder profile became more dispersed. The mean disclosure scores for dual-listed, JSE-only, dispersed and concentrated increased from 2012 to 2015. For dual listing status, we conducted a one-way ANOVA on the disclosure scores of companies for 2012 and 2015 respectively. The results indicate a highly significant difference in the disclosure scores for companies with a dual listing in both 2012 ($p = 0.00097$) and 2015 ($p = 0.01$) compared to those that were only listed on the JSE. We therefore accept Hypotheses 2(d) as being dual listed is significantly positively associated with the use of corporate websites as a communication channel in both 2012 and 2015. From Table 4, we can also see that being dual listed is weakly to moderately correlated (Spearman) with the disclosure scores and significant at the 5% level. An ANOVA was also conducted on the dispersion variable and disclosure score in each year. The result indicated no significant difference in the disclosure scores for companies with a dispersed shareholder base compared to those with a concentrated shareholder base in both 2012 ($p = 0.95$) and 2015 ($p = 0.63$). We therefore reject Hypotheses 2(e) as shareholder dispersion is not significantly associated with the use of corporate websites as a communication channel in both 2012 and 2015. Spearman correlations (Table 4) between shareholder dispersion and the disclosure scores were also not significant and almost non-existent.

Market capitalisation increased in nominal terms from an average of R45 billion in 2012 to R70 billion in 2015, while the average leverage ratio remained constant at approximately 50% (Table 3 Panel A). To test Hypotheses 2(b) and 2(c), we ran Pearson correlations. From Table 4, it can be seen that market capitalisation is strongly positively correlated with the total disclosure score in both 2015 and 2012, and this was significant at the 5% level. Leverage was only weakly positively associated with the total disclosure score; this was only significantly correlated in 2015 and not in 2012. We therefore accept Hypotheses 2(b) that there is an association between size and the use of corporate websites as a stakeholder communication channel, but we are undecided about Hypotheses 2(c) as leverage is significant in 2015 but not in 2012.

Table 4: Correlations

	2015					2012				
	TDS	**Size (ln)**	**Lev**	**Disp**	**Dual**	**TDS**	**Size (ln)**	**Lev**	**Disp**	**Dual**
TDS	1.00					1.00				
Size (ln)	0.60*	1.00				0.44*	1.00			
Lev	0.27*	0.31*	1.00			0.18	0.19	1.00		
Disp	0.06	0.05	0.12	1.00		-0.02	0.04	0.13	1.00	
Dual	0.29*	0.29*	-0.16	-0.01	1.00	0.42*	0.24	-0.13	-0.11	1.00

TDS is total disclosure score; Size is market capitalisation with natural log transformation; Lev is leverage; Disp is shareholder dispersion; Dual is dual listed. For binary variables (Disp and Dual), Spearman rank correlations are reported. For all other variables, Pearson correlations are reported.
* Significant correlations at the 5% or lower level. Two-tailed significant levels are reported for all correlations.

CONCLUSIONS AND CONTRIBUTIONS

The purpose of this study was to determine whether there were improvements in the usage of corporate websites as a communication channel with stakeholders. We obtained website disclosure scores of 58 JSE-listed companies in 2012 and 2015. Our findings are that disclosure behaviour overall did improve over the period for our sample, especially regarding extra content and technological features. When measured against the FASB (2000) framework, it seems that the financial reports are still in Quadrant III (textual reports in PDF and to a lesser extent HTML texts). Financial reports are still dominated by PDFs. Surprisingly, a decline was found in the provisioning of HTML reports, continuing a trend previously observed in 2012. Regarding extra content (results announcements, comparative figures and other non-financial forward-looking information) and technological features, companies have moved to Quadrant II of the FASB (2000) framework (dynamic presentation and extra content). This was probably enabled by improved bandwidth in South Africa over the period and the practice of integrated reporting that requires more disclosures.

Our study contributes to the theory of voluntary disclosure behaviour by showing that over time, companies can decide to reduce their disclosure effort. Previously it was usually assumed that disclosure behaviour would always increase or be stagnant over time. Comparing for the first time website communication practices over two periods for the same sample, our study seems to indicate that JSE-listed companies in our sample are exhibiting mimetic isomorphism in that they follow the lead of other companies that reduces the availability of HTML reports.

Our study also contributes to the field of study on corporate communication practices, especially regarding the use of corporate websites and internet technologies. As far as we can gather, this was the first study in South Africa that used longitudinal data for website disclosure scores. We investigated five factors that other studies reported as being associated with website disclosure behaviour. We found for our sample companies that industry type, shareholder dispersion and leverage were not associated with disclosure behaviour in each year. Market capitalisation and being dual listed were positively associated with disclosure behaviour in each year.

LIMITATIONS AND SUGGESTIONS FOR FURTHER STUDIES

Although it is admitted that the selection of our convenience study sample of 58 companies restricts the power of statistical tests, it is deemed acceptable given the non-availability of archived website data necessary for large-scale longitudinal studies. The convenience sample's findings can also not be extrapolated to all listed companies, although we are of the view that it is representative enough (the JSE has between 250 and 300 companies listed on its Main Board). We recommend that the study be repeated to obtain a third or more sets of data. Other researchers can expand the size of the sample or repeat the study in different domains. We also suggest that multivariate models for website disclosure behaviour be tested in addition to the bivariate associations that we tested. The surprising finding of reduced supply of reports in HTML format can be explored in a qualitative study by surveying investor relations practitioners as to possible reasons therefor.

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DIGITAL BUSINESS TRANSFORMATION: TOWARDS AN INTEGRATED CAPABILITY FRAMEWORK FOR DIGITIZATION AND BUSINESS VALUE GENERATION

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ABSTRACT

The recent successes recorded in digital customer engagement and robotic process automation are prime examples of how digitization has positively impacted organizations productivity and performance. The problem is that digitization is not cheap, and digital business transformation initiatives are failing due to the existing gap in the understanding of the mechanism through which firms attain business value from technology. More than technology, organizational readiness accounts for digital transformation success. Organization readiness refers to the ability to harness and orchestrate core organizational capabilities, namely; resource capability, process capability, and cultural capability in an integrated manner. This paper aims to examine the impact of resource capability, process capabilities and cultural capability on successful digital transformation.

Keywords: digital business transformation, resource capability, process capability, cultural capability, value generation

INTRODUCTION

In both speed and intensity, digital technologies are transforming the structure of social relationships in both the consumer and the enterprise space. These technologies are also reshaping traditional business strategy as modular, distributed, cross-functional, and global business processes that allow work across time, distance, and national boundaries (Matt, Hess & Benlian, 2015). This trend will continue, especially, as agility in organizational structures and information systems becomes an essential capability for enterprises as they are interacting within a highly dynamic environment with innovative endeavors to disrupt their industries and markets, or at the least prevent being disrupted. (Urbach, Drews & Ross, 2017; Bharadwaj et al., 2013).

The resulting changes from the accelerated rate of technological innovation and adoption, and the performance outcome from the exploitation of technology trends such as robotic process automation (RPA), social media, mobile, analytics, cloud computing, and internet of things (SMACIT) significantly influence processes, products, and services. Robotic process automation (RPA), for instance, is not only

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affecting cost reduction but also driving the development of the “digital workers” of the future with its demonstrable result in the efficient delivery of routine tasks, and its potential to learn machinal. Cloud computing has moved from aspirational discussion to a must-have technology for every enterprise in 2019, because as Kahre, Hoffmann and Ahlemann (2017) observed, cloud-based models provided enterprises with something more adaptable and scalable by leveraging automation and modern enterprise applications. The extent to which information technologies are applied to realize efficiency, business effectiveness and innovation is, expectedly, exponentially more significant in the future. (Bock, Iansiti & Lakhani, 2017; Urbach, Drews & Ross, 2017).

The potentials for business value generation through digital transformation is promising, but they do not come cheap, and worst still digital transformation initiatives are failing. In 2019 alone, according to IDC estimate, spending on digital transformation will exceed the earlier projections of US$2 trillion to about US$3.8 trillion, of which spending on digital transformation technologies will account for 40 percent of all IT spending (Ferranti, 2019). Hence, investment in IT continues to represent a significant proportion of capital outlay, adding another layer of difficulty to the already existing organizational hurdles in making a case for investment in transformational technologies.

Notwithstanding, organizations can rarely exercise choice not to invest substantially in IT, even when by the dominant econometric appraisal standards, they struggle to find demonstrable bottom-line justification. To avoid being disrupted by nimbler competitors, companies are innovating and reinventing themselves at a faster rate than ever and experimenting with new digital services and capabilities to augment their existing offerings or to slide into adjacent markets. It is hard today to find an enterprise that is not leveraging some combination of cloud, analytics, artificial intelligence, and machine learning to serve customers better or streamline operations. So that, in response to the changing business environment, some businesses for strategic reasons continue to make considerable investments in digitization.

Considering the high percentage of capital investment, and the high level of dependency of organizations and businesses on information systems and information technology, the general expectation is that these systems should improve the firm's competitiveness in the marketplace (Jafari, 2014). However, while IT expenditure trends at a geometrical progression, the investment benefits, on the contrary, is not keeping pace as evidenced in the scale of high-profile digitization failures which translates into business value slippage. The Wipro digital survey of 2018 indicated that many digital transformation projects were either failing outright or in danger of failing. While half of senior executives polled by Wipro Digital believed that their companies were not successfully executing 50 percent of their digital transformation strategies, one in five referred to their digitization effort as an outright waste of time. The survey established that digital transformations are lagging or even failing for several reasons ranging from lack of agreement on what digital transformation means to lack of organizational readiness for change.

Nothing today points to a fundamental departure from the preceding Wipro research conclusions. Lack of organizational readiness for change is a classical definition of the underlying causes of digitization failure over time. Therefore, even when progress has been recorded of late in the output-focused customer access, engagement, and relationship transformation using digital, organizations have not kept pace with building the necessary capabilities in operations, IT-business relationships, vision, and governance required for digital business transformation to succeed. This suggests that digital transformation failures are a function of mostly organizational factors. On the aggregate, it has been traced to a wide range of organizational factors from poor planning and delivery, organizational culture, and lack of exploitation of the potentials offered by IT. So that as it stands today, digital business transformation is already failing for reasons which are apparent but often ignored, historically. However, before delving into these critical transformation success factors, an understanding of the concept and the problem with digital business transformation is important.

What Is Digital Business Transformation?

Digital business transformation means many things to many people depending on their point of reference in the enterprise. Rob Llewellyn (2018) argued that digital transformation is not about digitizing old ways of working. Instead, it is transforming the business to align with the digital economy. Llewellyn differentiated between what is digital transformation and what could be described as technological change. He asserted that while "change fixes the past, transformation creates a new future without the constraints of the past." For this school of thought, "transformation" is the operational word in digital business transformation.

From the preceding analogy, what is mostly understood as digital transformation can only pass for digital change, because Mobile apps, AI-based chatbots, analytics, robotic process automation which is revolutionizing operations, and other digital services are often used to augment existing services. An output-focused business process such as marketing would regard digital transformation as using technology to change the way the company interacts with customers. Incidentally, this is where most organizations are currently in their enterprise digital transformation journey, as most organizations made the most significant progress on customer experience, with sharpened SMACIT strategies and exploitation of digital marketing technologies (MIT-Capgemini, 2018).

Digital business transformation is much more than SMACIT, chatbots, and AI. It entails technology adoption, but beyond that, it also entails process alignment and cultural transformation that the organizations require to meet their agility demands. Digital transformation refers to a fundamental change in productivity, which information technology happens to be a part. The changes could be efficiency-driven or innovation-driven. Hence, we can talk about "digital business transformation" or a "digital business optimization" as two dimensions of the same enterprise performance journey which IT underpins. For this writing, the working definition of Digital Business Transformation is organizational change leveraging digital technologies and business models to drive differential value creation aimed at enhanced productivity, performance, and profitability. These business values are the underlying benefits of enterprise digitization and have been the three cardinal promises of IT since the introduction of personal computers.

The Problem with Digital Business Transformation.

With the positive results coming out of digital business transformation efforts in recent times, the business value of information technology (BVIT) researchers have reasons, supposedly, to move the discussion on IT business value from the attempt to correlate a linear relationship between IT spend and the organizations financial performance as the sole success parameter, to the acknowledgment of various ways which IT is expected to support businesses today. Instead, technology business management (TBM) and IT business alignment models are back in the discussion. This is because, paradoxically speaking, digitization is failing at a time of quantum leap in technological innovations, and the hope on digitalization to transform business fading. So that as the conclusion of the Capgemini Digital Mastery survey (2018) indicates, many organizations are starting to face the realities of the complexities of their digitization journeys and realizing how challenging successful digital business transformation can be. The research also revealed that governance, skills, and culture are among the major challenges that stand in the way of digital transformation success. The same challenges have trailed all past efforts at digital enablement of business.

In practice, it is a lot easier to find and engage a vendor who can implement a given system, but much harder to prepare an organization to adapt to new technology. There is a distinction between invention and implementation, in the same token the ability to implement (deliverability) does not equal to the ability to utilize (exploitability) the transformation enabling capabilities inherent in the technology. While most of the investments are geared towards technology acquisition that promise to provide the enterprise a market edge against its rivals or enhanced operational efficiency that will exponentially lead to cost reduction, little attention is given to cultural changes and human capital development of the change. The problem with digital business transformation relates less to technology and more to the management of the organizational challenges created by a technological shift. This accounts for the frustration many managers are facing about the difficulty in getting expected results from technology even when they believe in the ability of technology to bring transformative change to the business (Fitzgerald, Kruschwitz, Bonnet & Welch, 2013; Marchand & Wade, 2014). As, Majchrzak, Markus and Wareham (2016) observed, it is not a deficiency of technology that it cannot solve problems all on its own.

Although prior studies showed the interrelationships between specific types of efficiency-driven and innovation-driven digitization strategy and elements of organizational capabilities as resources, process and culture (Chen et al., 2018; Felipe, Roldan & Leal-Rodríguez, 2017; Majchrzak, Markus & Wareham, 2016; Bock, Opsahl, George & Gann, 2012), not many studies have simultaneously evaluated the relationship between these constructs and digital transformation outcome holistically. This has left a persistent gap in existing studies with regards to the mechanisms through which technology generates business value. Previous researches that looked at IT resources discussed IT resources in terms of technical know-how and IT enabling capabilities. There is an absence of materials that investigated the place of resource structuring - orchestration and complementarity - in digitization synergistically. Even less is the number of inquiries into how organizational culture and practices impact digitization and business value generation. There is the need, therefore, to strive to identify the complementary assets and specific configurations associated with success by extending BVIT scholarly focus on the factors imperative to successful digitization and business value generation.

The effort in this paper is to move away from the dominant serial view of change and transformation success metrics to an integrative factor view of digital change and business transformation. In doing so, it is expected that this paper will provide some theoretical insights that can enrich the understanding of IT value generation and encourage the development of potentially promising interventions that could promote digital transformation competence. This paper is not intended to be a "how-to" manual, but an insight into these value generation factors and why they are instrumental in digital business transformation and value realization.

INTEGRATED CAPABILITY FRAMEWORK: AN OVERVIEW

Successfully incorporating digital technologies requires companies to operate in new ways. According to Westerman, Bonnet and McAfee (2014), only a very few organizations are indeed using digital technologies to drive higher levels of profitability, productivity and performance despite the hype on digital business transformation. The authors attributed it to the absence of the requisite capabilities to use technology to work differently and the lack of attention to the development of the skills on which the planning, execution, and exploitation of digital depend.

Johnson (2018) observed that besides a coherent business model, the intertwining elements of resources, processes, and the willingness to change people more than technology is the key to transformational business growth. The absence of these factors means that the adoption of and adaptation to a digital-based economy will be damaged notwithstanding the far-reaching impact and the current recorded results of the use of digital technologies (Tapscott, 2014). So that as Kane et al. (2015) surmised, it is not enough to acquire and implement the right digital technologies and expect successful transformation, whereas the success of the transformation effort lies in reconfiguring the business, to take advantage of the informational capability that the technology enables.

While capability is reflective of possible and available opportunities that an individual possesses in skills, knowledge and experience, conversion factors refer to the contextual characteristics such as processes and practices that positively or negatively affect an individual's capabilities and functioning (Akbar, Hirani & Richter, 2017). Capability-centric frameworks underscore the need for organizations to not only understand the critical organizational capabilities for growth and survival but also to help organizations to articulate, support and build such unique capabilities essential for a sustainable competitive advantage. Hence, in parallel to competence, it is imperative to attend to the need of developing an ability to produce a desired, repeatable output to a predetermined quality and quantity through enabling processes (Doherty & Terry, 2013).

The integrated capability framework adduced here is premised on the assumption that the ability of an organization to orchestrate its resources and process capabilities will be positively related to its ability to transform itself digitally, and realize benefits from IT investments. The assumption is anchored on the theorem that the combined and complementary use of distinct sets of resources produces an aggregate higher total return than the sum of returns that could have been achieved otherwise if each set of resources were utilized independently, ceteris paribus (Woudstra et al., 2017; Hock, Clauss & Schulz, 2015; Tang & Ghobakhloo, 2015; Hitt et al., 2011). A broad understanding of successful digital transformation and differential value creation factors as postulated in the integrated framework, necessitates drawing on a range of theoretical and empirical insights from strategic management, process engineering, and organizational sciences. That is the approach adopted here as advanced in the subsequent sections.

Resource capability. In the strategic management field, as Pettigrew, Thomas and Whittington (2002) observed, the human being as an actor has become lost among a flurry of independent variables such that little attention is paid to the impact of the individual and the networks they inhabit within the organization. This observation is particularly true in the field of enterprise information technology decisions, especially in the current digital business transformation dispensation. As technology portends to enable the business, there is a frantic effort at being at the forefront of the adoption of the latest disruptive technology, almost exclusive of other contingent success factors. When a newly acquired technology fails to deliver the expected value, as is often the case, another technology is layered on the old technology to bridge the gap created in business enablement by the previous technology. There is the silver-bullet view of digitization, that once a technology is adopted, the problem is solved.

The focus on hard technology is mostly because IT business value is considered a function of the information systems rather than the totality of the context within which it is adopted and how the system is exploited. However, research has shown that human and organizational implications associated with utilizing new technology which significantly impacts the success or failure of IT investments, are too critical to be overlooked or just ignored (Shahiduzzaman & Kowalkiewicz, 2018; Ching Gu, Hoffman, Cao & Schniederjans, 2014; Coombs, 2012).

While acknowledging the importance of capabilities and competencies in value delivery and organizational performance, most researches that looked at IT resources discussed IT resources in terms of technical know-how and IT enabling capabilities. But more than that, resource capability refers to functional competencies embedded in the ability to perform specific tasks as a result of skills, knowledge, and experience. Firm-level capabilities are often categorized as ordinary capabilities and dynamic capabilities. Ordinary capabilities are mostly operational - doing things right, whereas dynamic capabilities are generally strategic - doing the right things. That reflects the core underpinning of the resource-based view of the firm (RBV), which offers an understanding and explanation of how competitive advantage within firms is achieved and how that advantage might be sustained over time (Teece, 2017; 2014).

Capabilities stem partly from understanding the combination of resources and the leveraging of complementary assets. What a firm does with the resource assets available to it is as important as which type of resource assets it possesses (Hitt et al., 2011). As Hitt et al. (2011) and Wang et al. (2012) argued, a firm's ability to gain a competitive advantage is not guaranteed by resources possession alone but by adequate bundling and leveraging, because only with effective resource management is the full potentials of resources realized. It is important to highlight the difference between output efficiency often expressed in exploitation ability, and innovation ability often embedded in the exploration process, as being two unrelated but complementary organizational resource capability issues. According to Schienstock (2009), "exploration" is closely related with the organization’s effort at unique resource development as well as experimentation with new alternatives, while “exploitation” is related with the compelling utilization of the resource assets currently at the disposal of the organization.

Discussing the importance of resource capability in relation to information technology, digitization, and business value generation, Wood, Hewlin and Lah (2011) noted that technology does have its limits not because engineers cannot innovate, but because users cannot optimally use them. In his narrative on the untapped power of IT, Kenneally (2015) asserted that the rate of advancement in technology innovation outpaces organizations capability to leverage it. This situation creates a consumption or value generation gap. The level of value which IT can generate depends on if the system is deployed in such a way that it adequately leverages, in a complementary manner, on the existing organizational business and human resource assets. To buttress this point, the current Big Data hype readily comes to mind. The potential impact of big data as a business driver has gained an evangelical momentum in the marketplace such that organizations across all industries have invested heavily in Big Data initiatives. The result from the empirical study by Gupta and George (2016) positively validated the relationship between Big Data analytics capability and superior firm performance. However, the real-world evidence shows that big data is not a panacea, rather the interpretation of the data which continues to present the biggest challenge (Ransbotham, Kiron & Prentice, 2016). It is increasingly recognized that more qualified information translated into valuable insights meaningful to the management more than more data is what is needed. Embracing technology innovation as Big Data and data analytics in appreciation of its potential for competitive advantage is one thing, but the ability to exploit Big Data to generate business value is another.

Process capability. The ability to build new capabilities other than the human resource such as processes is a part of the firm's bundle of capabilities that generate value. While references to the "value and rarity" of resources are often made, not much is argued or established with regards to how these resources influence firm competitiveness. Resources alone do not account for a firm's competitiveness. The ability of an organization to harness and orchestrate its resources and the consequent performance optimization is largely enhanced by the presence of enabling business and managerial processes. Operational efficiency, which is the value proposition of the business process, expectedly provides management with the capability to monitor, analyze, control, and improve the organization's workflow and activities. A smoothly functioning business process consists of an interrelated set of activities designed to transform inputs into outputs (Berman, 2014). Adequately designed and implemented business processes make enterprise operations more efficient while improving products, services, and profits (Gupta, Viyas & Tripathi, 2014).

Empirical research has shown that there are specific characteristics of firms which have transformed themselves into companies that have significantly outperformed others. These firms with significant long-term performance outcomes use technology to accelerate their transformation, not by using technology as a transformative feature in and of itself; instead through the combination of a well-designed process with appropriate technologies, they create sustained business value (Collins, 2001). Project governance process, for instance, owing to its focus and visibility into the organizational goals, strives to and can align the enterprise technology projects with the long-term strategic goals as evidenced by the empirical studies by Debreceny and Gray (2013) and Ashurst, C. et al. (2012) which showed that successful IT project value realization is directly related to the maturity of the organizing processes**.** The inability to properly govern changes presents another kind of problem to business transformation, digitally driven or otherwise, as the translation of vision into action is mostly facilitated by a strong governance structure. As the MIT-Capgemini survey of 2018 shows, organizations aspiring to transform their businesses digitally remain challenged even on that front. So that besides the poor digitization vision and strategy, the survey showed that governance still presents a challenge which organizations face in their digitization journey.

The role of processes in change management notwithstanding, it is worth noting that the direct link between governance process and performance could be nonetheless disputed. Again, owing to the complexities involved in defining and measuring corporate performance, governance process, and productivity improvements, attributing enterprise change success to these factors is often difficult to substantiate. There is no doubt that if clearly defined business processes are absent, out of control and immature, the full potential of the adopted technology cannot be achieved. However, processes alone are not enough to deliver the business value of information technology. Preferably in combination with other success factors such as resources discussed in the preceding section. The interrelationship between resource capability and process capability is aptly summarized by Van Looy et al. (2011). While resource capability, to Van Looy and others, refers to the ability or competence – skills and knowledge- of an organization to achieve targeted result which leads to predictability, efficiency, and effectiveness outcome, process capability on the other hands is the degree to which an enterprise has deployed processes to aid organizations performance. These two organizational assets are complementary and reinforcing. Failures from change result from not recognizing and aligning these two assets, not having adequate processes to underpin organizations change activities, and not adapting the organization's structure and resources to align with the new and often better methods for working brought in by new technology.

Cultural capability. Organizational culture has been recognized as an essential and influential factor in analyzing organizations in various contexts, including its importance to establishing competitive and collaborative advantages, and its impact on organizations' long-term performance (Zhang & Li, 2016; Hogan & Coote, 2014; Bock et al., 2012). Hofstede (2010) and Schein (2010) enunciated the basic underlying principles, expressions, and manifestations of organizational culture. To them, organizational culture embodies widespread dominant practices and the underlying assumptions about "how things are done here." Based on these essential embodiments and manifestation of culture, both scholars – Hofstede and Schein - coalesced along a perspective that views organizational culture as a pattern of underlying assumptions, which have been either invented, discovered, or developed by a given group in dealing with its problems, considered to be valid based on the fact that it has worked well enough to be regarded as such, and are as such consequently transmitted as the correct way to deal with such problems.

Organizational activities, operations, actions, and practices representing patterns of behavior, are the visible manifestation of cultural values. These behavioral patterns – expressed and observable – do have an impact on organizational performance and in turn, determine its success.

Discussing the impact of organizational culture as one of the situational variables instrumental to the successful implementation of changes in organizations, Latta (2009) argued that organizational change readiness is culturally embedded, fundamental to change process and have moderating effect on organizational change. As Latta (2009, p.28) puts it, "regardless of the strategies and tactics employed to implement particular change initiatives, the impact of these efforts will be moderated by elements of institutional culture." The same author further argued that the moderating effect(s) of culture on change implementation has valence which is capable of either impeding or facilitating the change process, such that depending on the valence, the cultural moderation either creates a positive acceleration or a hindrance that will impact the expected outcome. Organizational culture as a sense-making process helps the employees of a given organization to understand the organizational events and objectives, in turn influencing the innovativeness, efficiency, and effectiveness of the employees (Shahzad, Luqman, Khan & Shabbir, 2012).

Interest in the impact of culture on the development, integration and actual use of information technologies (IT) has been increasing in recent years (Odusanya, Coombs & Doherty, 2015; Ching Gu, Hoffman, Cao & Schniederjans, 2014). This is informed by the realization that cultural traits are known to exert a strong influence on the adoption and delivery of IT at the aggregate enterprise level, but also on how users, on the individual level, interpret the features of an IT that have been adopted. The analysis of the studies conducted by the aforementioned researchers on the facilitators and inhibitors of IT business value realization, revealed that planned IT benefits had not been realized because of a lack of attention to technical as well as organizational facilitators and inhibitors as culture.

In today's knowledge-based economy, innovativeness is crucial to the survival and growth of businesses. A firm's innovation capabilities are its core competency, which can also be magnified or hindered by organizational culture amongst others factor. Chen et al. (2018) study demonstrated that the greater the fit between an organization’s innovation strategy and its organizational culture, the greater the innovation speed and innovation quality. Hence, in digital business transformation, competing on technology alone is not enough, organizations must also compete on culture because it is easier for organizations to formulate innovation and technology strategies than how to implement them. As the MIT-Capgemini 2018 research shows, 60 percent of organizations recognize that organizational culture is the number one hurdle to digital transformation, that digital transformation has more to do with culture than it has to do with technology, and the pressing need to address it.

Owing to the multidimensional understanding of culture as a concept, the role of culture in organizational performance is debatable. This is especially so when organizational culture is treated as a standalone concept. Often what is more discernible than not, is the impact on the organizational performance of the absence or the lack of maturity of organizational culture in any given organization and vice versa.

CONCLUSION AND IMPLICATIONS FOR PRACTICE AND RESEARCH

The paper examined a capability-driven approach to successful digitization and business value generation and argued that it is a product of organizational readiness for change. It postulated that the digitization success and future of digital business transformation would be well served through an understanding of the integrated capability effect. The assumption is that the ability of an organization to harness its core capabilities -resources, processes, and culture- positively relates to its ability to realize benefits from digital transformation investments.

The paper argued that a framework for digital business transformation should comprise of three dimensions that together explicate how (1) resources, (2) processes, and (3) contextual factors lead to the generation of value from information technology. As is mostly the case, there is a genuine intent to transform the business using digital. However, as is also often the case, the intention gets stuck on the technology piece with little or not much thought given to the mechanism of the transformation especially of resource, the underpinning process and the moderating impact of the prevalent organizational practices. It is essential for managers, therefore, that questions surrounding the delivery and exploitation capabilities of an organization and the maturity of the supporting process be answered at the onset if the identified digitization investment objectives and stakeholder values are to be realized.

In the current business environment where technology has become a mass market, bringing in new technology no longer offers an edge over the competition. Both the established as well as the below-the-radar but nimbler start-ups can adopt same or similar technology and faster too. The difference between success and failure depends on the organization's ability to mobilize its resource assets around a shared vision and value. It is essential therefore that managers prior to full-scale immersion in the transformation, evaluate not only the technology but also the organizations cultural and structural disposition to the anticipated transformation, and ensure a level of readiness which transforming the business digitally requires.

By addressing the issue with current digital business transformation practice which is technology driven bereft of organizational and digitization readiness, this paper intended to generate theoretical insights that can enrich the understanding of IT value creation, and proffered an integrated capability approach. The confirmation of the assumptions in the integrated framework postulated in this paper is subject to future empirical research.

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EMPHASIZING *MÈTIS* WITHIN THE DIGITAL ORGANIZATION

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ABSTRACT

Current and near future organizational strategies are placing great emphasis on automation, robots and AI – with the aim of improving efficiency (productivity), and maximizing profitability. In this paper, we first deconstruct certain popular discourses on AI capabilities. An examination of AI vs human decision-making abilities in the face of uncertainty, complexity and ambiguity show that humans are still better than AI in situations of uncertainty and ambiguity, while AI has an edge in situations of defined complexity. Dealing with uncertainty and ambiguity is what humans are better at then machines or AI across mètis knowledge. This inconspicuous and ambiguous category of human knowledge is briefly re-visited. Management can help enable mètis by encouraging individual and social practice, as well as dialogue within the workplace. Furthermore, organizations must consider partnering human decision makers with AI when facing the mutually inter-dependent aspects of uncertainty, complexity and ambiguity.

Keywords: Artificial intelligence, uncertainty, ambiguity, *mètis*

INTRODUCTION

Historically, robots and computers were used to eliminate cognitively monotonous, physically demanding, repetitive or dangerous jobs (Wallén, 2008). But high level reasoning can now be codified via algorithms, resulting in computers outdoing humans both in terms of speed and performance in a variety of tasks (Autor, 2015). Furthermore, where more tacit type tasks are involved, and thereby where engineers are unable to initially program a machine to simulate the task in question, machines can eventually master the task through a process of exposure, training, and reinforcement – known as machine learning (or 'deep learning') – Autor, 2015. Over 30% of tasks necessitating significant amounts of tacit knowledge can now be taken over by algorithms (Manyika et al, 2017). Working with Big Data are analytics to reduce machine error and improve efficiencies of machine time-motion performance.

As such, the overall quest for continued cost reductions, in not only monotonous tasks but in more complex professional tasks requiring elaborate analysis, calculations and certain levels of tacit knowledge, are not only being pursued across reduced labour costs, but also across productivity

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improvements via increased speeds and efficiencies. The modus operandi continues to be doing more with less (Autor, 2015).

Yet, many professional tasks currently being considered as being replaceable by learning algorithms still require intervention on the part of human professional experts when dealing with situations involving weak and ambiguous signals (Faraj et al, 2018). As such, this conceptual paper will first critically examine the discourses and realities on Artificial Intelligence (AI). We will then argue how learning algorithms are unable to successfully deal with situations involving uncertainty as well as multiple interpretations, i.e. ambiguity (Kahneman and Klein, 2009; Dejoux and Léon, 2018), while conversely, human expert knowledge workers have the capacity to do so across the mobilisation of what is known as *mètis* knowledge and skills (Baumard, 1999). Finally, we briefly discuss management implications in enabling *mètis* within the workplace.

THE DISCOURSES AND REALITIES ON ARTIFICIAL INTELLIGENCE (AI)

Various applications and techniques based on learning algorithms fall under the broad umbrella of what is termed "AI" (Jarrahi, 2018). The concept of AI is often loosely defined as 'intelligent' systems with the ability to 'think' and 'learn' (Russell and Norvig, 1995), encompassing what is known as machine learning. Machine learning consists of algorithms which enable systems to 'learn' (Jarrahi, 2018), that is, improve their outputs based on experience (or previous iterations). Deep learning, in turn, is a subset of machine learning involving artificial neural networks (a set of algorithms inspired and modeled loosely after the human brain) that 'learn' from large amounts of data. These neural networks are designed to identify numerical patterns extracted from numerical vectors into which all-real world/sensory data (ex. images, sounds, text or time series) is translated (Hagan, 2014). Deep learning across neural networks finds correlations across *approximations* (Palit and Popovic, 2005).

Artificial Intelligence's (AI) visibility and optimism in recent years is best captured by the developments associated to IBM's Watson and Google DeepMind's AlphaGo, which beat human champions at *Jeopardy* and *Go* (Dejoux and Léon, 2018). For Watson, it has been claimed that its 'natural language' algorithms (as specific forms of machine learning), across the use of approximations and probabilities, has "the ability to *understand* nuanced human-composed sentences, and assign multiple meanings to terms and concepts" (Jarrahi, 2018). It has been argued that such machine learning capabilities allow Watson to learn from experience and interaction with data, and to "develop intelligent solutions based on past experience" as well as to give it the ability to "discern cancer patterns" (2018: 578).

Before deconstructing the above events and discourse associated to both Watson and AlphaGo, we must first return to Turing's (1950) well-known paper reflecting on the possibility of machines being intelligent. Here, he proposed a method for evaluating whether machines could exhibit intelligent behavior equivalent or indistinguishable from that of a human, across the Turing Test. The rationale was that if a computer could imitate the sentience of a human being would that not imply that the computer itself was sentient? The test itself would consist of a human evaluator judging natural language conversations between a human and a machine, and would know in advance that one of the two partners in conversation was a machine. All participants would be hidden from one another with exchanges limited to a text-only channel such as a computer keyboard and screen. If the evaluator could not reliably distinguish the machine from the human, the machine would pass the test. The test results would depend on how closely the machine's answers would resemble those of a human. Also, the test would not include anything specific – no complex problem solving or requests to create art. To date no machine has passed the Turing test.

Watson and AlphaGo de-constructed

When we turn to AlphaGo's impressive wins at the game of *Go*, we again see a superhuman performance in a very specific sphere of activity – yet to say general intelligence, would be false. Combined with existing 'deep learning' approaches (i.e. imitation training) and predictive algorithms based on Monte Carlo tree searching and neural networks, Google's DeepMind (AlphaGo) was able to beat 18 time Go world champion Le Sedol 3 games out of 4 in early 2016. Yet, AlphaGo is still unable to read and *understand* text or carry out a spontaneous conversation. As Oren Etzioni (CEO, Allen institute for Artificial Intelligence) explains, "understanding a single sentence can be a lot more complicated than pl"For all its difficulty, Go is still an artificial problem with very simple rules," adds Pedro Domingos, a computer science professor at the University of Washington (Taves, 2016).

The Significance of Natural Language and Conversation

Numerous studies and papers have depicted the nature, role and significance of natural language and conversation from a social, psychological, communication, sense-making, knowledge, power and organizational perspective (Armstrong and Ferguson, 2010; Collins, 2010; Weick, 1995; Tsoukas, 2009). In this paper, our interest is simply to reiterate language and conversation's inherent complexity, uncertainty and ambiguity (Marneffe et al, 2012; Piantadosi et al, 2012). For example, McComb and Semple (2005) show the inter-relationship between social and language complexities, while Maddieson (1984) and Lupian and Dale (2010) present the phonological and morphological complexities of language, respectively. In turn, uncertainty phenomena in language/discourse and its own inherent complexities have been examined from various aspects, including syntactics, semantics and pragmatics (Marneffe et al, 2012; Saurí and Pustejovsky, 2012). Finally, language and conversation is inherently ambiguous (ex. sentence attachment, semantics, pragmatics, discourse, etc.), and paradoxically, it is these same ambiguities which give language and conversation its effective communicative function (Piantadosi et al, 2012).

Turing's conversation test is indeed a complete test of complexity, uncertainty and ambiguity. In the following sections, we return to consider in more detail each of these environmental aspects (complexity, uncertainty and ambiguity) in regards to organizational decision-making when comparing human and machine capabilities.

CHALLENGES IN DECISION MAKING

Context plays a vital role in decision making (Papadakis et al, 1998). In turn, environment is one of the key factors to consider within organizational contexts, and comprises of three related challenges to decision making processes: uncertainty, complexity, and ambiguity (Snow et al., 2017; Jarrahi, 2018). According to Pomerol (1997), uncertainty is where "the future states are obviously not known with certainty" (p. 5) and arises from a lack of information about the environment. Complexity involves "situations…characterized by an abundance of elements or variables". (Jarrahi, 2018, p. 5). Ambiguity is related to "the presence of several simultaneous but divergent interpretations of a decision domain" (Jarrahi, 2018, p. 5). In the following sub-sections we examine these three environmental challenges.

Uncertainty

According to Choo (1991), uncertainty is defined as a lack of information about the alternatives and/or their consequences, thus rendering the interpretation of a situation more difficult. Walker at al (2003) identify several levels of uncertainty as related to modeling. Variability uncertainty is due to inherent variability in the phenomenon, thus corresponding to indeterminacy. Context uncertainty is related to the choice and delimitation of system boundaries and the subsequent framing/formulation of the problems addressed within the confines of those boundaries. As such, context uncertainty can be seen to be related to ambiguity. Model structure and inputs uncertainty (aka conceptual uncertainty) can also play a role in ambiguity, whereby they involve the definition of relevant variables to be included or excluded within the framing of the problem. The remaining types of uncertainty as per Walker et al (2003) involve different forms of incomplete knowledge or information regarding a situational phenomenon.

According to Kahneman and Klein (2009), tacit knowledge about a situation within a context of uncertainty allows individual experts to recognize a pattern that they have stocked in their memories while making intuitive decisions. As such, humans use their intuition and their ability to recognize patterns that machines (AI) do not have or sense (Jarrahi, 2018). Intuition enables experienced decision makers under pressure to act fast, whereby most of the time they only think of one option across natural and unconscious cognitive processes (Dejoux and Léon, 2018). However, in most uncertain situations, there are components of certainty which AI can retrieve and make forecasts, using probabilities (Pomerol, 1997). Yet, unlike board games, in which the probability of the next action can be calculated, real-world decision making often involves uncertainty, and the sole reliance on probabilistic, analytical thinking tends to be insufficient (Campbell, 2016). As such, the support of machines within contexts of uncertainty can be complementary to human understandings of the situation by providing real-time information to support the decision maker across statistics and specific pattern recognizing algorithms (Jarrahi, 2018; Dejoux and Léon, 2018). Humans, with their global perspective, experience and 'deep smarts', are more suitable to take the final decision by leveraging insight and a qualitative assessment that is rooted in years of tacit experience and personal judgement (Leonard and Swap, 2004; Sadler-Smith and Shefy, 2004).

Complexity

Complex situations involve an abundance of elements or variables and can demand the processing of massive amounts of information at speeds much greater than the cognitive capabilities of even the smartest human decision makers (Jarrahi, 2018). AI's superior computational and analytical capabilities has surpassed humans in complex tasks (Marwala, 2015). AI can analyze different layers of complex information and masses of data coming from various sources in order to recognize patterns and weak signals (Parry et al., 2016). However, AI algorithms are also biased in that they "are formalized opinion that have been put into code" such that critical thinking is paramount (Dejoux & Léon, 2018: 205; Faraj et al, 2018). As such, human actors should critically review and control AI decisions (Dejoux & Léon, 2018). For example, has the correct question been posed in regards to the situation at hand (Brynjolfsson and McAfee, 2014)? Indeed, being critical means being able to raise new questions and reframe problems (Dejoux & Léon, 2018). An absence of human intervention on this aspect risks setting off political and knowledge biases manifesting themselves into self-fulfilling organizational structuration (Faraj et al, 2018). It is interesting to note that complex situations can sometimes be resolved by humans who experience "gut feel", as if they were making use of their instincts, such as instantaneously understanding whether to launch a new product, whether hiring one person is a good idea, etc. (Sadler-Smith and Shefy, 2004: 78). In this sense, freestyle chess players have adopted the *centaur* approach, marrying human intuition, improvisation and creativity with a computer's brute-force ability to calculate a staggering number of chess moves, countermoves and outcomes. Teaming the two in chess, experts say, produces a force that plays better chess than either humans or computers can manage on their own (Kasparov, 2017).

Ambiguity

Weick (1995) makes a clear distinction between ambiguity as too many interpretations of a situation, and uncertainty as being caused by a lack of information. Ambiguity refers to the meaning of a situation and which frame should be applied to make sense of it. Hence, “while uncertainty can be located at the boundary between knowing and what is yet unknown within a certain frame, ambiguity can be located at the boundaries between different frames of knowledge or different kinds of knowing” (Dewulf et al, 2005, p. 117). Conversely, Walker et al (2003) provide us with a more nuanced overlap between uncertainty and ambiguity, in which both context and conceptual uncertainty are shown to be strongly related to ambiguity.

Humans have an advantage over AI in ambiguous situations due to their soft skills and their perception (Jarrahi, 2018). AI, as an analytical tool, is not able to analyze the subtlety of human interactions and communications; nor can it contextualize information (Jarrahi, 2018). AI can perhaps analyze sentiments and predict reactions that are likely to occur as a result of organizational decisions, yet does not know how to interact with humans, nor how to motivate people or convince them of decisions under situations of ambiguity that will rally different stakeholders. Humans, on the other hand, use social intelligence and skills in situations of ambiguity to negotiate/convince others and understand the context in which the decision is taken - regarding social and political dynamics - (Jarrahi, 2018).

In the following section, we present the unique human knowledge category of *Mètis*, providing human experts the ability to deal with both ambiguity and uncertainty within complex environments.

MÈTIS AS AN AMBIGUOUS AND INCONSPICUOUS CATEGORY OF KNOWLEDGE

Mètis is a form of knowledge that is lived out, acquired and renewed across human practice and experience to face the most daunting situations and challenges. Détienne and Vernant (1978) emphasize its ambiguous nature as being called upon in "situations which are transient, shifting, disconcerting and ambiguous, situations which do not lend themselves to precise measurement, exact calculation, or rigorous logic" (p. 3-4). In turn, Baumard (1999) characterizes its ambiguous nature across two diadic pairs working in complementary fashion: namely, explicit vs tacit knowledge with individual vs collective knowledge.

Scott (1999) describes *mètis* as a form of wily intelligence and adaptable cunning described by Ancient Greek mythologies as an effective method to face adverse or confrontational situations against powerful adversaries in unstable and complex environments. "In a sense, *mètis* lies in that large space between the realm of genius, to which no formula can apply, and the realm of codified knowledge, which can be learned by rote" (Scott, 1998: 320). Aristotle singled out navigation and medicine as two activities in which *mètis* acquired across long experience was indispensable to expert performance. "These were seen as *mètis*-laden activities in which responsiveness, improvisation, and skillful, successive approximations were required…The problem, as Aristotle recognized, is that certain practical choices cannot, even in principle, be adequately and completely captured in a system of universal rules." (Scott 1998, p. 322). *Mètis* is used in sometimes similar, yet never identical, situations requiring quick and practiced adaptations that are second-natured to expert practitioners. *Mètis* cannot be simplified into deductive principles found in book learning alone, because the contextual environments in which it is exercised are too complex, non-repeatable and non-predictable in which general formal procedures are impossible to apply (Scott, 1998).

Contemporary examples of *Mètis* include surgeons, aircraft pilots and engineers, whereby all of these technical domains involve both uncertainty and ambiguity (Schrader et al, 1993). *Mètis* involves *mindfulness* which consists of an expansive 'attentional breadth' or directing attention toward external events and phenomena as well as internal states (Dane, 2013). It is a focus on the present moment which fosters regular updating. This increased attentional breadth means more cues can be considered in the course of sensemaking, which in turn, increases the vividness with which people interpret their surroundings (Weick and Sutcliffe, 2006). This vividness also enables individuals and collective groups to quickly identify effective courses of action with their present circumstances, perform them effectively and/or improve their capabilities to more swiftly cope with what is seen (Dane, 2013).

Management Implications and Policy

Unexpected emergencies and challenges present themselves across "dynamic ambiguity" (Baumard, 1999, p. 35). Such ambiguous situations may foster puzzlement and indecisiveness despite peoples' possession or access to impressive levels and quantities of codified knowledge (Baumard, 1999: 2). Factors contributing to this, includes the low degree of awareness people (or organizations) have of the knowledge they have access to as well as the low degree of internalisation or embodiment of such codified knowledge (Baumard, 1999; Dreyfus and Dreyfus, 2005). On the other hand, Weick (2015) argues that ambiguity within unexpected or sudden crises can only be addressed across intentional ambiguity; that is, ambiguous frames of minds generating impermanent interpretations. *Mètis* would appear to provide this across its "polymorphous knowledge" (Baumard, 1999, p. 62). It is a combination of 'street smarts' and 'deep smarts', the former being the ability to quickly detect and to quickly react to anomalies, and the latter as a deep theoretical *and* practical understanding and knowledge of associated patterns, phenomena and anomalies of a given domain (Hatt, 2007; Leonard and Swap, 2005).

In turn, management must support *mètis* within the workplace. This is achieved across the encouragement of i) social practice and dialogue (Colins, 2010; Dreyfus, 1972 and 1992), and ii) individual repetitive practice of technical knowledge in various contexts involving indwelling leading to transformations in both focal and subsidiary awareness (Polanyi, 1962 and 1975; Tsoukas, 2003). There is, however, an additional level of resolution to be found within both (i) and (ii). In both cases, a wariness, vigilance or more precisely, a "mindful experience" across "mindful observation" is called upon in order to achieve the required cunning and skill (Baumard, 1999; Aftel, 2014).

Uncertainty, complexity and equivocality are not mutually exclusive. As such, decision-making often involves all of these three characteristics of uncertainty, complexity and equivocality (Koufteros, Vonderembse, & Jayaram, 2005). Most organizational decision-making is best handled across the use of both analytical and intuitive approaches (Hung, 2003).

As such, a partnership between human decision makers and AI should also be considered in which:

1. Humans and AI can collaborate to deal with different aspects of decision-making. AI is superior with issues of complexity, allowing humans to focus on uncertainty and equivocality.

2. Humans should still however maintain overall control and oversight of decisions in complex situations, since humans have the capacity to reframe problems or pose new questions across critical thinking.

Decisions in complex situations still entail aspects of uncertainty and equivocality, further justifying human oversight. In turn, human decision makers facing situations of uncertainty and ambiguity can use AI to assist them.

CONCLUSIONS

In this paper, we re-examined the discourse and realities associated to AI by specifically de-constructing IBM's Watson and Google's AphaGo. In both cases, neither is anywhere near passing the Turing Test on natural language conversation. Such conversation involves uncertainty, complexity and ambiguity – three environmental challenges which also play a role in regards to organizational decision making.

An examination of AI vs human decision making capabilities in the face of uncertainty, complexity and ambiguity showed that humans, across *mètis* knowledge, are still better than AI in situations of uncertainty and ambiguity, while AI has an edge in situations of defined complexity. Management's role in enabling mètis includes the encouragement of individual and social practice, as well as dialogue within the workplace. Furthermore, organizations must partner human decision makers with AI in situations of uncertainty, complexity and ambiguity, whereby humans maintain overall control and oversight.

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