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EVOLUTIONARY DIFFUSION THEORY AND THE EXDOC COMMUNITY: GREATER EXPLANATORY POWER FOR E-COMMERCE DIFFUSION?

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Abstract

Improved understanding of the innovative technology uptake (ITU) problem is important for the further development of e-commerce and its integration into mainstream business activities. The discovery of a more effective explanatory theory thus presents exciting possibilities for improved understanding of issues affecting acceptance levels of new technologies in this area. This paper pioneers the application of Evolutionary Diffusion Theory (EDT) within an Information Systems context. The set of axioms the authors have derived from the literature of EDT is used to review the implementation of EXDOC, an online document delivery system introduced by the Australian Quarantine Inspection Service (AQIS) to food exporters and successfully diffused across a number of industry sectors. The authors' application of these EDT axioms to the EXDOC case study data demonstrates the theory's explanatory depth for reviewing uptake of innovative technology – both as an instituted process and as a socially-embedded activity.

1 INTRODUCTION

Many different theoretical frameworks and approaches have been used to study Information Systems (IS) diffusion processes (see, for example: Holbrook and Salazar, 2004; Baskerville and Pries-Heje, 2001; Edquist, 1997). Investigations of a number of these theories and models of Innovative Technology Uptake (ITU) have found that each has only a narrow perspective which tends to capture 'just one part of the story' and only highlights particular areas of interest. No single theory appears uniquely able to explain the circumstances of any particular case (Jones and Myers, 2001 p.1018).

Despite these limitations, influences on uptake and diffusion of IT innovations are of perennial interest to IS researchers and of those attempting to make progress in studying the ITU problem have had to grapple with the limited explanatory power of recognised diffusion theories over some four decades. The most commonly cited diffusion theory in the IS literature is Rogers' Classical DoI[1] theory, first published in 1961 (Clarke 1999). Rogers originally focused attention on the shape of the diffusion curve, describing innovation as a process that moves through an initial phase of generating variety in technology, to selecting across that variety to produce patterns of change resulting in feedback from the selection process, to the development of further variation (Rogers, 1995).

As a pioneering contribution to conceptualising adoption and diffusion, Classical DoI theory appears to have maintained its iconic status over time and continues to be cited in the IS literature, despite the fact that interest in innovation studies has moved on from the shape of the diffusion curve to a focus on articulating underlying dynamic mechanisms (Lissoni and Metcalfe, 1994; Nelson, 2002). The innovation 'journey' now appears to be more readily understood as a non-linear dynamic system, far less predictable and stable than staged models based on Classical DoI theory represented it to be (see for example Van de Ven et al., 1999). The static orientation of Classical DoI theory, its focus on individual firms; and a 'single innovation' perspective limit its relevance to the development of online technologies in particular.

The limited explanatory power of Classical DoI theory is well documented in the literature (see, for example: Downes and Mohr, 1976; Moore and Benbasat, 1991; Damsgaard and Lyytinen, 1996; Galliers and Swan, 1999; Clarke, 2002). Seminal work in the IS field (for example: Orlikowski and Hofman, 1997; Boudreau and Robey, 1999; Reich and Benbasat, 2000) has also clearly established a need for analytical theory in this field which:

- aligns more closely with the way beliefs, attitudes and understanding of plans and structures are known to influence organisational decision-making
- can articulate underlying dynamic mechanisms intrinsic to adoption and diffusion processes
- addresses how complex and networked technologies diffuse
- acknowledges the uncertainty and surprises that mark the ITU process

A single theory is needed for IS studies of ITU that is: appropriate to reviewing open-ended and customisable innovations associated with uptake of e-business technologies; takes into account issues of discontinuing practice or slowing uptake of inappropriate technologies; acknowledges the active role users can play in the innovation process; and allows for changes in an innovation during the adoption and implementation process. Such a theory must also be readily applicable in organisational settings featuring the adoption of complex, multi-user technologies – where the majority of potential

[1] Fichman (1992) uses the term Classical Diffusion theory to refer to Rogers' pioneering work on Diffusion of Innovation, subsequently extended and adapted by a number of IS researchers (see especially Kwon and Zmud 1987; Moore and Benbasat 1991).

applications of diffusion of innovation now occur. An analytical instrument which appears well suited to these requirements is Evolutionary Diffusion Theory.

In this paper, we begin by discussing the origins and principles of Evolutionary Diffusion Theory, and then discuss its explanatory strength. We illustrate the relevance of EDT to IS and, in particular, to the explanation of innovative technology uptake by applying four axioms drawn from EDT to a real-world government-to-business case study.

2 EVOLUTIONARY DIFFUSION THEORY (EDT)

The limitations of standard theoretical approaches to analysis of the influences on ITU in the field of Information Systems research have been increased by the fragmentation and minimal 'diffusion' of diffusion research itself. The lack of awareness which the various diffusion research traditions have of one another's work has hindered researchers in their attempts to grasp and frame the ITU problem (Rogers, 1995 p.38). Such communication gaps across the disciplines help to explain why Evolutionary Diffusion Theory does not feature among the analytical instruments referred to in the mainstream IS diffusion literature.

2.1 Evolutionary Diffusion Theory: Background

Evolutionary Diffusion Theory (EDT) emerged from Evolutionary Economics, a discipline which describes economic phenomena and deals, in particular, with situations of change, open systems and innovation processes (Nelson 1995). As a discipline it has had a major impact on more recent studies of firms, industries, and technical change. The idea of technological advance as an evolutionary process has been developed by scholars of technological advance operating independently in a variety of different disciplines. These disciplines include, but are not confined to: sociology (Constant, 1980; Bijker, 1995); technological history (Rosenberg, 1976; Mokyr, 1996); and economic modelling (Nelson and Winter, 1982; Saviotti, 1996; Metcalfe, 1994).

Evolutionary Economics – and Evolutionary Diffusion Theory (EDT) in particular – are relatively recent developments, with the bulk of the EDT literature having been published only since the early 1980's. The Nelson-Winter classic evolutionary model of technological change (1982) pioneered a relatively simple conceptual model of Evolutionary Economics which was crucial to the development of Evolutionary Diffusion Theory. The model played a prominent role in defining a paradigm for further research into the conditions which determine industrial concentrations, dynamic competition in alternative technological regimes and the relationship between innovators and imitators (Andersen, 1996). The model demonstrated the possibility of collating a wide diversity of elements and integrating them into an evolutionary process which could then be applied to understanding the uptake of innovative technology. Elements include: the processes of transmission; variety creation; and selection (Nelson and Winter, 1982, Chs. 4-5). We will refer to these elements in more detail in the next section of this paper.

Nelson and Winter's classic evolutionary model of technological change (1982) was followed by several overviews of Evolutionary Economics (see, for example, key publications by Silverberg, 1988; Saviotti and Metcalfe, 1991; Dosi and Nelson, 1994; Andersen, 1994; Nelson, 1995). These contributions to the Evolutionary Economics literature share a concept of innovation as a process that moves through an initial phase of generating variety in technology, to selecting across that variety to produce patterns of change resulting in feedback from the selection process, to the development of further variation under continual injections of novelty (Dopfer, 2001). Researchers within this paradigm now apply their attention to enduring issues in innovation studies; and to finding reasons for unexplained outcomes from technology adoption and diffusion.

Instead of the more traditional application of DoI theory to an individual firm, EDT reviews the impact of diffusion theory when applied to the more complex environment of a market (Lissoni and

Metcalfe, 1994). Placing theory in a market context raises questions of particular interest to e-business practitioners, such as why all potential users do not immediately adopt innovations which appear to be advantageous compared to existing technology (instead of some firms as potential users adopting later or not at all); and why some agents who can be identified by their spatial location always adopt later than others (Lissoni and Metcalfe, 1994, pp.106, 127). Table 1 presents in summary form a synthesis of EDT's key features as reported in the literature.

	Evolutionary Diffusion Theory Key Features
AXIOMS	*Explains the innovation process an non-linear and rarely predictable (Kowol & Kueppers, 2003)*
	Explains innovation and diffusion in market environments (Lissoni & Metcalfe, 1994)
	Presents the policy maker's role as one of stimulating the building of innovative infrastructure cooperatively with local institutions (Norgren & Hauknes, 1999)
	Accepts the possibility of human intervention in the process of technology development (Nelson, 1995)
	Describes the natural trajectory of an unpredictable original selection where the outcome is not always the best one (Saviotti & Metcalfe, 1991; Arthur, 1994).
	Stresses the gradualism of internal adoption (Lissoni & Metcalfe, 1994, p.108)
	Defines a clear role for Government as a policy maker coordinating institutions in innovative systems and seeking solutions which are context specific and sensitive to local path dependencies (Lambooy & Boschma, 2001).
	Presents adoption of single innovations as part of a greater process of change impacting on organisations and their culture (Lissoni & Metcalfe, 1994).

Table 1. Key Features of Evolutionary Diffusion Theory.

Following this outline of the origins and background of Evolutionary Diffusion Theory and a synthesis of key features of EDT outlined in the literature, we now draw attention to the explanatory strength of the theory when applied to specific examples of ITU in the IS (and particularly the e-commerce) context.

2.2 Evolutionary Diffusion Theory: Explanatory Strength

Evolutionary Diffusion Theory offers the IS researcher a basis for reviewing innovative technology uptake (Kowol and Kueppers, 2003; Lambooy and Boschma, 2001; Norgren and Hauknes, 1999; Amin, 1998; Lissoni and Metcalfe, 1994; Saviotti and Metcalfe, 1991) which includes:

- A focus on unexplained outcomes
- An emphasis on gradualism of internal adoption
- A concern with development and diffusion of new variety in market environments
- Acceptance of input from a variety of disciplines
- Acceptance of human intervention in technology outcomes
- A clearly defined role for policy makers fostering innovative technology uptake

Many examples of the explanatory strength of Evolutionary Diffusion Theory can be drawn from the literature. A set of examples having clear relevance and application to IS research on issues related to innovative technology uptake are set out in Table 2.

Evolutionary Diffusion Theory
Describes the natural trajectory of an unpredictable original selection where the outcome is not always the best one (Saviotti & Metcalfe 1991:11; Arthur 1994)
Explains the innovation process as non-linear and rarely predictable (Kowol & Kueppers 2003)
Explains innovation and diffusion in market environments (Lissoni & Metcalfe 1994)
Stresses the gradualism of internal adoption (Lissoni & Metcalfe 1994)
Accepts the possibility of human intervention in the process of technology development (Nelson 1995)
Defines a clear role for Government as a policy maker coordinating institutions in innovative systems (Lambooy & Boschma)
Envisages policy maker's role as stimulating the building of innovative infrastructure cooperatively with local institutions (Norgren & Hauknes 1999)

Table 2. Examples of the explanatory strength of Evolutionary Diffusion Theory

We required an analytical instrument to examine issues in the uptake of innovative technology in a specific case. The case study – introduced here but described more fully in Section 3.0 of this paper – refers to the introduction of EXDOC, an innovative online technology, by the Australian government agency AQIS (Australian Quarantine and Inspection Service) to support the needs of food producers who required export documentation across a number of sectors. These producers subsequently became the EXDOC community and the population of the case study. Once key features of EDT had been synthesised from the literature and their explanatory strength for the IS/e-commerce context established, it became a matter of deciding how best to apply EDT as the instrument to analyse ITU issues within the case study.

Four axioms derived from the literature of Evolutionary Diffusion Theory provided the required analytical instrument. Section 2.3 sets out each of the four EDT axioms and their application to a specific case study of ITU uptake.

2.3 The EDT-based Axiomatic Model

According to the literature of EDT, key features of Innovation Diffusion Theory are: the *rejection of optimisation* or the feasibility of determining one 'best' policy; *a focus on systems and markets* rather than individual firms; *the acceptance of human agency* in technology development; and *the role of government as policy maker*. These features are described and explained in some detail as the basis of the four EDT axioms which formed the analytical instrument used to examine the case study data. *Elements* related to each of the four axioms were then drawn from the EXDOC case study. The four axioms and related elements are set out diagrammatically in Figure 3.

Rejection of Optimisation: Innovation Diffusion theory rejects the idea of optimisation or implementing one 'best' policy at both macro and micro levels. At the macro level, rejection of the

possibilities of optimising is one of the strongest points of differentiation in the conceptualisations that have emerged from Evolutionary Economics (Metcalfe, 1994). *'If one wants a model in which it is presumed that the actors fully understand the context ... then the formidable challenge facing the 'rational' models let alone a supposedly 'rational' actor is what it means to 'fully understand' the context, whenever the latter depends in some complex, non linear ways on the distribution of micro decisions and on chance and is always full of surprises'* (Dosi and Nelson 1994, pp.163-164). Instead of optimisation, the Evolutionary Diffusion model presents the idea that a diversity of policies is necessary to allow for a variety of development paths (Amin, 1998). Economists argue that *path dependency*[2] means that systemic technological and innovative capabilities can only be enhanced by openness of competition, lowering barriers to innovative entry; and nurturing interactive learning as a source of innovation (McKelvey, 1997).

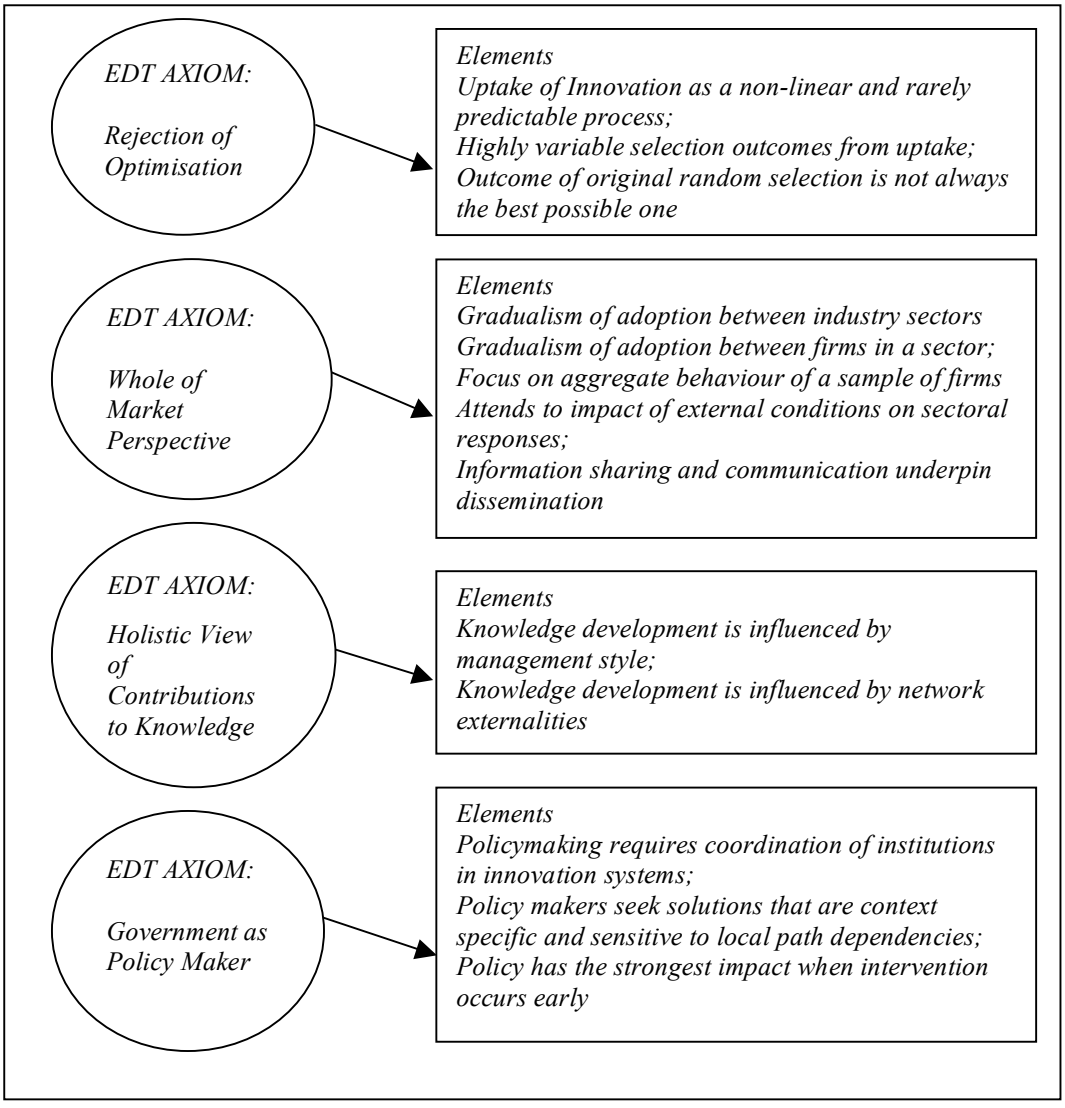

Figure 3. Axioms and Constituent Elements of Evolutionary Diffusion Theory

[2] Path dependence is a key concept of Evolutionary Economics, usually explained in association with an industrial process e.g. the QWERTY keyboard. It describes the natural trajectory of an unpredictable original selection where, although many outcomes are possible, under increasing returns the process becomes path dependent (Arthur 1994; Nelson and Winter 1982). Path dependence suggests that it is often costly to change technologies in production processes. When the costs of change are large, it is possible that firms will continue to use sub-optimal technologies.

Evolutionary Diffusion Theory also rejects the assumptions that: individual firms behave optimally at the micro level; that adoption is a one-off decision; and that uptake of new technology is more or less instantaneous. Innovation processes are described instead as: multi-referential; non-linear; depending on various framing conditions; and rarely predictable (Kowol and Kueppers, 2003). Once diffusion is viewed as a selection process it becomes evident there is no guarantee that more optimistic or better-informed firms will adopt earlier. Successful innovations represent the outcome of multiple and contingent variables and do not always have to be the best ones (Saviotti and Metcalfe, 1991). Models based on Evolutionary Diffusion Theory stress the gradualism of internal adoption between firms and over time. *'Firms called 'adopters' at a given time actually differ in the extent of their commitment to the new technology ... some of them may subsequently reverse their adoption decision'* (Lissoni and Metcalfe, 1994, p.108).

Market Focus: Evolutionary Diffusion Theory is primarily concerned with the development and diffusion of new variety or innovation in an economic system. Evolutionary models serve to extend traditional DoI theory from studies of individual firms to explaining the impact and effects of innovation and patterns of diffusion in the more complex environment of a market (Lissoni and Metcalfe, 1994). A focus on firms alone misses the contributions and investments of a wider population of stakeholders into relevant knowledge development. The literature of Evolutionary Diffusion acknowledges the need to encompass these additional sources of information in explaining the diffusion process and thus shifts attention to the aggregate behaviour of a sample of firms, without necessarily relying on explicit modelling of a single firm's decision processes (Nelson and Winter, 1982; Nelson, 1995).

Human Intervention in Economic Processes: Implicit in Evolutionary Diffusion Theory is the assumption that there is a possibility of intervening in the process of technology development; and that the selection of a theory can influence the design of policy. Evolutionary Economics accepts the possibility of human intervention in economic processes where *'users are not exclusively selectors but also involved in the shaping of innovations'* (Tushman and Rosenkopf, 1992, p. ?). Once the soft components of technology innovation are recognised, actors must be understood as capable of consciously attempting to change their environment (Nelson, 1995). Evolutionary models draw on a number of reference disciplines to expand the definition of technology to include organisational and cultural elements as well as human artefacts such as machinery and materials. (Lissoni and Metcalfe, 1994.

Government as Policy Maker: The role policy intervention can play and the institutional pressure government can exert to stimulate ITU have been explored by Lissoni and Metcalfe (1994). More recently, the application of EDT to understanding the role of government as policy maker has been extended in work by Lambooy and Boschma (2001) who emphasise the need for ITU solutions to be context-specific and sensitive to local path dependencies. At a regional level, government can use policy measures to stimulate technological and innovative capabilities and minimise adjustment problems.

Figure 3 sets out the four axioms we have derived from Evolutionary Diffusion theory and their associated elements. As noted earlier in this paper, the four axioms are synthesised from readings from the growing body of literature associated with Evolutionary Diffusion theory already discussed. The elements describe the features associated with each axiom which are pertinent to understanding influences on the uptake of innovative technology.

Clearly, there is no limit to the number of areas to which Evolutionary Diffusion Theory can be applied. It would not be possible, however, to discuss all – or even a sizable sub-set – within the constraints of a single research paper. We have therefore limited the application of EDT in this paper to a brief discussion of one case study within the Australian food industry; and of the ITU problems in

a government-to-business (G2B) implementation of electronic commerce – more broadly described as e-business technologies[3].

Section 3 provides a description of the key features of the case study and an explanation of how the four EDT axioms were applied to an analysis of ITU uptake in this specific context.

3 EDT AND THE EXDOC COMMUNITY: ANALYSIS OF AN ITU CASE STUDY

The Australian Quarantine and Inspection Service (AQIS) developed EXDOC[4] to support the preparation of food export documentation by Australian primary producers, who require a health and/or phytosanitary export certificate from AQIS. Health Certificates generated by AQIS are the official means by which the Australian Government certifies to an importing country that a product meets that country's import standards and regulations. The Phytosanitary Certificate is a type of Health documentation testifying to the health status of the certified product. AQIS procedures ensure products meet Australian legislative and importing country standards and requirements; and EXDOC is an integral part of these procedures, providing greater certainty[5] in certification through the standardisation of documentation and the consequently enhanced integrity of Australia's certification systems. The type of product and the destination determine which (if any) certificates are required.

The system operated by AQIS has been in production since August 1992. Originally designed for Meat exports, it was then redeveloped for use by non-meat commodities and, by April 2000, had been made available for exports from the Dairy, Fish, Grain and Horticulture sectors. Key events in the development of EXDOC by AQIS are set out in Table 4.

[3] There are a plethora of definitions of e-business/e-commerce definitions (Wyckoff and Colecchia 1999; Wigand 1997; Zwass 1996) with attendant conceptual problems discussed in Wilkins et al (2000). The definition which best suits the focus of this research project describes e-commerce as *'enabling design and deliberate strategic deployment of linkages and networks among cooperating firms intended to achieve joint strategic goals to gain competitive advantage'* (Wigand 1997, p.7).

[4] A simple overview of the EXDOC system can be accessed at the AFFA website link http://www.affa.gov.au/content/publications.cfm (under AQIS publications). The following description of the EXDOC system draws on the following sources: an earlier case study of AQIS and EXDOC as part of a major research project on EDI systems integration (Swatman, 1993); the Minter Ellison 2002 Report; information provided by the EXDOC administrator Mr N Scott 2002/4.

[5] In December 2002 the move to harmonisation of regulatory systems and standards gained impetus when the Australia New Zealand Food Standards Code became the sole Code for Australia and New Zealand. FSANZ assumed responsibility for standards setting in the primary production sector in Australia so establishing for the first time a single standards-setting body for the whole of the food chain (reported in Global Supermarket p10, vol 7 no 1, 2003).

EXDOC Development Date	Description of Activity
1990 July:	Development of original EXDOC by AQIS (end date)
1991 Jan:	AQIS Reforms: Commercialisation of Services
1992 August:	EXDOC in production
1997 March:	Development work starts on new EXDOC and extra commodities
1997	The Nairn Report: 109 recommendations on improving quarantine – 'a shared responsibility'
1998 July:	MEAT EXDOC implementation begins
1998 Nov:	DAIRY EXDOC implementation begins
1999 Nov:	FISH EXDOC implementation begins
2000 April:	GRAIN EXDOC & HORTICULTURE EXDOC begin
2002 March:	Minter Ellison Post-Meat Implementation Review reports
2003 June:	WOOL EXDOC & SKINS & HIDES EXDOC begins

Table 4. Key Events in the AQIS Development of EXDOC[6]
(source: N.Scott, EXDOC administrator October 2004).

The original version of EXDOC had been developed by 1990. EXDOC relied on open EDI systems at the data communication, application system and document translation levels, in line with the latest trends at the time. Internal AQIS systems and processes had to be redesigned around electronic trading and a number of organisational changes were identified – such as the need to replace the physical signature of an authorised veterinarian with an electronic authorisation – which necessitated process redesign at a number of levels, including that of Human Resources.

In spite of significant problems, the phased implementation of EXDOC survived and developed over time. This AQIS-led project served to stimulate uptake of new technology, supporting improved food industry supply chain management within and across the food sectors and increasing Australian competitiveness on world markets. The case study also revealed that coordination of innovative technology implementations was strongly affected by existing industry culture. Hence it appears that policy maker interventions are most successful where there is a real and recognised need for policy change

A cross-disciplinary review of the literature enabled the authors to synthesise key features of EDT to develop four axioms and apply them to case study analysis As indicated in section 2 of this paper,. Table 5 now sets out the four axioms drawn from the EDT literature with their associated elements in order to present a theoretical basis for analysing case study findings from this specific example of ITU issues.

[6] Aspects of the EXDOC case study have already been reported in the proceedings of BLED 2000, ECIS 2000, ECIS 2003; and in IJEC 2002 and EM 2001 journal articles

Evolutionary Diffusion Theory	Contribution to Case Analysis
Rejection of Optimisation	Explains: • No predictable pattern of uptake. • Unexpected and lengthy delays delay diffusion across sectors after initial swift uptake and industry support • Unpredictable (and costly) processes that frequently occur throughout the implementation
Innovation and diffusion from a whole-of-market perspective	Explains: • Gradualism of internal adoption within firms in a sector • Differing rates of uptake across sectors • Impact of external conditions on sectoral responses
Holistic View of Contributions to Knowledge Development	Explains: • Importance of ensuring consistency and compliance with international standards across sectors • Need to improve supply chain management across sectors in a globalised environment
Government as policy maker	Plays key role in: • Coordinating stakeholder institutions within innovation system • Seeking an acceptable business solution to ensure diffusion across sectors • Intervening with context specific solutions sensitive to local path dependencies

Table 5. Applying EDT to the AQIS EXDOC Implementation

4 CONCLUSION

Analysis of this case study showed it was impossible to predict a single 'optimal' policy development path for groups of firms targeted for uptake of innovative technology. Uptake and diffusion of innovative technology in the food industry sectors took unpredictable and non-linear paths. A whole-of-market perspective, however, served to explain the apparently confused and confusing patterns of uptake which occurred during EXDOC's phased implementation. A holistic view of contributions to knowledge development and consideration of the role government can play as policy maker contributed to the conclusion that rapid dissemination of innovative G2B technology in the Australian food sector depends on compatibility with existing commercial practice, cooperation with local institutions and accommodation of key stakeholders.

On the basis of this analysis of the theoretical and empirical evidence gathered for this paper the broader IS investigative approach of Evolutionary Diffusion Theory effectively explained the impact(s) of diffusion in the more complex environment of a market, in a way the more restricted alternative diffusion of innovation theories could not match. The axioms of EDT provided the explanatory depth to review uptake of innovative technology both as an instituted process and a socially embedded activity.

This paper, therefore, provides not only an introduction to evolutionary diffusion theory, but also shows how this approach to analysing and explaining the diffusion of innovation can be effectively applied in Information Systems environment. Specifically, it explains many of the complex and interrelated issues applying to e-business/e-commerce cases in a way which is not matched by either Classical DoI theory, or by the network-based extensions to that approach. We believe that EDT offers a richness of analytic approach and a powerful explanatory capability which makes it particularly appropriate to discussing the diffusion of information technology.

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