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Behavioral Patterns of Agents in the Transfer Processes of (Internet of Things) IoT Technologies in Agricultural Production Chains

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Abstract: The transfer of technologies in the productive chains of the agricultural sector plays a key role in achieving optimal levels of productivity and competitiveness in local, regional and international markets. The developments in the Internet of Things (IoT) have contributed to better management of soil, nutrients, water, pests and to implement methods of collection, storage, transformation and transport of agricultural products to the market. However, the existence of technology by itself does not guarantee its impact on the productivity or competitiveness of a sector, a region or a country which shows a gap between the development of this type of technology and the capacity of adoption by the agricultural producers. The transfer of technology is a process that involves agents interacting in a network under an institutional infrastructure such as generation, diffusion and use of technology. It can also be the economic, legal, cultural and social factors that affect the decision to adopt it or not a technology. The purpose of this review is to provide elements for the understanding of the technology transfer processes in productive chains from an approach based on behavioral patterns. These patterns emerge in a dynamic network of agents involved in technological innovation systems. The results of this study could potentially boost the design of strategies in science, technology and innovation policies at a national level.

Key words: Technology transfer, behavioral patterns, aptitude, perception, internet of things, agricultural food chain

INTRODUCTION

The increase in population, food security and urban concentration have increased the pressure to improve productivity and develop best practices in primary production (Manning, 2013; Tey and Brindal, 2012). It is regarded that the adoption of emerging technologies (e.g., IoT, big data, machine learning) in agriculture is a key element for overcoming poverty and improving productivity in agricultural areas that develop self-consumption and marketing activities, oriented to a structural transformation of the rural sector (Swinnen and Kuijpers, 2019).

Knowledge (tacit-explicit) and technology are recognized internationally like sources of productivity and profitability in agricultural systems (Mysore, 2015). In recent years, the developments on the IoT has contributed to better management of soil, nutrients, water and pests and more efficient methods of collection, storage, processing and transport of agricultural produce to the market (Sankat *et al*., 2005).

However, it is recognized that there are noticeable difficulties throughout the process of technology transfer since it requires deep participation of different agents (transferor-transferee) to transfer tacit knowledge (Lipinski *et al*., 2008). The agents (institutions-actors networks) play a central role in relation to different resources and the value is given to the beneficiary farmers (Chandra *et al*., 2018), therefore, there is an interconnection between the social entity and the institutional entity through knowledge and technology (Chandra *et al*., 2018).

Institutions, networks and actors involved in the technology transfer process might be studied from the perspective of the technological systems, understood as a dynamic network of agents that interact in a specific economic/industrial area under a particular institutional infrastructure involved in the generation, diffusion and use of technology (Carlsson and Stankiewicz, 1991). Some of the problems associated with the transfer of innovations or technologies evidence the need to have a complete view of the system in which the technology will be introduced (Carlsson and Stankiewicz, 1991). Technology itself cannot be assumed as tested and used effectively by default (Carlsson, 1994).

The adoption of technology by farmers is dominated by these factors different models of technology acceptance such as Technology Acceptance Model (TAM) have been proposed to understand the drivers of human behavior (Verma and Sinha, 2018). The intention of a person to behave in a certain manner is essentially, based on two factors: attitude and perception (Rehman *et al*., 2007). Models such as the

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TAM postulate two particular beliefs, ease of perceived use and perceived utility (Far and Rezaei-Moghaddam). Nevertheless, different investigations confirm that TAM needs to receive additional variables to provide an even more robust model (Adrian *et al*., 2005; Far and Rezaei-Moghaddam, 2017).

Factors such as the environment of the transfer and those related to the transferor and transferee have a direct relationship with the attitude and perception that in turn may influence the behavior patterns of a technology's transfer-adoption. The perception can be seen from the perceived relative advantage and is used to evaluate innovation increases. The benefits of the technologies that are intended to replace must outperform in order to not lose farmer's investments (Tey and Brindal, 2012). An attitude is defined as a belief or negative or positive evaluation that a person has towards a goal (Ajzen, 2005). A positive attitude can play a major role in influencing the transfer of appropriate technology from the organization (Kumar *et al*., 2015a, b).

The impact of these factors, both internal and external, on the behavior patterns of the agents involved in making decisions about the transfer-adoption of technology have not been studied extensively from a systemic approach (Verma and Sinha, 2018). The reasons for perception and attitude are important on adoption decisions (Adrian *et al*., 2005) as they allow to demonstrate the relations between agents their exchange of knowledge, technologies and the emergent phenomena product of this interaction.

Selection of the appropriate technology, the identification of barriers and facilitators and the prioritization of a suitable provider are critical stages for the development of successful technology transfer processes (Aliakbari *et al*., 2015), the speed of transfer will depend on the use of appropriate models that contemplate the systemic dynamics generated among the agents of the technological system. The result of this speed is the creation of gaps between technological development and technology adoption (Chandra *et al*., 2018).

Conceptual framework

Technology transfer: Technology transfer has been defined as the process of adaptation in which a technology, knowledge or information developed by a particular organization for a particular purpose is applied to different purposes in different areas and by different organizations (Winebrake, 1992). Nowadays, small and medium enterprises require efficient processes of technology transfer to improve their productivity and competitiveness in highly uncertain and interconnected markets (Chehrehpak *et al*., 2012; Lee *et al*., 2012) and the creation of new markets. Main stages of technology transfer strategies (e.g., identification, evaluation and prioritization) are complex due to decision-making problems related to the stakeholder involved, qualitative-based evaluation and lack of precision an certainty in the decision-making processes (Dinmohammadi and Shafiee, 2017).

Transferor and transferee: Transfer of technology takes place in a scenario where three elements are protagonists; the technology that is in the center, the transferor and transferee. This complex structure of generators, diffusers and users of technology that participate actively in the process without any restriction or coordination makes the efficiency of the process difficult to evaluate, so that, failures can occur due to organizational or cultural features according to the complexity of technology (Lai and Tsai, 2009).

A transferor is the owns the knowledge and the beneficiary or claimant is called the transferee, however, it is assumed that the simple fact that both exist it makes the transfer is done naturally and that communication channels and other elements are not needed (Khabiri *et al*., 2012). More complex the technology, the greater the level of cooperation between the agents is required in order to improve the use of the same (Chen, 1995), on the other hand, the attitude and aptitude of the transferor and the transferee and the training services can support the transfer process, since, a positive attitude and the acquisition of knowledge can lead to success in the process (Chen, 1995; Diaz-Diaz *et al*., 2006).

A theoretical framework of technology acceptance models: The specialized literature presents several theoretical models in the field of dissemination and acceptance of information technologies which are based on the discipline of sociology in the studies carried out by (Rogers, 1983). The researcher include the Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Innovation Diffusion Theory (IDT), Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) (Far and Rezaei-Moghaddam, 2017).

Each of these models postulates variables that try to explain the principles on which the behaviors around the adoption decisions (or not) of technology from the side of the transferee are established. The Theory of Reasoned Action (TRA) is considered useful for the prediction of human behavior in many domains (Bakhsh *et al*., 2017; Fishbein and Ajzen, 1995).

Theory of the Diffusion of Innovation (IDT) has been applied to study the innovations of both agricultural and business systems (Pedersen and Lind, 2017). It has a

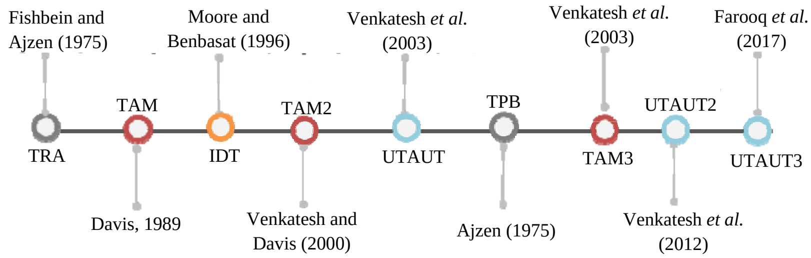

Fig. 1: Time line theoretical models of technology acceptance, researcher

comprehensive variety of features adapted from other models that provide a strong predictive support major in the study of the acceptance of technology (Moore and Benbasat, 1996).

TAM was proposed by Davis (1989) which is an extended version of TRA. TAM is a model that has good explanatory power, specially, designed for the domain of information technologies and has a widely accepted conceptualization (Bakhsh *et al*., 2017). TAM is based on two variables (perceived utility and ease of perceived use) that attempt to explain the intention of behavioral use and the actual use of the system.

Based on TAM (Venkatesh and Davis, 2000) develops TAM2 that seeks to improve the development of technology transfer strategies by the users, understanding mainly the drivers of perceived use (Venkatesh and Davis, 2000). In the same fashion (Venkatesh and Bala, 2008) broadens the spectrum of understanding of the model and raises the TAM3 that aims to improve the understanding of the determinants of perceived ease of use.

UTAUT is a tool for managers that contribute to a better understanding of the drivers of behavioral intention to adopt and use new technologies than other theories and models (Venkatesh *et al*., 2003). The main variables explaining the intentions of behavioral use are expectation of performance, the hope of effort, facilitating conditions and social influence. In the same way, the model involves age, experience and gender as predictors since it allows focusing on organizational and social contexts to the adoption of technology Fig. 1.

An extension of the UTAUT is proposed by (Venkatesh *et al*., 2012). The main difference of the UTAUT2 is that it includes variables such as hedonic value, price value and habits and tries to understand the user behavior not from the organization but also from the consumers as users of the technology. A further evolution of UTAUT2 is the UTAUT3 proposed by Farooq *et al.* (2017). Unlike the UTAUT2 it involves a variable called "personal innovation" understood with the predisposition to experiment and adopt new technologies.

The Theory of Planned Behavior (TPB) considers the attitude as one of the influences of the behavioral intention which is the latent and unobservable construction that immediately precedes the behavior (Azjen, 2005; Naspetti *et al*., 2017). However, in the TPB model, subjective norms contribute, along with attitudes, to influence intentions (Naspetti *et al*., 2017). The following are the strategic decision variables addressed in the theoretical models of technology acceptance:

Internet of things IoT: IoT is pondered the third wave of the global information industry after computing and the internet (Chen *et al*., 2014; Wang *et al*., 2014). The "Things" are everyday life devices which communicate data obtained by the actuators to virtual addresses or to each other through gateways no supervision. The IoT also includes the hardware, software and network infrastructure services for "things", guaranteeing their interoperability.

Among the fields of application of the IoT are transport, smart grids, asset and inventory tracking, the automation of cities and finally, one of the sectors with the highest potential that of agriculture. Traditional agriculture is in a process of change towards modern agriculture in which IoT technology plays a fundamental part. This can be incorporated into crop management such as real-time monitoring of food traceability, storage and transportation of products, early diagnosis of pests and diseases and other potential fields of application (Duan *et al*., 2014).

IoT allows going from a crop management per hectare to one management per square meter where the environmental parameters can be taken for each plan or even for each leaf, overcoming the limitations that generated crop losses and, taking agriculture to another level (Chen *et al*., 2014).

It is expected that the application of IoT technology will greatly reduce the costs of agricultural production and increase the economic benefits of the activity (Chen *et al*., 2014). IoT would allow the producers and processors of the country to reach competitive capabilities that take the sector to another level within the national economy.

Iot structure: The internet structure of things IoT is divided into 4 layers as shown in Fig. 2, the sensor layer is composed of any variety of devices or a sensor that captures some data related to an important variable of

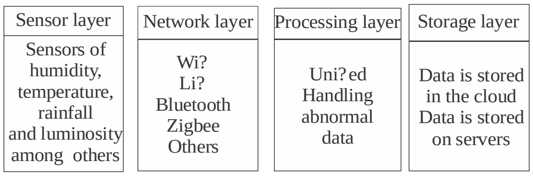

Fig. 2: IoT structure model, Adapted from Wang *et al*., 2014)

measurement (e.g., humidity sensors, temperature). The network layer or transport receives the signals captured by the sensors in various types of protocols and converts them into bytes. The processing layer is the platform where data is temporarily transported to be unified and debugged. Finally, 4 the storage layer where the processed data is stored to move to the big data stage, this storage can be in the cloud or in servers according to the defined architecture.

Revision planning: In order to respond to the defined objective, a systematic review of the scientific literature is proposed, following the steps described below. The definition of the search keywords associated within the research area and then the search was done in the SCOPUS database. Three groups of keywords were created, these are shown in Table 1.

Keywords for the search

Group 1: "Transfer of technology; "technology transfer"; "technology appropriation"; "technology adoption"; "technology choice"; "technology appropriation."

Group 2: Agriculture; husbandry; crop; farm; cultivation.

Group 3: Perception; attitude.

Based on these groups of words a query or search algorithm was designed for the SCOPUS database, a period of 10 years was considered and the search fields selected for the recovery of the scientific literature were Title (Title), Abstract (ABS), Keywords (KEY) and publication period (PUBYEAR).

Query (((Group 1) AND (Group 2)) AND (Group 3)): TITLE-ABS-KEY ("transfer of technology") OR ("Technology transfer") OR ("technology appropriation" OR ("technology adoption") OR ("technology choice") OR ("technology appropriation") OR ("technology Acceptance"))) AND (TITLE-ABS-KEY (("husbandry" OR ("crop") OR ("farm*") OR ("agriculture") OR ("cultivation"))) AND (TITLE-ABS-KEY (("percept*") AND ("attitud*"))) AND PUBYEAR>2008.

In order to ensure the quality of the results, a manual review of each of the papers was carried out and only those that met the following criteria were selected.

Table 1: Variables or key constructs of the theoretical models of technology acceptance

Adoption model/key decision variables	Reseaercher
TRA	
Attitude toward behavior	(Fishbein and Ajzen, 1975)
Subjective norm	
IDT	
Image	(Moore and Benbasat, 1996)
Relative advantage	
Complexity	
Compatibility	
Triability	
Observability	
Attitude	
TAM	
Perceived ease of use	(Davis, 1989)
Perceived utility	
TAM2	
Subjective norm	(Venkatesh and Davis, 2000)
Image	
Job relevance	
Output quality	
Results demonstrability	
TAM3	
Computer self-efficacy	(Venkatesh and Bala, 2008)
Perceived external control	
Computer anxiety	
Computer playfulness	
Perceived enjoyment	
Objective usability	
UTAUT	
Performance expectancy	(Venkatesh *et al*., 2003)
Effort expectancy	
Social influence	
Facilitating conditions	
UTAUT2	
Hedonic value	(Venkatesh *et al*., 2012)
Price value	
Habits	
UTAUT3	
Personal innovation	(Farooq *et al*., 2017)
TPB	
Attitude toward behavior	(Azjen, 2005)
Subjective norm	
Perceived behavioral control	

- Have a direct relationship with the central topic of study (transfer of IoT technology in agriculture)
- Provide clear information about the theoretical model of acceptance of the technology used

Based on this criterion, the volume of results is reduced and the quality of the sources that can be used to fulfill the stated objective is guaranteed. These inclusion criteria were carried out in two stages, initially, reviewing the summary to verify compliance and keeping them on a waiting list to subsequently make a complete reading to decide whether to keep them or discard them. The analysis of the prioritized ones was carried out manually.

RESULTS AND DISCUSSION

The protocol described in the previous section was used to search, select and analyze scientific documents.

Table 2 Application of theoretical models of the acceptance of technologies associated with the transfer of IoT technology

Researcher	Framework of analysis	Mathematical model	Kind technology	Country
(Jayashankar *et al*., 2018)	Technology Acceptance Model (TAM)	Structural equation modeling	Agriculture (IoT technologies)	United States
(Tamayo *et al*., 2010)	Technology Acceptance Model (TAM)		Agriculture (Wireless sensor networks)	Mexico
(Ullah *et al*., 2018)	Technology Acceptance Model (TAM)		Agriculture (IoT Technologies)	Australia
(Far and Rezaei-Moghaddam, 2017)	Technology Acceptance Model (TAM)	Structural equation modeling	Agriculture (Precision farming)	Iran
(Adrian *et al*., 2005)	Technology Acceptance Model (TAM)	Structural equation modeling Analysis of Moment Structures (AMOS)	Agriculture (Precision farming	United States

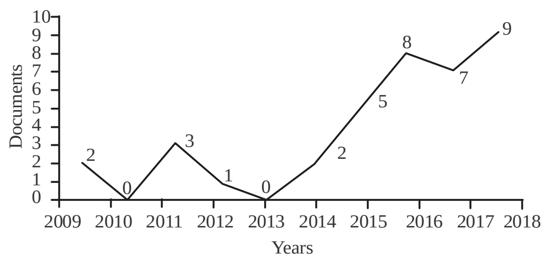

Fig. 3: Publication overtime for the period 2008-2018, SCOPUS

For the search process, the algorithm defined in Table 1 was used in the SCOPUS database, a total of 37 scientific documents related to the search topic were obtained, of which five were selected.

As shown Fig. 3, the scientific production in the area of interest for the period 2008-2018 presents a positive slope which indicates a growing interest in the development of this area. The countries that have contributed most to this generation of knowledge are Great Britain (9), United States (8), Australia (6) and Holland (6).

The institutions that concentrate this scientific production are the University of Gent, Scotland's Rural College and Wageningen University with 4, 4 and 3 articles, respectively, the following are the results of the in-depth review of the most relevant publications.

The five selected papers were reviewed in depth in order to identify the application of theoretical models of the acceptance of technologies associated with the transfer of IoT technology (Table 2).

In all cases, the structural equations model is used to evaluate the correlation variables of the theoretical model of technologies acceptance for empirical validation. It is evident that trust has a positive relationship with the perceived value of adopting IoT technology (Jayashankar *et al*., 2018). Aptitude and perception strongly determine the attitude of behavior. Through an in-depth analysis, empirical validation showed that confidence attitudes towards the use of IoT technologies, perceptions of net profit, farm size and educational levels of farmers positively influenced the intention to adopt IoT technologies (Adrian *et al*., 2005; Jayashankar *et al*., 2018), the age of farmers is another factor that affects the IoT technologies adoption. Jayashankar *et al*. (2018) identified that older farmers prefer not to apply IoT technologies. Based on the results, the behavioral attitude is the most important determinant of the intention of the experts towards the use of IoT technologies (Far and Rezaei-Moghaddam, 2017). The deep knowledge of the technology, the understanding of the processes, the regulations and the success stories obtained by the farmers in the area are also determining factors in the adoption of this type of IoT technology (Ullah *et al*., 2018). A good understanding of technology, confidence in the use of these technologies and learning improves the level of confidence in farmers who in turn are more likely to adopt this type of technology (Adrian *et al*., 2005; Daxini *et al*., 2018) identified that the social effect of adopting an IoT technology can influence the intentions and behavior for decision-making whether the results of a group are favorable that is application pilots or demonstrations with a promising effect on others farmers to adopt IoT technologists when the results are positive.

The TAM as a construct used to study the attitude towards the use and the behavioral intention for the use of a technology, can limit the understanding of the phenomenon, since, the development of constructs that link other variables such as management could lead to a better understanding of motivations and capabilities of agricultural producers (Adrian *et al*., 2005).

A validation is needed for each agricultural chain to determine the barriers and drivers of the technology transfer, from the models of technology's acceptance. For developing countries, the geographical disparities deliver different barriers and strategies to be implemented in the transfer processes of emerging technologies.

The technology transfer model identified (Fig. 4) is one that contemplates both the barriers and limitations of the technology issuer, the broadcaster, the receiver, the technology, the socio-cultural and political aspects and

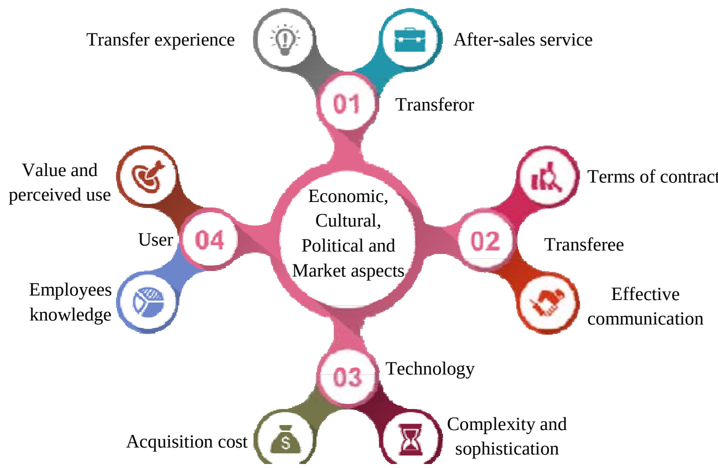

Fig. 4: Basic structure of technology transfer for IoT technologies in agricultural production chains researcher

the economic and social market. The above in order to guaranteeing an efficient process and that R&D investments do not turn into obsolete products that did not manage to be inserted in productive processes and improve the competitiveness of agricultural chains, due to minor limitations the user faced that forced him to abandon the technology and to keep working with their traditional process.

CONCLUSION

IoT technologies are gaining more traction in the agricultural sector by the multiple options presented in services and products that support decision making for farmers, in addition to the impact on productivity and efficient use of resources which in turn improves food security. Based on the findings, it is necessary to create policies or strategies that facilitate understanding among all actors in the technology transfer process, since, attitude, trust and perception is a key element for farmers adopting this type of IoT technologies.

Trust among the agents is one of the criteria that directly affects the perceived value (both monetary and non-monetary) (Jayashankar *et al*., 2018). So that, an efficient relationship between the transferor and transferee of the technology could improve the transfer and adoption process. Attention must also be paid to B2B relations, in order to expand the variables that affect the adoption of this type of technology, especially, in sectors such as agriculture (Jayashankar *et al*., 2018).

This is why research in this area of knowledge has been seeking to broaden the understanding of the transfer phenomenon from a global perspective of the process that includes both the transferor, the transferee and the intermediary of this type of technology. Research in this area has been developed, identifying that different factors can influence the technology transfer process. Investigations carried out by Adnan *et al*. (2017) have applied TPB and included other factors to explain the adoption behavior of agricultural technologies (Chandra *et al*., 2018) such as agro-ecological factors, socio-economic factors, institutional factors, information factors, behavioral factors, farmer's perception and economic factors (Adnan *et al*., 2017).

Under these circumstances, technology transfer then becomes a complex and difficult process (Lipinski *et al*., 2008) that includes the active participation of the agents and not a simple passive copy of the technologies of more advanced economies (Sankat *et al*., 2005). This includes factors related to economic aspects (Kumar *et al*., 2015; Kamal and Alsudairi, 2009), legal aspects of the appropriability of technology (Lee *et al*., 2010 related to the sophistication of technology (Lee *et al*., 2010; Ma *et al*., 2013; Nilashi *et al*., 2016), related to the market (Kumar *et al*., 2015; Kamal and Alsudairi, 2009), related to the transferor (Gupta *et al*., 2017; Ma *et al*., 2013; Tektas and Gozlu, 2008), related to the transferee and finally factors related to the transfer environment.

RECOMMENDATIONS

Regarding policy recommendations, some researcher suggest (Daxini *et al*., 2018) that an effort should be developed to guarantee technical support during the process of transfer of IoT technologies, since, this could improve the level of control over the application and use of this type of technology. Literature in the technical aspects of IoT is more numerous than the behavioral and attitudinal aspects. This indicates the need for more research in that field (Al Hogail and Al Shahrani, 2018), in addition, if the IoT technologies for the agricultural sector are specifically, taken into account, since, the scientific literature is scarce.

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