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Uptake of Digital Technology by Small and Medium Beef Cattle Producers: The Influence of Learning and Cost on the Extent of Usage

Abstract

This research investigates the use of digital information, primarily through computers and the internet, by small and medium beef cattle producers to see how access, acquisition, interaction, generation and use of information takes place within their enterprises. From qualitative data, cost and learning effects for uptake of digital technology are isolated from age and gender influences. This research uses cost and learning theory to point to the means of growing producer capabilities to implement digital technology as part of a production system, and to explain why, in many cases, implementation of digital technologies has resulted only in use as communication or storage devices rather than tools for analysis of production.

Keywords

Innovation, Learning, Beef Cattle, Digital Technology

Cover Page Footnote

An earlier version of this work was presented at the Digital Rural Futures Conference in Toowoomba, 25-27th June, 2014. The author is grateful for the comments of those who attended. The author would also like to thank two anonymous referees for their helpful comments.

Introduction

Digital technology offers beef cattle producers unprecedented levels of information for decision making and the future development of their enterprise if they can harness its full potential. This research project investigated the relationship between information acquisition, generation, accessibility, transfer and use by small and medium beef cattle producers in New England, the role of interaction to convert information to producer knowledge, and the innovation those producers undertook within their enterprises. It took up the point that small and medium beef cattle enterprises would be more productive and sustainable if they were more innovative (Griffith, Heydon, Lamb, Lefort, Taylor, Trotter and Wark, 2013). A significant innovation for some which could be advantageous for others, is the use of digital technologies for acquiring and generating information. Production data, professional services, advice and extension about production techniques, notice of industry events, market opportunities, social groups and computer-based tools can be accessed as digital information by beef cattle producers. However, the research showed that only a few of the producers interviewed use digital technology as a processing instrument to generate new understanding, and that most of the use of digital technology is in the form of computers used for either communication or storage of information. As such, much of the use of digital information is through linear communication channels, underutilising the capabilities of specialised software, online tools and services available. Used as a communication and storage device, a computer will indirectly influence the technical capabilities of an enterprise's production system rather than directly being part of it.

There has been increased usage of digital technology within small and medium beef cattle enterprises, however, opportunities and benefits exist from further take up if barriers to use can be overcome. A combination of learning and cost effects are posited as highly influential in the process of implementation by a producer, and where conditions are congenial to learning and reduction in costs, a producer is more likely to develop skills and use the technology to the extent of those skills within the enterprise. Evidence of the use of digital technologies by small and medium beef cattle producers has been gathered from semi-structured focus groups and interviews. Four broad categories describing the extent of usage were exhibited within the data. Cultural and demographic influences, such as gender and age, are reported as explanatory in the use of digital technology by participants, but these are not ubiquitous. The use of another innovation, complementary to digital technology usage, provides a means to show that where cost and learning principles align, gender and age patterns can be overcome and a higher level of uptake within the beef cattle community is achieved. A simple model of induced innovation is introduced as a possible way to explain the

behaviour of producers through the learning and cost effects. The conclusions drawn from the data and inference from the model suggest that for the present time most enterprises will implement some form of digital technology to a degree but the potential extent of use as an analytical tool will not occur.

Background

A long term increase in the use of digital technology, principally comprising computers and the internet, has occurred across agricultural industry, including the beef and beef-mixed farm industry sectors (ABS, 2000; 2001; 2004; 2005; 2006; 2009; Behrendorff, 2011), although the small and medium beef cattle enterprises were slow in adoption of computers and the internet (ABS, 2009). The opportunities for the use of digital technology, such as equipment, software, online tools, services and databases, in a farm enterprise are increasing and interest is mirrored from the farming community for greater use (Griffith et al., 2013). However, the initial implementation of such technology and use of the resultant information involves barriers apparent to the producer community (Ritman, Kelley, Bruce, Walcott and Loch, 2011; Noble, 2013).

The opportunity for the enhancement of production from the uptake of digital technologies is substantial, including improvements in supply chain engagement, biosecurity, food safety and carbon management (Griffith et al., 2013). In terms of production, digital technology offers a producer remote monitoring, production automation, precision agriculture techniques and superior data management (Ritman et al., 2011). Where new measurement or awareness is achieved through the uptake of such an innovation, the resulting benefit to the internal production system within the whole complex farming system is applied not only to the immediate task where the innovation has occurred, but it also reduces the costs and increases the accuracy of implementing future production tasks which utilise this localised knowledge.

Barriers to the uptake of digital technology have been found to include high costs of devices (Griffith et al., 2013) and a lack of acceptance socially by the producer community due to the design of hardware, online access, and network structures (Behrendorff, 2011). Beyond the hardware components, accuracy of software, online information or services, and industry databases is often called into question by a producer. However, in addition to these social and economic elements there is a strong learning element that also has to be integrated into an account explaining low take-up. Learning provides the capabilities for a producer to act, while economic cost provides a motivation and budgetary constraint to using digital technology. This dichotomy bears similarity to the Technology Acceptance Model 2 (TAM2) from Venkatesh and Davis (2000) where they propose that

acceptance of a digital technology for use is contingent on three factors: perceived usefulness, perceived ease of use and social norms.

The Vygotskian conception of learning, which emphasises the potential to learn in the social environment, is a theoretical means to include the perceived ease of use and social norms from TAM2 with learning. The ability to learn a concept can be explained through the theory of the personal zone of proximal development (ZPD) (Wertsch, 1985; Rieber and Carton, 1987; Daniels, Cole and Wertsch, 2007) wherein given a person's current understanding, they can learn more with the assistance of a more knowledgeable person than if they were learning alone. As well as the traditional notion of a person's innate ability affecting what they are able to learn, the ability of a person to learn a concept is influenced by the extent that they can interact with the concept: learning is situated (Wertsch, 1985; Lave and Wenger, 1991; Greeno, 1998) and is influenced by other people present (Resnick, Levine and Teasley, 1991), culture (Cole, 1996) and the artefacts (Pea, 1985; Hutchins, 1999) present while a task is performed. The person is not isolated and the influence of others, such as through social norms, advice or assistance sways the development of knowledge and subsequent activity to use digital technology, because, as Cole (1996) explains, learning is not only the direct activity focused on a task but also the social milieu that mediates the activity undertaken (Cole, 1996).

Economic cost, whether pecuniary or imputed costs, such as time requirements of labour, can be interpreted in this discussion as perceived usefulness because the activity taking place within an enterprise, at least in part, is concerned with profit. However, the 'stickiness' (von Hippel, 1994) of digital technology requires on-going investment, because although once generated the information produced can be replicated with relative ease, the means to use the information requires complementary capabilities in terms of physical capital, human capital and organisational routines. The information resulting from digital processing must reflect the individual producer's understanding of what that information represents. Even though a technology may provide another enterprise with substantial benefits, these benefits may not be procurable by the producer's own enterprise. The perceived value from seeing benefits others have accrued may lead a producer to attempt to introduce the technology, but upon taking an initial action, the technology does not provide the benefits first expected because resources are not organised in the same way or different knowledge is present. The required change for a small and medium beef cattle enterprise is costly, uncertain and may take considerable time before benefits are realised.

A producer has to orientate the enterprise so that activities fit the digital information offered. When the perceived economic costs (incentives) to do so are

favourable, a producer is more likely to attempt to implement a digital technology. However, the potential to learn must also be present and this is a matter of degree. A producer may implement technologies with only limited skills developed rather than gaining a strong mastery of concepts. Even those with some experience in using hardware, such as computers, may require considerable resources to learn how to use a new software package. As David (1975) shows, both learning and cost sometimes enable and at other times constrain the actions of a producer. The uptake of digital technology is an individual outcome which is a coevolving pastiche of cost and learning effects. Small influences matter in an individual's decision making matter.

Methodology

Data was collected from fifty participants comprising thirty six beef cattle producers and fourteen of their nominated information sources. Three focus groups and thirty five semi-structured in-depth interviews were conducted where both producers and information sources were questioned about where they received information, what processes were involved in implementing change within the enterprise, the role they played in communication between themselves and others, and what information was communicated. Producers were selected as an opportunity sample which targeted small and medium size enterprises from the New England area of NSW.¹ Qualitative data provides insights into aspects of production that are important in explaining how producers operate and is informative in ways that quantitative data sets are not. Accounts provided by participants and observational data show that learning is a helpful construct in understanding how and why (or why not) producers use digital technology. Four categories or levels of digital technology use were observed through producers' accounts in interviews and other materials they provided. A producer's use was classified according to the following traits:

1. *Little or no use of digital technology.* Did not use digital technology personally for their enterprise. They are not comfortable or cannot see the benefit of use, especially where effort is needed to acquire skills. Resistance to implementation is likely to be fuelled at least in part by fear of failure, looking inept in front of others or not seeing that being a beef producer is also being a digital technology user, i.e. the producer holds the view the task of being a beef producer involves physical, spatial, biological, animal

¹ ABARES defines the size of a beef cattle enterprise by the number of stock held by the enterprise. Small and medium beef cattle enterprises in southern Australia have 100 to 200 head and 200 to 400 head respectively (Thompson and Martin, 2014).

behavioural and mechanical components conducted ‘hands on’, ‘in the paddock’ with stock.

2. *Simple linear model or rote processes.* Used digital technology to search for information through the internet - i.e. a simple linear transmission model. The producer may try other packages if supported.
3. *Socially interactive and exploratory.* Interacts with other producers and/or advisers online in regard to their own enterprise – involves a personal relationship with the others involved and may be supported by other social mechanisms as well.
4. *Uses digital technology analytically.* Records and analyses their own data, markets own stock using digital technologies etc. – uses digital technologies as a central input to enterprise management.

As each classification proceeds, from type 1 to 4, it involves a more sophisticated use of digital information.

Results

Cross-tabulation of the four tiered classification system and characteristics of producers in the sample, such as age, gender and their use of other production techniques, is used to elucidate the theory discussed above. There was considerable variation in digital technology use from both producer and information source participants. Most of the discussion provided by participants revolved around the use of computers, internet, webpages, software, online services, databases and email, although digital measurement devices, including ultra-sounds,² weighing scales³ and NLIS scanners,⁴ were discussed. Within the sample, cultural and demographic variations between age and gender groups were explanatory in the use of these devices. Consistent with other research, (Bryant, 1999; Stewart, 2004; Mackrell, von Hellens and Nielsen, 2009) a reduction in the likelihood of use of computers and the internet is present as the age of a producer increases, and gender biases the likelihood of computer and internet usage

² Ultrasound technologies are employed in a number of different ways, but most frequently to determine whether a cow is pregnant.

³ Weighing scales are used measure the weight of an animal or a group of animals. The animals are walked onto the scales and a measurement is taken before the cattle are walked off.

⁴ The National Livestock Identification System (NLIS) is a supply-chain management system that allows an individual animal or carcass to be identified and traced as it moves between vendors through the supply-chain. It is compulsory for all beef cattle to be assigned a unique identification number by the NLIS database before they are turned off. Usually this number is displayed through an ear tag, although other methods, such as an internal bolus, are also available. A producer can purchase a scanner as an optional device which will read the identification number from the tag and store it digitally so that other data or computer tasks can be matched to it.

towards women. The sample is further decomposed between those who use phenotypic and genotypic breeding technologies (PGBs). The trends between digital technology usage and cultural or demographic characteristics are not displayed by PGB users. There is a high rate of usage of digital technology amongst participants who have learnt complementary knowledge, for example, making records or receiving results, creating a relative cost advantage in applying that knowledge to other tasks.

Below, in Table 1, is a breakdown of the participant producers by age and their relative competency with using a computer. The majority of participants were in the 50-60 years and 60-70 years of age ranges which is in line with the median age of all Australian farmers (ABS, 2012). Within the sample, only four participants (11%) are classified as Type 4, compared to fifteen (42%) as Type 3, suggesting that producers are developing their capabilities to be socially interactive or exploratory but not further.

Table 1: Simple Computer Literacy Breakdown by Age⁵

Producer's Age	Number of Producers	Number of Producers in Classification			
		Type 1: Little or No Use of Digital Technology	Type 2: Simple Linear Model or Rote Processes	Type 3: Socially Interactive or Exploratory	Type 4: Uses Digital Technology Analytically
20-30	1 (0.03)			1 (0.03)	
30-40	1 (0.03)			1 (0.03)	
40-50	6 (0.17)			4 (0.11)	2 (0.06)
50-60	11 (0.31)	1 (0.03)	7 (0.19)	3 (0.08)	
60-70	12 (0.33)	2 (0.06)	2 (0.06)	6 (0.17)	2 (0.06)
70-80	3 (0.08)	1 (0.03)	2 (0.06)		
80+	2 (0.06)	2 (0.06)			
Total	36	6 (0.17)	11 (0.31)	15 (0.42)	4 (0.11)

⁵ The bracketed values in Tables 1 to 4 are the proportions of the number of participants from each sub-category compared to the total number of participants in the sample.

It can be seen from Table 1 that there is some age effect where older producers are less likely to be computer literate. As expected, low levels of usage are particularly apparent in participants seventy years of age or older. However, the age effect is not strong enough to suggest that an individual of a particular age would or would not use a computer competently. As can be seen, a high proportion of participants (67%) in the 60-70 year age bracket for this research were classified as Types 3 and 4 because they extensively use a computer, suggesting that another influence on uptake may be present.

Table 2: Simple Literacy Breakdown by Gender

Gender	Number of Producers	Number of Producers in Classification			
		Type 1: Little or No Use of Digital Technology	Type 2: Simple Linear Model or Rote Processes	Type 3: Socially Interactive or Exploratory	Type 4: Uses Digital Technology Analytically
Women	9 (0.25)		3 (0.08)	5 (0.14)	1 (0.03)
Men	27 (0.75)	6 (0.17)	8 (0.22)	10 (0.28)	3 (0.08)
Total	36	6 (0.17)	11 (0.31)	15 (0.42)	4 (0.11)

A gender effect can be viewed in Table 2, where all the participants who are women used a computer although competency for these women varied between Types 2 to 4. Overall the proportion of women participants using a computer is higher than for men participants with two-thirds of women being classified as Type 3 or 4 compared to under half of the men. The differentiation between women and men using a computer can be put down to cultural differences. Participants reported that the labour structure of some enterprises was orientated around gender and that this meant that women were more likely to be using computers. In these enterprises where men were more production (field) orientated, women often carried out many of the office tasks required. By undertaking office tasks, computers are used repeatedly over time and the potential to build further knowledge of digital (computer) technology is enhanced. In regard to innovation and training, in general, participants reported that there was a culture where men are reluctant to appear unknowledgeable in front of their peers. Despite computers and software technology being applied increasingly in the activities of the production system, the way in which these artefacts are implemented is culturally influenced. The greater willingness of women to engage

in processes either primarily for learning or incidentally contributing to it, through practice, socialising, or collaborating with knowledgeable others is leading to greater uptake and competency.

However, the patterns due to age and gender trends within the sample are not present when a complementary technology is taken up and used in a sustained fashion within the enterprise. Phenotypic or genotypic breeding (PGB) technologies,⁶ such as BREEDPLAN⁷ or GeneSTAR,⁸ have been selected as examples of complementary technologies because they are generally implemented over a substantial period of time within the enterprise and, as Pruitt, Gillespie, Nehring and Qushim (2012) argued there was significant complementarity between the uptake of breeding technologies or management practices, and the use of computers or the internet in an enterprise. Complementarity between PGBs and digital technologies entails that if a PGB is implemented then the benefit from implementing a digital technology is likely to be greater or require less effort to implement. The willingness to improve skills to record data is linked to a central production activity: scoring of animal attributes. As it is believed the skills will be learnt and used, the expected cost is lower than if the learning of the skill was not tied to a production activity. The repetitive use over time increases the net benefit. A complementarity between a central production activity and the use of digital technology provides a substantial incentive to gain the digital literacy even though there is an initial cost to the enterprise.

To illustrate this, the sample is decomposed by age (Table 3) and gender (Table 4) between stronger usage (Types 3 and 4) and weaker usage (Types 1 and 2) with those using PGBs separated, to show that age and gender trends are present, but among those using the PGBs these trends are not followed because stronger capabilities have been learnt. The 'stickiness' of using other digital technologies is reduced and the capability to learn the necessary skills is increased through complementary knowledge. While the causation cannot be demonstrated because

⁶ These products are packaged computer generated statistics which are processed externally to the beef breeding enterprise by a commercial provider. Data from samples or measurements sent by the producer are processed by the commercial provider. The statistics produced are designed to assist the producer to make decisions about which animals have particular traits that are believed to be desirable. While use of a computer by the breeder is not essential, the analysis is digitally generated and these participants in this study used a computer to send or receive statistics on their stock.

⁷ BREEDPLAN is a joint program marketed by the Agricultural Business Research Institute (ABRI) that provides statistics called Estimated Breeding Values (EBVs) which indicate the future value of an animal's progeny.

⁸ GeneSTAR is a genetic marker technology provided by Zoetis Genetics Australia that identifies the tendency that an animal will possess a characteristic of interest from its genes.

of the length of time for implementation that has taken place, the correlative effects are present.

Table 3: Breakdown of Age and Literacy with Complementary Technology Usage Isolated

	Number of Producers	Years of Age						
		20-30	30-40	40-50	50-60	60-70	70-80	80+
Uses PGB technology	12 (0.33)			3 (0.08)	3 (0.08)	6 (0.17)		
Type 1 and 2 that does not use PGB technology	17 (0.47)				8 (0.22)	4 (0.11)	3 (0.08)	2 (0.06)
Type 3 and 4 that does not use PGB technology	7 (0.19)	1 (0.03)	1 (0.03)	3 (0.08)		2 (0.06)		
Total	36	1 (0.03)	1 (0.03)	6 (0.17)	11 (0.31)	12 (0.33)	3 (0.08)	2 (0.06)

From Table 3, the age effect becomes much more pronounced when the complementary technology users are removed from the rest of the data. The high proportion of producers 60-70 years of age in Table 1 is shown to comprise of either genotypic or phenotypic breeding technology users. The age trend amongst users of the technology also appears to be reversed, suggesting that age is not as strong an influence on computer literacy if learning and cost conditions are conducive to the use of digital technology

Table 4: Breakdown of Gender and Literacy with Complementary Technology Usage Isolated

	Number of Producers	Men	Women
Uses PGB technology	12 (0.33)	7 (0.19)	5 (0.14)
Type 1 and 2 that does not use technology	17 (0.47)	14 (0.39)	3 (0.08)

Type 3 and 4 that does not use PGB technology	7 (0.19)	6 (0.17)	1 (0.03)
Total	36	27 (0.75)	9 (0.25)

Whether complementarity in technology overcomes gender influences is not clear in Table 4 because the sample size for women is relatively small with more women using the complementary technology than not. However, of the women who did not use PGB technologies, a greater proportion did not use a computer extensively in their enterprise. Of the male participants, the proportions of non-users of computers has increased towards Type 1 and 2 users suggesting that, for men, the use of a complementary technology does increase the rate of use of digital technology overall. With caution about low sample sizes, these results suggest gender may not be a strong hindrance to development of literacy either. The data favours the hypothesis that complementarities reduces the ‘stickiness’ of digital technology in spite of culturally created gender effects but needs to be strengthened with higher sample sizes to be more conclusive.

The value of using digital technology and the cost of developing digital literacy were prominent in the minds of producers and influenced the decisions regarding improving their digital skills. Costs were perceived as a barrier to the establishment of a suitable literacy, but once constructed, the capability granted the producer a reduction in costs. Producers classified in Types 3 and 4 reported that being able to search for information reduced costs through almost costless replication of information, improved timeliness and coordination of delivery. More broadly the perceived value of software and online information in terms of quality was discussed by participants within all literacy types. The veracity of online information was a concern to a number of producers citing that often authorship, trust of source and evidence supporting information was lacking. The limitations of digital information as measurement or modelling of the real world meant that often producers would use such information as a guide rather than basing decision-making on it alone. In a small number of cases, social norms caused the producer to maintain usage but shortfalls in the accuracy of information were a substantial concern, suggesting that the value in the technology was not in its contribution to the enterprise, but in how other producers perceived the value of produce.

A substantial proportion of producers (17%) within the sample had no effective computer literacy. This did not mean that many had not attempted to learn but that a producer’s initial efforts may have failed. These producers were experienced in other aspects of production but inexperienced in the thinking needed to use

hardware or, if some mastery was obtained, software then presented a challenge. Frustration of not being able to solve a problem impeding use became a barrier to attempting further use and acquiring literacy. However, participants with low levels of literacy had metacognitive understanding of learning, suggesting that the individual's activity was purposeful and that it is a matter of increasing capability to bring knowledge to bear on the nuanced situation. Type 1 users may have underestimated the required investment to implement after seeing potential benefits but did not understand the commitment needed in terms of time and cost in their enterprise, for example, where a producer bought a desktop computer, but after initial interest, discontinued use.

In contrast, comments from some producers in Type 1 classification who had unsuccessfully attempted to implement digital technology, suggested that they did not see the potential or the immediate benefit. Such comments point to a fundamental barrier to adoption of digital technology. For example:

I know the information can be put into the computer, but I can do everything the same with a pencil (Participant BT)⁹

indicates that the perceived benefit is not considered to be high and nor are the potential future benefits of building a literacy that would enable other uses to be explored.

When a producer has to act outside their knowledge capabilities to achieve implementation, it is through social collaboration that the necessary concepts for implementing digital technology could be placed within an individual's zone of proximal development. The knowledge applied by some producers to understand computers or digital information does not support interaction with digital technology: instead this knowledge is based on other competencies that the producer has developed. One producer, Participant VA, exemplified this when attempting to purchase a desktop computer. This person applied highly reasoned thinking to the task but did not succeed without assistance in purchasing the computer. The participant could see the need to purchase a screen and a printer, because of the physical utility of seeing information and printing the documents that these components provide, but did not see the requirement for the system case. As such, the barrier to implementation was a factual knowledge capability, requiring a change in the producer's understanding to gain competency. Acting in isolation, the producer did not have the required understanding to start using digital technology, but with help from another knowledgeable person was able to develop relevant knowledge to accomplish the tasks.

⁹ In this research a two letter code has been assigned at random to each participant to preserve anonymity.

The zone of proximal development extending the capabilities of a producer can be witnessed from the interactions between a producer and their advisors. Producers in Type 2 category, which represented 31% of the sample, use digital technology for a small range of limited processes that they have achieved themselves, perhaps following suggestions from others, such as looking at a favourite website or provision of an URL. However, experimentation beyond this basic level is limited and learning does not proceed beyond this without technical assistance. In such cases of limited knowledge, implementation of digital technology is achieved through social collaboration in person, where the task is presented with the aid of a knowledgeable person guiding the producer through the task. New websites and online tools may be introduced, enabling important tasks for the enterprise, such as the purchase of stock, to be undertaken digitally. Participants WF and GM (differing in age by 20 years) were introduced to AuctionPlus, an online auction system for buying and selling cattle through real-time transactions. This represents use of more advanced concepts than previously attempted. The participants gained knowledge when they were assisted, showing that age demographic is not a limitation for these producers to undertake the task, but the learning required conducive conditions for them to achieve it and increase implementation of digital processes within their enterprises. At a more advanced level of literacy (Type 3), participants reported extensive use of digital technology as a communication device for accessing and recording information. Frequently platforms discussed were Facebook, Microsoft Excel, Microsoft Word, MYOB, QuickBooks, Google and email as well as agriculturally orientated websites from suppliers, service providers, breed societies, government departments and industry bodies. Many of these producers have their own websites to market their products or promote their political organisation, and are active in their online routines. Although their use includes software specific to agriculture, such as stock recording packages, the levels of information generation and analysis within the business tended towards non-digital means, such as visual inspection rather than by measurement using instruments. These producers reported a disparity between the acquisition of information digitally from an external source and the generation of information internally. They were critical in evaluating the information acquired, but substituted other methods information search and record keeping with the use of platforms not specific to agriculture. The lower use of agriculture specific software, tools or equipment to generate and analyse information arises because of cost and issues of perceived information quality.

Participants classified as Type 4 are differentiated from others by their greater generation and analytical use of information, especially from within their own enterprise. Compared to producers classified as Types 1, 2 or 3, these producers based a greater proportion of decisions on measurements taken and analysis using software and tools instead of using experiential and intuitive means of judgement

and decision-making. Each producer in the Type 4 group used PGBs and demonstrated detailed knowledge about the construction and use of these technologies and similarly provided opinions on the benefits and shortfalls of digital technologies they had encountered. For them, learning processes are less of a barrier to uptake, and emphasis is placed on the potential value to the enterprise and the reliability of information generated. In general a high level of innovative effort was displayed with a willingness to continue innovating in digital areas, even when previously implemented technologies may not have delivered the expected benefits.

The increased availability of digital instrumentation, software, and online tools provides opportunities to make production more effective if the information generated can be analysed. The results of this research show that learning processes and cost or benefit to an enterprise explain the uptake of digital technology. The use of PGBs is correlated with a higher level of uptake and that learning and cost effects are relatively strong influences compared to age and gender characteristics. From the accounts provided by participants, learning and cost factors are not independent but co-evolve to reinforce the outcomes of each other.

A Simple Model of Induced Innovation

In accordance with the accounts provided by participants, a model based on David's (1975) theory of induced innovation explains the observed 'sticky' (von Hippel, 1994) cost and learning effects on digital technology implementation. The David (1975) model suggests two points of interest for small and medium beef cattle enterprises: firstly, that localised quasi-neutral technical improvements lead to wider spread improvements in production processes through spill-overs; and secondly, that the processes of learning will be path-dependent, leading to heterogeneous technical progress by an enterprise. The first point, that localised technical improvements will lead to spill-overs into other production processes, is inconsistent with the findings in Noble (2013): learning from production processes did not lead to spill-overs where a producer could use the localised knowledge as complementary to generalised knowledge to generate alternative production processes. Instead, newly learned complementary knowledge generally built on existing localised processes. However, the second point that path-dependency, particularly created through an individual's learning, is present in small and medium beef cattle enterprises, is supported by the evidence in Noble (2013). A simple view of the induced innovation model with the inclusion of the learning of localised processes is shown in Figure 1 below.

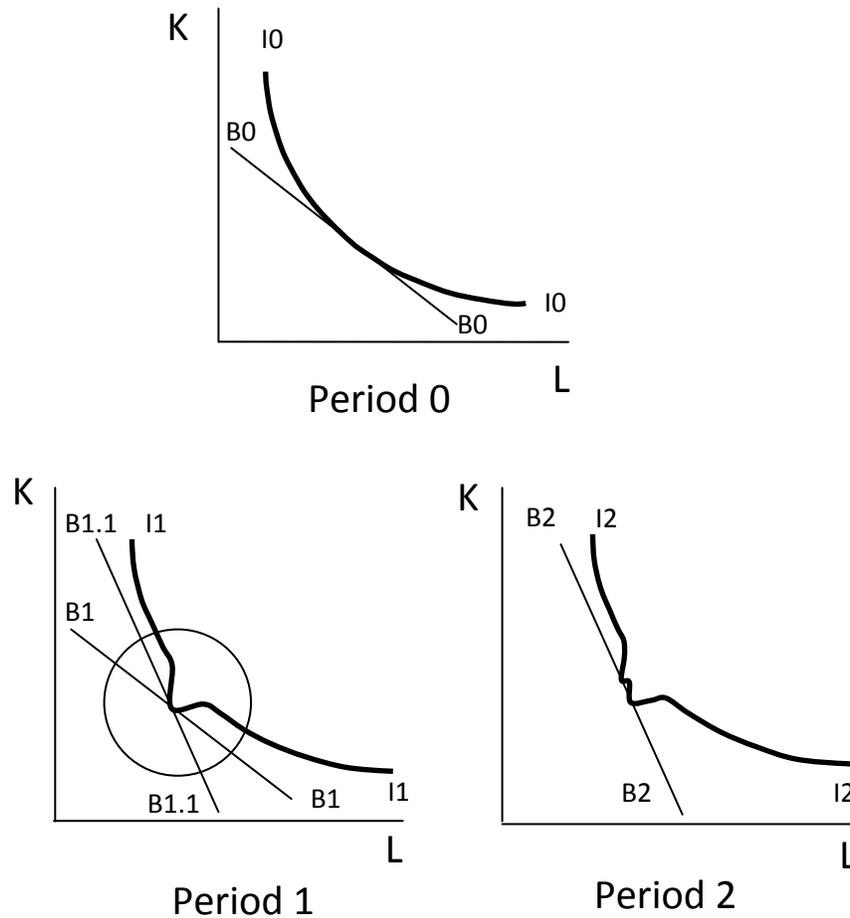


Figure 1. Model of Induced Innovation with Localised Learning

The diagram above demonstrates an induced innovation model with, for simplicity, production using only two inputs, capital (K) and labour (L). The set of three isoquants, I0, I1 and I2, are in time sequence showing the evolution of the shape of the isoquants. Initially, a regular isoquant is assumed at Period 0 and is tangentially touched by the budget curve B0, indicating the producer's best choice of production inputs between K and L. In the next time period (represented by isoquant I1), the producer has learnt more about their production using that particular process, learning-by-doing (Arrow, 1962), and relative to other production processes along the isoquant (I1) the producer can consequently create the same level of output with less resources. Unlike the David (1975) model, the 'bump' (highlighted above by the circle) is maintained for small to medium beef producers because spill-overs into alternative production processes do not occur leading to irregularity in the isoquant shape particular to that enterprise's actual

production. The effect of learning-by-doing is that in addition to a reduction in the levels of inputs required for a level of output, it creates a tendency to continue using that production method. A change in the budget curve from B1 to B1.1 affects only a minimal change in the composition of production inputs. Finally in Period 2, after the change in budget from B1 to B1.1, the isoquant I2 exhibits additional irregularity due to further learning. The unique shape of an enterprise's isoquants as they evolve provides a way to answer Ruttan's (2002) challenge that path-dependency be incorporated into induced innovation models. It also suggests that unless there is substantial change in prices that shifts the point of tangency away from the area of the 'bump', production processes will stay quite close to the original point where previous learning has taken place. Likewise the disrupted convexity of the isoquant at the bump means that some combinations of inputs near it are unlikely to be used.

To incorporate the capability side into the modified model, innovation potential curves (IPCs) (Ahmad, 1966) are placed to distinguish where feasible production points exist, as shown in Figure 2. The conception of IPCs is modified from Ahmad's original design so as to map an enterprise's technical capabilities to produce based on the individual producer's knowledge rather than the beef cattle industry's technical capability based on all knowledge in the industry.

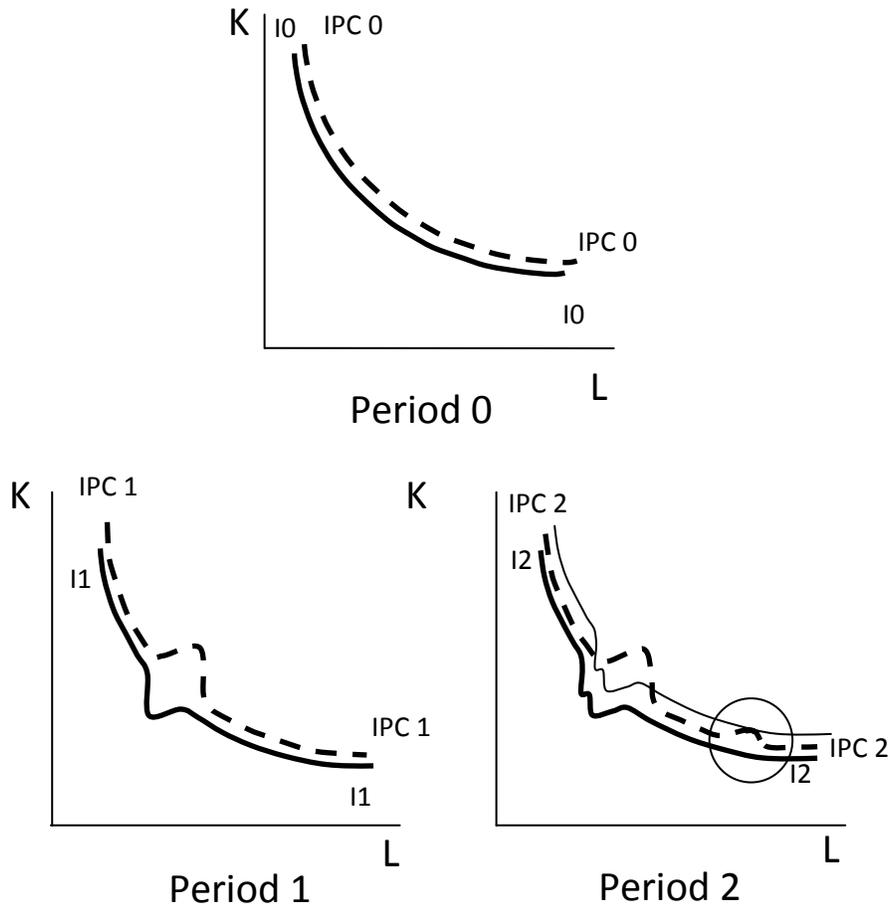


Figure 2: Model of Induced Learning with Innovation Potential Curves

In Figure 2 the innovation potential curves showing the producer's technical capabilities are dashed lines and the 'bumped' isoquants showing production with particular input combinations and the effect of learning during production are solid lines. The IPCs lie slightly beyond the isoquants, I_0 , I_1 and I_2 , where production is currently undertaken. Similar to the isoquants, the IPCs have a bump where current production takes place. The bump is concave to the origin (appearing reversed to the bump on the adjacent isoquant) because the producer is more knowledgeable in the processes they are currently using and can innovate to a greater extent using that knowledge if they use a process based on their previous process but with the innovation included. Through the bumps of isoquant I_1 and IPC_1 coinciding, it can be seen that using processes similar to current production, a producer can achieve a higher level of benefit through innovating; they receive both a capability and a cost benefit. If the producer were to choose an entirely

different production process than the benefit of the learning (which caused the bumps) is forgone. The lack of spill-overs suggests that a new production position in terms of the capital to labour input combination would remain hypothetical. Consider in Period 2, what happens if the producer receives assistance in the form of social collaboration to develop a new process for the enterprise. This will cause a new bump on IPC 2 because the producer's ability to innovate is increased (as shown in the circle). However, the benefit in terms of cost on isoquant I2 is not present. The new process would provide some benefit but not as much as continuing to use the original production process.

From this model, a producer's choice to maintain current production processes is rational and there is a possibility of the production system becoming entrenched. Favourable learning conditions, such as collaborating with an advisor, will provide some incentive to change, but the cost side needs to be taken into account as well to explain innovation. The empirical results show that an induced innovation effect is present where an improvement in learning leading to greater development of digital literacy, and changed costs will lead to greater potential for development of the enterprise through use of digital technologies. In this study, only four producers out of the thirty-six within the sample were using digital technology to generate information (Type 4), suggesting that these are barriers hindering other successful producers from developing this capability. These barriers are comprised of cost and learning factors. Each of these four producers classified as Type 4 has a lengthy background in building these analytical skills indicating that the cost may be substantial and that there is a requirement of concerted learning over time to develop this capability.

Conclusion

The evidence from the participating small and medium cattle enterprises of this research suggests the influence of learning and cost effects are present as a melange rather than providing a clear cut distinction that aids analysis. Repeated collaboration with more knowledgeable persons is required for many producers to gain the necessary skills to use digital technologies competently. The underlying population of small and medium beef cattle producers is heterogeneous, which means the accounts of participants and their use of digital technology vary from a strict compliance with the generalisations of taxonomies, learning theory or cost based implementation models. This implies that if increasing the use of digital technologies among small to medium beef cattle producers is to be pursued as a goal, success is more likely if individual producers are supported as they learn how to use a technology, and if it is applied in their production system so as to create complementarities that reduce costs with their existing processes.

Age and gender characteristics do influence the likelihood that a producer implements a digital technology, but it is found that under conditions of social collaboration between a producer and another, uptake of digital technology can occur to the extent that a producer will use it as a communication or storage device. It is argued that such collaboration will continue the trend of small and medium producers to digitally communicate or store information, but the analytical knowledge possible with digital technology use will be underdeveloped, and instead, for the time being, will continue to be built on information assembled externally to the enterprise.

In enterprises where PGB technologies have been used, a higher level of digital technology, particularly online content, software and online services was employed in the enterprise. Findings show that a correlation between patterns of usage is present but not causality, leaving open the possibility that the influence is bi-causal or possibly reversed. There are other influences which may accelerate the uptake of digital technology, such as legislation which requires action within which producers become familiar with the operation of various databases and websites. Perhaps increases in uptake are due to improvements in the quality of information available to producers more than improvements in the hardware available for use. Such flow-on effects increase the use of digital technology beyond that which would have occurred otherwise.

While ABS (2000; 2001; 2004; 2005; 2006; 2009) research shows a general increase in the usage of computers and the internet across agriculture, differing levels of uptake have been achieved amongst individual industries. Further work needs to be undertaken to determine whether the level of sophisticated usage for other industries is also low, or whether that is more specific to small and medium beef cattle enterprises.

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