Technological innovation antecedents in the UK ceramics industry

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Abstract

The role that innovation plays in industry is, usually, exclusively discussed in more technically advanced industries (for example, automotive and pharmaceuticals). More mature and established industries, such as textiles and ceramics, are often neglected. This article redresses this balance by considering the role of technological innovation in the UK ceramics industry. Case analysis comprising both retrospective and current innovation in the industry is used to highlight the role of innovation and some of the antecedents to successful technological innovation.

Keywords: Technological innovation; UK ceramics industry; Innovation influences; Mature industry

1. Introduction

The subject of innovation and factors facilitating and hindering its progress has been of interest for many years. In arguably one of the most innovative periods of the 20th century, during and immediately after the Second World War, many policy makers believed that pure science alone could provide self-sustaining economic growth [2]. Key empirical studies in the 1970s, though, challenged this and brought to the fore other factors affecting an organisation’s ability to successfully innovate. These developed further into innovation models that have, overtime, evolved into the fourth and fifth generation models that are recognisable today.

Apart from initial case-based research, these models have been borne out of the mass sampling research methodology route. Despite this work, there is still no comprehensive recipe for successful technological innovation [3]. Balachandra and Friar [4] recently identified 72 such influences on the innovation process. This begs the question of whether such a comprehensive, universal model of innovation can be generated. This article argues that, instead, innovation should be considered at a more micro, industry level. This way, it is possible to gain an improved understanding of the real influences of innovation in UK industry.
In order to do this, the article considers the UK ceramics industry, a mature industry often perceived as being unable or unwilling to germinate, develop and transfer technological innovation ideas.

The paper is divided into four sections. The first of these describes the evolution of innovation models and extracts from these some of the more important influences on the process. Then, after considering the methodology followed by the research, the findings are segmented two-fold; firstly, considering the general role of innovation in the ceramics industry and, then, working towards a framework of influences and antecedents affecting and leading to technological innovation in the setting of the mature ceramics industry.

2. Review of relevant literature

2.1. Conceptualising innovation

Innovation is an elusive term which is often difficult to define (North and Smallbone [5]). Studies frequently fail to distinguish between different types of innovation, assigning anything that enters the marketplace with innovation status. However, recent work has shown there to be vast differences in managing different types of innovation (see, for example, [6]). If innovation is considered purely from an economic standpoint, then the definition of Schumpeter should be considered; innovation occurring as soon as the first commercial transaction of a product or process takes place. Innovation is more than just the final commercial exploitation though: it is concerned with the entire process, from idea conception through to commercial exploitation and beyond, and is something that encompasses the whole business [7].

Distinctions between innovations exist. Freeman [1] classifies by product and process innovation, Wheelwright and Clark [8] by incremental, new generation and radically new and Balachandra and Friar [3] merely by radical and incremental. These definitions identify two fundamental properties innovation possesses; a degree of newness (or innovativeness) and its type (whether a product, process, service, etc.). It is with these two variables in mind that innovation can best be described.

2.2. Empirical directions and studies

Understanding what factors underpin innovation success are important for two reasons [9]:

1. It offers an insight into how new product projects should be managed.
2. It gives guidelines for screening new projects.

Empirical studies over the last 30 years have been concentrated in three directions; key reasons for innovation failure, factors leading to innovation success and comparisons between new product and process successes and failures [9,10].

By considering past product and process innovation failures, research has attempted to identify the reasons for such failures and, therefore, provide management with a platform to avoid future repetition. Studies have been conducted according to three different lines [11]:

- Development of decision rules and support systems to aid project termination decisions (see, for example, [12]).
- Development of indicators for identifying project problems before they lead to failure (see, for example, [13]).
- Suggestion that project success is associated with several critical implementation factors, e.g., clear project mission and sufficient resources (see, for example, [11]).

Research has also sought to consider characteristics common to new product successes. These include the analysis of highly successful Canadian case histories [14,15] and Rothwell's [16] textile machine industry study.

These two research foci, however, were perceived to be somewhat flawed since they exclusively considered innovation successes or failures [9]. Instead, it was believed that a real understanding of success characteristics could only be achieved if research sought to compare innovation successes and failures. This lead to the third, and most fruitful, research direction and includes such studies as Project SAPPHO [17], Project NewProd [18,19]
and, more recently, the Project Implementation Profile [11].

These research studies have culminated in the development of generations of industrial innovation models, all which have held certain dominance over the last 30 years [2].

2.2.1. First and second generation industrial innovation models

In the 1950s, these models assumed the industrial technological innovation process to be a linear one. The first generation *technology push* model, believed the technology developer to be the instigator in technological innovation and the marketplace as a passive recipient of the outcome. Despite such pioneering research by Carter and Williams [20], this model was in widespread evidence until the late 1960s, when empirical research came to the fore which laid emphasis on marketing related influences on the process. Studies like Myers and Marquis [21] were at the forefront of this. This lead to the second generation *market or need pull* model, which proposed that innovations took place as a result of a perceived, and sometimes clearly identified, customer need. This need would lead to a highly focused R&D effort to produce ranges of products to satisfy the identified need.

2.2.2. Third generation industrial innovation model

The 1970s saw growth in the belief that linear innovation models over-simplified the coupling between science/technology and the marketplace [2]. Many studies highlighted this by showing the combined importance of both marketing and technical factors in innovation success. These *coupling models* regarded innovation as logical, although not necessarily continuous, sequential process that could be divided into a series of functionally distinct yet interacting and inter-dependent stages and that linked the entire organisation to the marketplace and the wider scientific and technological community [22].

2.2.3. Fourth generation industrial innovation model

These are the more *integrated* models of today and represent a departure from the traditional sequential view of the innovation process to that of a parallel one [2]. These models are not just defined by inter-functional integration, but also increased integration, both horizontally, vertically and between companies [2]. These include increased relationships and strategic alliances with others in the supply chain. In Japan and Europe, the nemesis for these consortia has been the government, while in the United States the initiative has been taken by the private sector [2].

2.2.4. Fifth generation industrial innovation model

Recent developments in information technology have seen a move toward a fifth generation of industrial innovation model, the *strategic integration and networking model*, in which the innovation process is seen to parallel the integrated process both within and outside the organisation. Strong up-stream supplier linkages are in evidence with close coupling with leading edge customers. There is also an emphasis on collaboration and integration between R&D and manufacturing [23]. This represents somewhat of an idealised version of the integrated model.

2.3. Commonalties and characteristics of previous research

Certain common findings arise from many of these studies. They often attempt to deduce a comprehensive model of what leads to successful innovation and, in doing this, usually develop lists of facilitating factors. Technological innovation, however, is unpredictable by its very nature and, thus, the number of potentially affecting variables can escalate. In a recent study, Balachandra and Friar [3] noted 72 different characteristics, whilst extensive reviews for this paper have identified upwards of 60. Much previous research has also highlighted how organisational and industrial factors (for example, [24,6]) often have overriding influences on innovation. For these reasons, the search for such comprehensive models of technological innovation is possibly a fruitless one.

From these studies, factors which affect technological innovation can be segregated into various groups. Although these classifications, naturally, overlap, they can be seen as falling into three groups: Technology factors, market factors and factors affecting the organisation and management of the innovation process.
2.3.1. Technology influences

These relate to the deliverable technology that is the core of the innovation effort and the technical resources, skills and activities needed to realise the innovation process. Initially synonymous with technology push innovation models, these factors highlight the importance of developing the right innovation (be its product or process) and having the right technical capabilities for doing so.

Calantone et al. [25] note the importance of both technical and production-related activities as precursors to product success. The ability to develop technology and development ideas lies in the organisation having, or acquiring, necessary technical and production activities and be proficient at them [26, 27] and these can only be in place if there are adequate development funds and the support and drive of a technical entrepreneur [17, 28].

Before this, one of the key antecedents to successful technological innovation is having the ability to generate, recognise and harness innovation and technical opportunities. This is especially true where more bold innovative ideas are involved [29]. The ‘degree of innovativeness’ [3] is often seen as an important factor possessed by a potential innovative or new technology-based idea. However, the degree to which it effects innovation success is debatable. It has been shown that innovative product and processes have a greater chances of success than non-innovative ones [30, 31]. This has been contradicted, for example, by Klein-Schmidt and Cooper [32] who found a ‘U’ shaped, as opposed to a linear, relationship between the degree of innovativeness and successful innovation. Closely related to this is the patentability of an innovative idea. Many studies (see, for example, [33, 34]) have commented on the importance of patentability but, equally, have reported its lack of adoption in industry [31, 35].

Another often reported antecedent to successful innovation is the need for a project champion or technical gatekeeper [36, 37]. This enthusiastic supporter of the innovation project is someone who is personally committed to it [38]. Although their presence may not guarantee innovation success [36], their inclusion is, nevertheless, vital in the innovation process.

2.3.2. Market influences

There is general agreement on the significance of marketing factors in technological innovation, especially product innovation. In the industrial setting, anything deliverable from the innovation process will lead to changes in the stimulation of the marketplace. The role of ‘market pull’ ideas has frequently been commented upon [14, 26], as has the manner of market entry; including entry strategies [39] and timing of entry, both early entry [31] and, in some cases, later [40].

The rate of new product introduction has been seen as an important factor since, as some studies have found [31, 40], a higher rate of introduction implies increased competition and, hence, a negative effect on commercial success.

The role of the marketing function and market intelligence have also been highlighted. Adequate performance of all marketing activities is key to technological innovation success [19, 9] and this means the organisation must be proficient at understanding customer need and facilitating effectively external communications [17]. Expressed conversely, insufficient market analysis, sales effort, distribution or promotion of innovation tend to lead to failure [41, 42].

Over-reliance on market variables, though, can detriment the innovation effort. Too much market analysis can drive out innovation and, often, relevant market information is difficult to obtain [3, 4]. This is true of most information concerning innovation, especially at its earlier stages.

2.3.3. Innovation organisation and management influences

If the organisation itself is not capable of getting an innovation off the ground then failure is inevitable [3]. The organisation and management of the innovation process is key to success. However, unlike many other influences this is, at least partly, under the influence of the organisation and its members.

Key to innovation success is the organisation structure in which the innovation effort resides. Miller and Dröge [43] define the structure as the company’s level of authority centralisation, formalisation, complexity and integration. One of the initial discussions of differing organisation forms
came from Burns and Stalker [44]. They found two ideal types of organisation, *mechanistic* and *organic*, that are still often quoted today. Mechanistic structures, appropriate to stable conditions, can be characterised by a more hierarchical and rigid management form, control and authority with specialised differentiation of functional tasks. Conversely, organic structures are more suitable to unstable conditions and represent a more horizontal form in which control, authority and communication are more network-based [44]. It is important to emphasise that these forms represent polarity and not dichotomy since various forms of structure can exist in between. Since Burns and Stalkers time, many have reported that more flexible [45] and organic [24] processes and structures tend to facilitate improved innovation and that more centralised structures lead to inter-functional communication problems [46]. It has been noted, however, that the nature of innovation changes as it progresses and, consequently, organisational structures should mirror this [47].

One of the key communication interfaces often identified as most affected by organisation structures is that between R&D and marketing functions. Many studies have split the innovation process into these two activities, sometimes sandwiched around manufacturing. Therefore, effective communication, especially between these two functions, is vital [48].

A further key influence is the degree of fit between projects undertaken and the company’s existing products, processes and skills (*project / firm synergy*). If a new innovation venture is to prove successful, it must be introduced into an organisation that has the technical, marketing and management skill levels to facilitate it [19,49]. Other organisation influences have also been associated with successful innovation, including planning and scheduling of innovation [31,33] and internal sources of ideas [18,50].

3. Research methodology

The paper, and the methodology on which it is based, is borne out of ongoing research in the UK ceramics industry. In order to consider successful technological innovation in the industry, four case studies of ceramic new technology and innovation are considered. Selecting this methodology above the usual survey-based approaches to have proliferated the area of technological innovation was purposeful. Early research on innovation was very much grounded in the case research approach [37]. Since, at this time, nothing was known about the area, the research direction used was that of presenting detailed descriptions of each phase of the process of developing new technologies (see, for example, [51,52]). Since then, researchers have sought a more universal approach to the subject. Despite all this activity, there is still no precise and comprehensive recipe for successful technological innovation [2]. This begs the question if such an all-embracing prescription can be achieved.

Previous research also highlights some methodological issues and weaknesses. The majority of previous studies have centred around historical data based on retrospective examples of technological innovation. Very little data collection takes place during a new technology project’s life. There is also, often, only one person – per company used as a data source [3]. As well as contributing to the usual objectivity and triangulation dilemmas of the research, there is also the question of the accuracy of some information collected from one source on a phenomena that could have taken place 5–10 years ago. For these reasons, it was decided that a case-based approach to the research was appropriate.

Through initial contact in the ceramics industry, a snowball approach was used to select the case studies. The cases were chosen to represent both retrospective and current advanced technological innovations that have taken place in the industry over the last decade. These technologies also represent varying degrees of innovativeness, from new product developments to substantial innovations incorporating much of the industry, and cover both product and process innovations (see Fig. 1).

Data collection was based on case study research practices, incorporating interviewing, document analysis and, where applicable, participant observation. The observation aspects of data collection were only of real value for the current innovation
projects in the ceramics industry, mainly the Solid Oxide Fuel Cell case study. Observations were conducted on a non-participatory level in order to keep the affected cases congruent with the others in the study. To complement these cases, more general research and findings from the industry are included in this paper. In total, 15 companies, to date, have been part of the research. Single and cross-case methods were used to analyse data, including ordered displays, pattern matching and cognitive mapping.

The findings from this research are presented in the following two sections. The first of these considers the more general role of innovation and new technology in the ceramics industry and the second works towards a framework of influences and antecedents affecting and leading to technological innovation in the ceramics industry. Naturally, due to the methodology used in this research, findings cannot be taken as representative of the entire UK ceramics industry.

4. Innovation and new technology in the UK ceramics industry

4.1. A brief history of the UK ceramics industry

Ceramics are defined as non-metallic inorganic materials and the word ceramics derives from the Greek Karamos, which roughly translates as fired earth [53]. The famous potters Josiah Wedgwood, Thomas Minton and Josiah Spode founded potteries in Staffordshire, in the UK, in the 18th century in the towns that were to amalgamate and become known as Stoke-on-Trent [54]. This region was most suitable for pottery production due to its abundance of local clay and coal for kilns. These resources aided the initial growth of the UK pottery industry along with the Trent and Mersey Canal in 1777 [54].

This concentration in Stoke-on-Trent came to be known as the Potteries and now has high local significance, employing a large proportion of Staffordshire’s workforce. Its national significance is also in evidence, as it represents the centre of the UK ceramics industry [55]. The Potteries is centred mainly on six towns in Stoke-on-Trent itself; Tunstall, Burslem, Hanley, Stoke, Fenton and Longton [55]. This concentration of the industry to a specific location is not confined to the UK. Similar geographic concentrations of ceramics producers exist in both Europe [55] and the remainder of the world:

- Bavaria and Rhineland (Germany),
- The Emilia-Romagna region of Sassuolo (Italy),
- Limoges (France),
- East Liverpool, Ohio (United States).

As with Stoke-on-Trent, the choice of these traditional locations was based on the availability of raw materials and fuel.

4.2. The role of innovation and new technology

It can be argued that the UK ceramics industry has witnessed two technological innovation and new technology revolutions. When the first potters started production of ceramics in Stoke-on-Trent they, effectively, turned what was a craft into an industry. This initial production of traditional ceramic goods (i.e., tableware, tile, brick and
sanitaryware sectors) brought with it the main innovating problem of obtaining output continuity; manufacturing one cup, tile or brick as mentioned previously. To respond to this, revolutionary production units were established, the forerunner to this being Wedgwood [56]. Much of the industry then witnessed an extended period of consolidation and, up until the middle of the twentieth century, the manufacturing of ceramics goods had hardly changed from the revolutionary production units of 200 years ago.

The last three decades, however, have seen somewhat of a second revolution for the industry. Mechanisation has replaced much manual processing and brought with it improved control and consistency of raw materials and products [56]. Such technological improvements have not been uniform throughout the industry, though, with developments occurring fastest in the cheaper end of the industry (for example, earthenware) and slower in the more expensive end of the market (for example, bone china). Some industrial sectors also appear more willing to accept industrial innovation than others. For example, fast and single fire technology has been incorporated into production processes in some of the UK’s premier tile manufacturers for almost a decade, whereas, some sanitaryware and tableware manufactures have only recently had such installations and, in some instances, are still assessing its potential.

Today, new technology is of increasing importance to the UK ceramic producer. With increased competition from both other materials (for example, glass and plastic) and foreign markets, the need for new technology to provide faster throughput times and greater reliability is of great importance [55]. The majority of this innovation activity is concerned with making ceramic goods quicker, cheaper, more reliable and long lasting. Increased mechanisation is also being sought in the majority of the main manufacturers from tile, sanitaryware and tableware manufactures:

The industrial potter’s ideal is a single machine into which are fed the powdered raw materials at one end and which turns out the fully finished pieces of ware, ready for despatch, at the other end. (Source: [56, p. 226]; emphasis added)

4.3. The role of the research and technology organisation (RTO)

RTOs and Research Associations are private sector companies that specialise in the provision of services to the complete spectrum of UK and international companies, generating and diffusing innovation across the technology spectrum [57]. An RTO will usually represent an industry or technology-type and draw its member base from the companies it serves. Their unique position enables them to understand the mechanisms, requirements and needs of their particular industry or sector, which makes them the ideal broker in the provision of innovation for that sector. Their discourse with regulatory bodies, as well as the member base, also makes them ideally placed to understand technological and innovation drivers in their industry. The RTO for the ceramics industry is CERAM Research. Established in 1948, it offers a wide range of services (for example, consultancy, testing and technical support) for all ceramic sectors; which includes traditional ceramics and structural (bricks and roof tiles) and advanced ceramics. However, CERAM’s major strength in aiding and facilitating innovation amongst members of the industry, is its ability to facilitate funding and management of collaborative research, development and technology transfer projects. An example of how CERAM has aided innovation in the ceramics industry is presented by Warren and Tan [58].

Despite this, the UK ceramics industry is still often regarded as being unable or reluctant to successfully embrace innovation and transfer technology. Campbell [59] reports comments such as “the [ceramics] industry is more than 5000 years old – there is nothing left to invent” [59, p. 245]. In such a mature industry, however, the discovery and exploitation of creativity should not be left to chance [7]. Even with CERAM Research being at the forefront of much technological innovation and change in the industry, being involved in the development of such technologies as firing techniques and even granular pressing, the commercialisation

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1 For more detail on RTOs and Research Associations see Tan [57] and for an example of CERAM Warren and Tan [58].
of new technology and innovation has increasingly taken place abroad, especially in Germany and Italy [60]. Campbell [59] recognises that, on this domestic scale, past failures have been more to do with a lack of business vision than a lack of technology.

There is, however, evidence of attempts to improve this business awareness in the industry. The development of various industrial think-tanks and strategic direction groups, for example, the Manufacturing Improvement Club (see [61]), and the introduction of research projects, akin to this, have highlighted a certain willingness to further cognise innovation processes. In some organisations, more accepting and inquisitive business attitudes are also displayed by being enthusiastic about exploring other industries in grossly different sectors in order to apply manufacturing process technology, productive technologies and business perspectives. A recent, although slight, trend of employing managers and executives from other, more technologically advanced, industries underlines this.

5. Factors affecting innovation in the ceramics industry

Within the UK ceramics industry, the technological innovation process is affected by influences that can be grouped four-fold:

- The nature of the innovation itself.
- The organisation and management of the innovation process.
- External influences.
- Further influences and considerations.

5.1. Nature of the innovation

Although most authors have included, in the definitions of innovation, products processes and services, the focus of research has been concentrated on product innovation in the guise of new product development. In the ceramics industry, although the majority of larger ceramic manufacturers have their own new product developers, a significant proportion of industrial innovation activity surrounds more process innovations. Some of the major innovations over the past twenty years have seen significant improvements in the firing, drying (two of the case studies in this research) and printing procedures in ceramic productions, in a variety of ceramic sectors.

Much of the driving force behind this, as described in Section 4.2, has been to increase mechanisation in the production process and, ultimately, produce more reliable and long lasting ceramic-ware in a quick and economical manner. Allied to this have been various environmental, legislation and energy influences. For example, firing and drying of ceramic-ware represent the two most energy intensive processes in ceramic production. The development of single and fast firing techniques and more advanced drying processes (primarily airless and, potentially microwave, drying), have facilitated the potential for tremendous manufacturing energy savings.

These types of innovation projects, though, are seldom conducted in-house, by a single company. In line with the rest of the UK manufacturing base, the ceramics industry is proliferated with smaller producers (about 88%). For this reason, the majority of basic research and larger innovation and technology development efforts takes place with the RTO. This can take the form of either a single-company contract service, as a collaboration club project along with other ceramic companies, or as a part of an entire industrial sector project.

Previous literature has often considered the nature of the innovation as a factor of success (see, for example, [9]), but have treated it as the outflow from an organisation in the form of new products or services. Evidence from the ceramics industry reminds us that it is also important to note the importance of the adoption of innovative products, processes and practices in the production of ceramic-ware. One company cited the installation of a new Information Technology system as a recent innovation. They saw this as something that would improve the existing functionality and facilitate further technological progress. This adoption of innovation, though, is not so forthcoming for more radical innovation.
This is similar to suggestions by Rothwell [27], and others, for obtaining proficient technical and other skills and infrastructures in order to expedite industrial innovation. This also follows the belief that innovation can be something new to the business [22] as well as a deliverable product or a process new to the industry [62].

5.2. Organisation and management of innovation

As past literature illustrates, the organisation and management of innovation is key to overall business success, especially since it is something that can be controlled. This is no different in the ceramics industry, where effective organisation, planning, scheduling and implementation of innovation is of great importance. One interview respondent commented that the process had to be treated as if it were a business in its own right:

You can’t handle it from the inception point in anything other than with business objectives at the end.

Much of this project planning and consequent management is, however, very dependent on the source of funding for innovation. As emphasised above, many ceramics companies do not have the resources to innovate beyond incremental improvements and amendments, in the form of product range additions, etc. Therefore, they seek external funding and project management support. Such sources include government, Department of Trade and Industry (DTI) and European Commission funding (see Section 5.4). However, when such funding is secured, there are often concrete targets set and deliverables required by the funding source. This is because, today, much Government and European funding for commercial research and technology transfer requires comprehensive justification. Consequently, much of the planning and management procedures for externally funded projects are determined as a result of contractual agreements between the funding body and the innovating organisation. An example of this, in the Ceramics industry, is Airless Drying (see [63]).

Another significant organisation and management related influence on innovation in the ceramics industry is that of personalities; individuals and groups that facilitate and stimulate the process of innovation. Often referred to in the literature as project champions or (technical) gatekeepers, there is much emphasis on the need for such individuals in the ceramics industry. The term personalities is used purposefully, since observation and interviews have highlighted that this is often what is needed in order to drive innovation forward. Interviews also emphasised some of the traits such as thorough flexibility and experience of the industry a personality should have.

Flexibility of thought is vital to the process of innovation. One interview respondent discussed an example of a current process innovation which failed to make an impact in one sector due to its cost and the amount of process change it would have imposed on adopters. Persistence and consideration, though, lead to a successful re-direction of the technology to a different sector. As the respondent commented:

You should look at things not in terms of how they were originally conceived, but how they can be adapted and re-invigorated.

Experience in the ceramics industry is also important. This experience should include both technical knowledge of ceramic production and materials and a more general knowledge of the ceramic community. In a traditional industry like ceramics, experience brings with it a wealth of understanding of those involved in the industry. This is facilitated by the close geographical proximity which the majority of ceramic companies share. Amongst, other things, this experience leads to heightened communication among companies, something often identified in the literature as vital to innovation success. This is an area where the RTO can play a key role.

An often cited example of a project champion in the ceramics industry is that of Pilkington. Particular material folklore has it that Pilkington wanted to produce flat screen glass, yet was unsure how to do it. One day, one of the members of the Pilkington family was washing up and noticed how the grease and washing fluid floated on the surface of the water. In a Eureka moment he posed the question to his organisation if it was possible to float glass in a similar fashion to produce an even
layer. The result was a process for floating glass on liquid tin and drawing it through. Be it fact or fiction, this highlights the role of both the project champion and the technical gatekeeper.

Much of this industry experience results from having current managerial and director-level members residing in the industry since leaving school, collectively developing *through the ranks* of their respective companies. This has had profound effects on the industry. Firstly, this has led to a certain *old boys network*, where everybody appears to know everybody else. This can make for a vital aid or complex barrier to the facilitation of innovation. On the one hand, such collective knowledge and understanding lends itself to being a close community, notwithstanding competitive tendencies, where collaborative efforts can often be easily forged and organised. Conversely, this *old boys network* can, collectively, fuel the stagnant attitude towards innovative thinking that the industry is renowned for having. Secondly, this history has meant that today's managers have been trained in the technical and materials side of the industry as well as in its management, allowing them to consider the feasibility of ideas from both commercial and technical standpoints.

Herein these two effects lies a current industry-wide concern. With jobs no longer being guaranteed for life, it is feared that future generations of managers and directors in ceramics companies will not have the technical or industry knowledge and background to *understand how the industry works*. While other industries have evolved, and survived, this is felt in many quarters that this could change the face of ceramic production for good.

5.3. External influences

In the ceramics industry, there are also certain influences on industrial innovation that extend beyond the scope of the organisation.

Consistent with the literature, a good market understanding is imperative if innovation is to be successful. Although vital to North Staffordshire and the UK, the ceramics industry is, relative to other industries, not that large. It generates a turnover of about £1 billion, comparable to a large supermarket chain. This does not give the ceramic innovator much of a market to work with. This is further complicated if the technologies being developed are aimed at the ceramic manufacturing community, for example, process innovations. In this situation it is possible to witness the frequent postulation that ceramic companies are unable or unwilling to adopt innovations. This is more common, the more complex or *innovative* the technology is. As one interview respondent remarked:

[Ceramics companies] are happy to bring new technology on but its got to be factory proven and somebody else has got to take the risk … they'll be interested, but they'll not be the first.

This, in turn, very much affects exploitation and diffusion strategies within the industry, putting emphasis on the need for industrial prototypes of developed technologies.

The research also highlights how the scope of innovation can extend beyond the boundaries of the organisation. Literature often considers innovation in terms of taking place in the organisation. Although more recent generations of innovation models (e.g., coupling and integration models) have added communication links to other organisations and the wider scientific and technical community, there is still relatively little written about innovation through collaborative efforts. As explained above, much of the more large-scale and radical innovation is too extensive to be undertaken by one organisation. In these situations, collaborative efforts are often sought, with the RTO at the heart of the organisation and management of the effort, combined with gaining co-supportive funding. The development of both Airless Drying and Solid Oxide Fuel Cells in the ceramics industry represent examples of this. The RTO, however, is constantly involved in similar collaboration projects.

Within this collaboration process, the relationships and information flows between the various collaborators and participants can be seen as somewhat of a complex network or web of innovation (Fig. 2), which involves what Cooper [14,15] sees as a series of information acquisition activities. As Fig. 2 shows, this form of innovation is defined by
interaction, be it interaction with collaborators or as an information acquisition exercise with universities, regulatory bodies and the like. Whatever the interaction, it is not just a one-off relationship. Due to the timescales involved with innovation and transfers of technology (see Section 5.4), this intercourse is on-going.

5.4. Other influences on innovation

In addition to the above highlighted influences on the innovation process in the UK ceramics industry, there are others that very much shape the context and manner in which industrial research and innovation is conducted.

The time that an innovation effort can take from the point of inception, through realisation and exploitation and to gaining a meaningful payback is something that is not often considered in the literature. In the ceramics industry, the timescale of innovation is of great importance. The research identified two timescales which affected innovation:

- **Inception to realisation** – Depending on the nature of the innovation this can take up to a decade. Airless Drying took about seven years from first entering the ceramics industry as a potential solution to high energy and time demands in the drying of ceramic-ware. Solid Oxide Fuel Cell research has been ongoing for approaching a decade. Although, many would say that this is a perennial problem for the UK manufacturers, and not specific to the ceramics industry, this does represent an elongated timescale.

- **Realisation to payback** – Once an innovation has been realised, it has to be either sold or installed before it can be judged as a success or failure and before any payback can be achieved from its use.

These timescales highlight how organisations are no longer investing today to reap for tomorrow, but to possibly reap in anything up to 15 years.

Funding considerations are also key to innovation success in the industry. Interviews highlighted five forms of funding, based on sources both internal and external to the organisation:

- **Internal source**: (1) in-house funding; (2) building research facility;
- **External sources**: (3) private projects with other organisations; (4) collaborative projects with RTO and member companies and (5) with end-users.

However, as referred to, the ceramics industry is proliferated by companies that do not have the financial resources to fund internally. Therefore, external funding is often sought. Sources of external funding include both the UK government (for example, DTI, Energy Technology Support Unit) and European Commission (for example, Joule, Themie). Funding of this nature is usually available for both the basic and more applied research efforts. An example is ETSU, who manage the Energy Efficiency Best Practice programme on behalf of the Government. They offer funding to organisations in a range of industries, for projects that seek, as their aim, to stimulate a reduction in the UK energy consumption. They offer funds for both basic research (Future Practice R&D Projects) and more applied and commercially orientated projects (Good Practice Cases and Good Practice Guides).

Such funding is often difficult to obtain, however, and has certain conditions that must be met in order to achieve eligibility. Often, one of these is the need to have multiple organisations involved in any project and, therefore, it is unusual to see a company seek such funding independently. For these reasons, CERAM Research is often...
utilised as the focus for funding requests. RTOs, rather like universities, are past-masters in bringing funds and so using them in the preparation and management of an innovation project requiring such funding enhances the chances of proposal acceptance. With knowledge of, and contacts throughout, the ceramics industry, CERAM is also in the best position to find potential collaborative partners.

6. Summary and conclusions

Although technological innovation is usually researched in more technically advanced industries, the present research highlights how innovation and new technology can infiltrate and influence even the most mature of industrial settings.

The ceramics industry illustration reiterates many previously identified antecedents to technological innovation and also brings to the fore other influences not previously emphasised. The role of the RTO in the industry is vital to maintain and further technological development. In an industry, such as ceramics, that is so geographically close, the RTO facilitates communications that not only allows companies to compete within, but also to collectively contest with an ever increasing foreign competition.

Sources of funding and possessing individuals with in-depth knowledge of the industry are also shown to be important facilitators of innovation. Again, these are two areas in which the industry’s RTO can play a role. The scope of innovation is also important, showing that innovation need not exist exclusively in one organisation, but can migrate to several companies, an entire industrial sector or, in some cases, the entire industry.

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