# DETERMINANTS OF AGRICULTURAL TECHNOLOGY ADOPTION BY SMALLHOLDER FARMERS IN DEVELOPING COUNTRIES: PERSPECTIVE AND PROSPECT FOR INDONESIA

## *Determinan Adopsi Teknologi Pertanian oleh Petani Kecil di Negara Berkembang: Perspektif dan Prospek untuk Indonesia*

**Suprehatin[1,2]**

[1]*Department of Agribusiness, Faculty of Economics and Management, IPB University, Bogor, 16180*
*Jln. Kamper, Kampus IPB Darmaga W4L5, Kec. Dramaga, Bogor, Jawa Barat 16680*
[2]*Center for Agriculture and Rural Development Studies, IPB University, Bogor, 16129*
*Telp. 0251-8629654, Fax. 0251-8629654*
*E-mail: suprehatin@apps.ipb.ac.id*

## ABSTRACT

The role of agricultural technology is important in developing countries. However, in many cases the adoption rate of modern agricultural technology by smallholder farmers is low. Therefore, a better understanding of agricultural technology adoption determinants is important as a major component of agricultural growth. This paper is a review and synthesize of the literature related to potential factors that may constrain or encourage smallholder farmer adoption of new agricultural technologies. The determinant factors influencing smallholder farmer adoption of new technologies in developing countries vary from study to study based on contextual applicability and specific local condition. There are four major typologies of determinant factors are identified to help explain low adoption rates of particular agricultural technology in developing countries which are technology attributes, farmer or farm household characteristics, farm characteristics and institutional factors. Future policy recommendations on adoption decision should consider all those four important factors to provide better understanding of new agricultural technology adoption by smallholder farmers, resulting in improved livelihoods for smallholders.

**Keywords:** Agricultural, technology, adoption, farmer

## *ABSTRAK*

*Peran teknologi pertanian sangat penting di negara berkembang. Meskipun demikian, tingkat adopsi teknologi pertanian baru oleh petani kecil masih rendah. Oleh karena itu, pemahaman terhadap faktor-faktor yang menentukan keputusan petani dalam mengadopsi teknologi sangat penting untuk meningkatkan pertumbuhan sektor pertanian. Tulisan ini adalah hasil sintesis terhadap beberapa literatur ilmiah yang berkaitan dengan faktor penghambat atau pendorong petani kecil dalam mengadopsi teknologi pertanian. Faktor yang memengaruhi petani kecil mengadopsi teknologi pertanian di negara berkembang berbeda antarstudi berdasarkan kebutuhan dan kondisi lokal tertentu. Empat kelompok utama faktor penentu yang dapat menjelaskan rendahnya adopsi teknologi di negara berkembang yaitu atribut teknologi, karakteristik petani, usaha tani, dan faktor kelembagaan. Rekomendasi kebijakan terkait keputusan adopsi teknologi seharusnya mempertimbangkan keempat kelompok faktor tersebut untuk dapat memahami lebih baik adopsi teknologi baru oleh petani kecil guna meningkatkan kesejahteraannya.*

***Kata kunci:*** *Pertanian, teknologi, adopsi, petani*

## INTRODUCTION

Agricultural technology adoption in developing countries is important to enhancing agricultural productivity for food security and poverty alleviation (World Bank 2007). Adoption of agricultural technology is also a fundamental driving force for economic development (Barrett *et al*. 2010; Foster and Rosenzweig, 2010). For a long period of time, there are many new or improved agricultural technologies has been developed as one of the most important factors that would contribute to increase agricultural production (Monu, 1995). In the case of this paper, it is important to remind the reader that the term "agricultural technology" refers not only agricultural machinery, but also new crops (e.g. horticulture) and improved varieties of crops (e.g. hybrid seed, high-yielding varieties), farming systems (e.g. organic farming, sustainable agricultural practices-SAP), post-harvest practices/activities (e.g. marketing channel choices, drying technology), smart agricultural technologies (e.g. robots, sensors), and other agricultural innovations (e.g. information and communication technologies-ICTs, silage methods, fertilizer, crop insurance).

However, in many cases the adoption rate of agricultural technology (new/improved/modern) is low. For example, a recent study by Suprehatin (2019) in Indonesia show that there were relatively low adoption rates (10%) of new horticultural crops amongst

smallholder farmers across Java Island. This means that the majority of smallholder farmers continue to rely on their traditional cropping patterns or farming practices. In general, millions of smallholder farmers developing countries also remain in the lack of use improved technologies. This raises an important question why smallholder farmers in developing countries are not improving productivity by adopting a greater number of improved agricultural technologies. On the other hand, the agricultural sector in developing countries remains a central sector of the economy and agricultural technologies is the key to the agricultural growth.

Therefore, one of the major challenge for policy makers and practitioners to improve agricultural productivity is to increase the adoption rate of improved/ innovative technologies for smallholder farmers. This is because not all smallholder farmers are able and willing to adopt new agricultural technologies because of the challenges and constraints to adoption imposed by various different factors. There is a long and rich tradition of empirical studies that seeking an explanation to smallholder farmers' adoption of particular agricultural technologies or innovations[1]. These studies have covered a wide range of new agricultural technologies or innovations from new/improved input technologies to information and communication (smart) agricultural technologies. Thus, this paper aims to provide a review and synthesis of the numerous studies that have examined smallholder farmer adoption of different agricultural technologies in developing countries. More spesifically, the paper aims (1) to describe different types of agricultural technology adoption, (2) to analyse determinant factors of agricultural technology adoption and (3) to explore agricultural technology adoption and its policy recommendations for Indonesia.

The study used a desk study approach by reviewing the previous adoption studies of different agricultural technologies in developing countries. This review adopted partially a scoping review methodology framework developed by Arksey and O'Malley (2005) to allow the researcher to engage with a wider literature on the relevant studies. The steps are as follows: First, identifying the research questions. The research questions of this study are: *what is known from existing literature about the types of new agricultural technologies adopted by smallholder farmer adoption in developing countries? What the determinants factors that significantly influencing smallholder farmer adoption of these new agricultural technologies?*

Second, searching and identifying relevant studies used the following bibliographic databases: Google scholar and Science Direct. The main keyword search related to the review topic used in this study were adoption/application/participation, agricultural technologies/innovations, smallholder farmers/farmers, and determinants/factors. As a result, this desk study reviewed more than 60 literatures including seminal works

and studies that have summarised previous adoption literature (Doss 2006; Feder *et al.* 1985; Knowler and Bradshaw 2007; Prokopy *et al.* 2008; Rogers 2003). The process involves two following tasks which were a review of the context of adoption and a review of significant factors. The significant variables were identified among the numerous studies that have examined farmer adoption of different agricultural technologies.

Third, summarising and reporting. A thematic analysis was conducted to summarize and analyze findings from research on both types of agricultural technologies/innovations and important factors affecting smallholder farmer adoption.

## DIFFERENT TYPES OF AGRICULTURAL TECHNOLOGY ADOPTION

As explained previously, the role of improved agricultural technology is important in developing countries. This section reviews the literature related to different types of agricultural technologies adoption by smallholder farmers.

In terms of different types of agricultural technology adoption, the previous empirical studies have covered a wide range of new agricultural technologies or innovations from new/improved input technologies to information and communication (smart) agricultural technologies. *First*, the majority of adoption studies conducted in developing countries have focused on adoption of improved or new agricultural input technologies by smallholder farmers. These innovations relate to new/modern/improved input technologies, such as high yield crop varieties including hybrid seed (Asfaw *et al.* 2012; Fisher and Kandiwa 2014; Kuntariningsih and Mariyono 2013; Matuschke and Qaim 2009), pesticides (Abdollahzadeh *et al.* 2015; Abebaw and Haile 2013), fertilisers (Krishnan and Patnam 2014; Lambrecht *et al.* 2014; Yu and Nin-Pratt 2014) and agricultural machinery, including tractors (Cunguara and Darnhofer 2011; Pingali 2007). Most existing studies have focused on adoption of new agricultural technologies to improve productivity of staple crops, such as hybrid rice and maize varieties (Ghimire and Huang 2015; Khonje *et al.* 2015; Mathenge *et al.* 2014). Most studies examined adoption of individual technologies in specific production zones that have been promoted by governments to encourage greater production of staple food crops.

*Second*, many studies on new farming system technologies, such as integrated pest management (IPM) techniques and organic farming, have focused on sustainability of staple food crop production. Such studies have examined new/modern farming systems or production practices, such as organic farming (Hossain *et al.* 2007; Pornpratansombat *et al.* 2011; Wollni and Andersson 2014), IPM (Mariano *et al.* 2012; Parsa *et al.*

2014; Wahida 2015), systems of rice intensification (SRI) (Laksana and Damayanti 2013; Noltze *et al.* 2012) and sustainable agricultural practices (SAP) (Manda *et al.* 2015; Ng'ombe *et al.* 2014; Teklewold *et al.* 2013). The aim of these studies focused on developing and disseminating ecologically sound and sustainable agricultural technologies, such as IPM techniques, organic fertiliser use and conservation tillage.

*Third*, numerous studies have been conducted to investigate smallholder farmer adoption of new agricultural technologies responding to ongoing agricultural food market transformation. For example, recent studies have examined smallholder farmer adoption of new marketing channels to enter modern markets (e.g. Hernández *et al.* 2007; Neven *et al.* 2009; Rao and Qaim 2011; Sahara *et al.* 2013) and contractual agreements between smallholder farmers and agribusiness firms (e.g. Barrett *et al.* 2012; Miyata *et al.* 2009).Such studies have identified new post-harvest technologies enabling greater access to new market channels[2] offering potential benefits for smallholder farmers. Another recent study examined adoption of post-harvest practices/activities such as maize drying technologies (Kariuki 2017).

*Fourth*, many recent empirical studies have been examined smallholder farmer adoption related to the ICTs and smart agricultural practices. These studies include adoption studies on certain ICTs such as mobile phones (e.g. Baumüller, 2013; Tadesse and Bahiigwa 2015), *WhatsApp* usage (e.g. Naruka*et al.* 2017), digital platform (e.g. Demenongu *et al.* 2018; Zhang *et al.* 2016), and climate-smart agriculture practices(e.g. Long *et al.* 2016). However, these technologies in agriculture are still at a nascent stage with a low rate of adoption due to strong barriers such as technical issues and the complexity of the platforms (Ezeomah and Duncombe 2019).

# DETERMINANT FACTORS OF AGRICULTURAL TECHNOLOGY ADOPTION

Previous empirical studies have examined agricultural technology adoption. However, in many cases the adoption rate of modern agricultural technologies is low. Therefore, a better understanding of agricultural technology adoption determinants is important as a major component of agricultural growth (Foster and Rosenzweig 2010).This section reviews the literature related to potential factors that may constrain or encourage smallholder adoption of new agricultural technologies

In terms of determinant factors of adoption, an extensive strand of the empirical literature has addressed determinant factors of agricultural technology adoption. On the other hand, there are also seminal works and studies that have summarised previous adoption literature (e.g. Doss 2006; Feder *et al*. 1985; Knowler and Bradshaw 2007; Prokopy *et al*. 2008; Rogers 2003). In addition, there is also another seminal work and study that proposed farmer types and adaptations of Ajzen's Theory of Planned Behaviour or attitudes as a different approach to the study of adoption of agricultural technology (see Ajzen 1991; Morrison *et al*. 2012). Drawing on these seminal works and empirical studies, four major typologies of factor characteristics are identified to help explain low adoption rates of particular agricultural technology, particularly in developing countries. These are technology attributes (e.g. higher expected profit, less labour required), farmer or farm household characteristics (e.g. age, education, household assets), farm characteristics (e.g. farm size, land tenure) and institutional factors (e.g. credit constraints, market access). Each of the four factors are discussed below.

## Technology Attributes

A given agricultural technology or innovation embodies a number of important attributes that may influence adoption decisions. Important work by Rogers in 1962 introduced five attributes of innovations to help in assessing different rates of adoption (Rogers 2003). Those attributes were relative advantage, compatibility, complexity, trialability and observability. After Rogers (2003), Fliegel and Kivlin (1966), Tornatzky and Klein (1982), and Moore and Benbasat (1991) addressed more than 25 attributes of innovations, such as cost, communicability, social approval and visibility, rather than Rogers' innovation attributes. These studies proposed better understanding of the effects of technology attributes as they significantly influence adoption of technology or innovation. However, only Rogers (2003) and Fliegel and Kivlin (1966) focused on agricultural technology attributes.

Previous studies have examined the effects of technology attributes on farmer adoption decisions (e.g. Adesina and Zinnah, 1993; Batz *et al*. 1999; Hintze *et al*. 2003; Lunduka *et al*. 2012). Adesina and Zinnah (1993) showed that farmer perceptions of attributes of modern rice varieties significantly influence adoption decisions in Sierra Leone. Batz *et al*. (1999) revealed that relative complexity and risk of agricultural technologies are important factors in farmer adoption in Kenya. Hintze *et al*. (2003) found varietal attributes are significant factors contributing to low levels of adoption of improved maize varieties in Honduras. Birol *et al*. (2009) identified the significant role of farmer perceptions of technology attributes on adoption decision-making in Mexico. Another study by Lunduka *et al*. (2012) demonstrated that specific attributes of different maize varieties are an important factor for farmer adoption in Malawi. Indeed, these studies show the importance of farmer preferences

for attributes of new agricultural technologies on adoption behaviour.

The studies under discussion used a different approach from this study to elicit farmer preferences for technology attributes. Adesina and Zinnah (1993) used a farmer subjective assessment to measure dichotomous scales, in terms of yes or no, of preferences for technology attributes. Similarly, Lunduka *et al.* (2012) applied dichotomous questions to examine farmer preferences for modern maize varietal attributes. Batz *et al.* (1999) employed a scoring approach which involved assessments made by extension workers in the study area. Hintze *et al.* (2003) applied a rating method to each variety using a three-scale method of very good/good, regular/average/sufficient and bad. In summary, those approaches may have potential weaknesses. For dichotomous scales, respondents are required to choose response that does not exactly reflect their answer and the researcher cannot further explore response meaning. A rating scale may create median responses which often occurs in ranking and rating methods (Balcombe *et al.* 2014). Recent studies used the innovative method of best-worst (BW) scaling to elicit farmer preferences for technology attributes (e.g. Ochieng and Hobbs 2016; Umberger *et al.* 2015). A benefit of this method over others is that respondents choose both the best and worst attributes and are forced to make trade-offs amongst subsets of crop attributes. According to (Vermeulen *et al.* 2010), BW scaling yields considerably more information about individuals' preferences compared to traditional choice methods. As discussed above, studies on farmer preferences for technologies and technology attributes should be considered when investigating farmers' needs when making adoption decisions. In addition, farmer needs could be indicative of constraints in adopting new agricultural technology.

## Farmer and Farm Household Characteristics

The importance of farmer characteristics in agricultural technology adoption has been widely acknowledged. The broad literature on agricultural technology adoption has suggested three key farmer (or farm household) characteristics that influence adoption of agricultural technology. These factors are human capital, household assets and financial capital. According to the literature, the importance of each factor and direction of influence depends on the nature of the technology (Doss 2006; Feder *et al.* 1985; Knowler and Bradshaw 2007).

Human capital, such as education, experience, age, and family labour availability, have emerged as variables that potentially influence adoption of improved technologies (Feder *et al.* 1985; Knowler and Bradshaw 2007). More highly educated farmers are more likely to adopt new agricultural technologies faster, particularly for knowledge-intensive technologies. For example, empirical studies by Rao and Qaim (2011) and Sahara *et al.* (2015) proposed that education is positively correlated with adoption of new modern market-channels, which often require substantial changes in traditional practices. Similarly, more experienced farmers tend to adopt new agricultural technologies (e.g. Kabunga *et al.* 2012). A previous study by Ainembabazi and Mugisha (2014) in Uganda found that experience relates positively to adoption of bananas and maize in the early stages of adoption. A younger farmer also tends to be a potential adopter of new agricultural technologies (e.g. Adesina *et al.* 2000; Nkonya *et al.* 1997; Suprehatin 2019). Household availability of labour required for adoption is also important. Horticultural crop technologies, for example, are often more labor-intensive, so their adoption depends on family labour availability (Joshi *et al.* 2006; Minot and Roy 2007).

Household assets can also influence adoption of new agricultural technologies. Assets deal with whether farmers have the requisite physical (material) essentials for agricultural technology adoption. Productive assets, such as transportation (e.g. a motorbike), agricultural production (e.g. water pump, sprayer and tractor) and storage assets, are commonly captured in studies on agricultural technology adoption (e.g. Feder *et al.* 1985; Suprehatin 2019; Wahida 2015). Productive assets are assumed to be positively related to adoption decisions and innovativeness of a farm household (Feder *et al.* 1985). If a farm household has more assets, it may easier to cope with drawbacks from unsuccessful agricultural technology adoption.

Another farm household characteristic that may play an important role in agricultural technology adoption is financial capital. Farmers are often constrained regarding access to financial resources, such as credit and off-farm incomes (Doss 2006). Finance-constrained farmers are more likely to show slow and low adoption of agricultural technologies, particularly when large investments and inputs are required (Doss 2006; Pannell *et al.* 2006). As explained above, farmer and farm household characteristics are important factors in adoption decision. Therefore, future studies should include farm household characteristics in modelling agricultural technology adoption.

## Farm Characteristics

The third important factor in adoption of new agricultural technology is farm characteristics. A large body of literature attempts to explain farm characteristics of decision-makers (farmers) that tend to increase agricultural technology adoption. These factors include farm size, land tenure, type of irrigation land, land ownership structure and supply of complementary farming inputs (Feder *et al.* 1985; Knowler and Bradshaw

2007). Knowler and Bradshaw's (2007) study concluded that farm size and land tenure (leased) appeared to have different impacts on agriculture technology adoption. However, farm size is often found to significantly influence adoption of agricultural technologies. In addition, in their review, Feder *et al.* (1985) cited several studies that conclude that renters are less likely than landowners to adopt conservation practices such as conservation tillage and contour farming.

Modern agricultural technologies such as smart agricultural practices, agricultural ICT, and post-harvest technologies may involve constraints related to farm characteristics, particularly those of smallholder farmers. They are often unable to bear larger investment, such as land required to produce high value agricultural crops. Therefore, future studies should consider farm characteristics, such as farm size and land tenure, in examining agricultural technology adoption.

## Institutional Factors

Institutional factors can influence farmer decisions to adopt new agricultural technologies. From an extensive review of literature on agricultural technology adoption by Doss (2006) and Feder *et al.* (1985), institutional factors include exposure of extension services, availability of information on new technologies and accessibility of markets for products and inputs. Many studies are concerned with these factors which influence farmer adoption of agricultural technologies and result in various impacts (e.g. Kabunga *et al.* 2012; Krishnan and Patnam 2014; Moser and Barrett 2006). However, institutional constraints could generally be a problem for smallholder farmers in adoption of agricultural technologies in developing countries, particularly when the technology is new and not widely known (Feder *et al.* 1985). Another institutional factor that is important to agricultural technology adoption is farmer membership in producer organizations. An empirical study Abebaw and Haile (2013) found that membership in farmer cooperatives has a significant effect on adoption of chemical fertilisers and improved seeds. The result is also in line with a recent study by Suprehatin (2019) which show producer organizations and farmer field school (FFS) make effective contribution to new horticultural crop adoption in Indonesia.

Beyond farm, farmer, and household characteristics, external factors can also be important to adoption of new agricultural technologies. These include government policy (e.g. subsidies), infrastructure (e.g. distance to road, distance to markets) and agro-ecological zones (e.g. elevation) (Basu and Qaim 2007; Doss 2006; Feder *et al.* 1985; Fisher and Kandiwa 2014). In addition, another strand of literature also explores social network, ambiguity, trust and communication (see Barham *et al.* 2014; Breetz *et al.* 2005; Maertens and Barrett 2013;

Morrison *et al.* 2011) as important factors of agricultural technology adoption.

## AGRICULTURAL TECHNOLOGY ADOPTION IN INDONESIA

In Indonesia, like in many developing countries, agricultural technology plays a vital role to increased productivity and was successful during the first Green Revolution as supported by appropriate policy support, high rates of investment in crop research, infrastructure and market development (Pingali 2012). As discussed above, most adoption studies including in Indonesia examined adoption of an individual farm technology in a specific geographical area. Such studies have explored different types of agricultural technology adoption among Indonesian smallholder farmers included along the continuum of new agricultural technologies from improved input technologies to market channels. The type of agricultural technologies included varieties or crops, farming practices or techniques, tools or equipment, know-how and skills, information and communication technologies or combinations of the aforementioned components.

Current agricultural inputs technologies have been promoted by Indonesian government, industries or universities such as improved varieties (e.g. true seed shallots, rice variety IPB 3S) and fertiliser (e.g. organic fertilizer, cocoa-spesific NPK fertiliser). In 2019, Ministry of Agriculture (MoA) has launched the improved rice varieties that known as functional rice (food) such as Baroma, Pamelen, Pamera, Paketih, Jeliteng, Inpari IR Nutri Zinc, Sembada Hitam, and Sembada Merah with potential harvest more than 9 ton per ha. This means that agricultural technologies are developed for improving both food and nutrition security. Indonesian government also encourage farmers to adopt or participate in agricultural insurance such as rice insurance (AUTP) and livestock insurance (AUTS) to protect smallholder farmers from failure. Other current agricultural technologies have also been introduced for Indonesian farmers: farming practices (e.g. organic farming, *jajar legowo*, climate smart agriculture, smart farming), post-harvest operations and processing technologies (e.g. threshers, drying technologies, controlled atmosphere storage), ICTs (e.g. mobile phones, mobile applications, internet), improved marketing practices (e.g. contract farming, supermarket channels, e-commerce channels).

The types of agricultural technology adoption in Indonesia also vary from study to study based on applicability and specific local conditions and needs. In other words, the agricultural technology adopted by Indonesian smallholder farmers varied and developed based on the development and availability of agricultural technologies. Those agricultural technologies have been promoted by governments, industries, universities,

research centres, NGO and other stakeholders to enhance agricultural productivity and livelihoods of Indonesian farmers. However, smallholder farmers in Indonesia is often still practised their farming activities without the benefit of modern tools or improved seed varieties (FAO 2018). It means that, although there were many new agricultural technologies has been launched and promoted but the rate of adoption of these technologies has remained low in Indonesia such as in horticultural crop adoption (see Suprehatin 2019). Therefore, there may be opportunities for policy makers to support smallholder farmers to adopt new/improved agricultural technologies for their own benefit and for the benefit of national agriculture as a whole.

## POLICY RECOMMENDATIONS TO FOSTER AGRICULTURAL TECHNOLOGY ADOPTION IN INDONESIA

As discussed above, the previous extensive empirical studies have contributed to the existing literature by highlighting specific factors which influence the farmers' decision to adopt a new horticultural crop. Based on critical examination of adoption literature, characteristics of farmer (or farm household), farm, institutional and technology are among the most important determinants of agricultural technology adoption. However, some studies have focused exclusively on characteristics of farmers, farm and institutional factors, while other studies focused on attributes of technology. Few studies have attempted to integrate technology attributes, socio-economic and institutional factors shown in previous research to be determinants of adoption. Several studies have been conducted to integrate drivers and preferences that farmers place on technology attributes (e.g. Adesina and Baidu-Forson 1995; Batz *et al.* 1999; Hintze *et al.* 2003; Useche *et al.* 2009).

Therefore, future studies and policy recommendations on adoption decision should consider all four important factors as discussed above. This integrated adoption model (Figure 1) is expected to provide better understanding of new agricultural technology adoption by smallholder farmers, resulting in improved livelihoods for smallholders. While some smallholder farmers have the potential to successfully adopt a new agricultural technology, others may not. Therefore, based on the results from the findings from the literature review as discussed above, a number of policy recommendations could be considered to foster adoption of new agricultural technologies among Indonesian smallholder farmers.

First, policy makers and practitioners may consider four major groups of important factors influencing agricultural technology adoption such as technology,

farmer (farm household), farm and institutional characteristics (Figure 1). In other words, examining these diverse important factors is essential since it might directly impinge on the primary drivers for the adoption of improved agricultural technologies. For practitioners (e.g. agricultural input companies, digital platform-based companies), it will inform practical interventions and marketing strategies required to improve smallholder farmers' adoption of new agricultural technologies and ultimately, secure their livelihood and welfare. For example, in terms of adoption (participation) on marketing channels, it will be more comprehensive understanding of market choice decision facing smallholder farmers in Indonesia. Among the four main of important factors, Indonesian policy makers and practitioners needs to analysis which significant factors influence Indonesian smallholder farmers' decision whether to sell their products in different markets.

Second, understanding these diverse determinants of agricultural technology adoption allow policy makers and practitioners to targeting groups of farmers rather than all farmers to promote new agricultural technology adoption. In other words, not all programming and marketing strategies works similarly for all Indonesian smallholder farmers. For example, many previous empirical findings showed that younger farmers are more likely to adopt agricultural technologies (e.g. Adesina *et al.* 2000; Nkonya *et al.* 1997; Suprehatin 2019). Therefore, policy makers needs to develop tailored strategies to target Indonesian young farmer to adopt new agricultural technologies earlier. Another example, promoting policies that improve access to credit for certain groups of Indonesian farmers may be important as this was found to facilitate adoption of new agricultural technologies. However, the viability of these group of farmers needs to be assessed properly before the credit is provided.

Third, policies to promote and improve access to agricultural education and trainings for Indonesian smallholder farmers is important based on the previous findings that education facilitate agricultural technology adoption in Indonesia (Sahara *et al.* 2015; Suprehatin, 2019). The development of vocational institutions and training programs that focus on particular aspects of farming in certain agricultural areas could be an option for improving knowledge and skills of farmers. However, the programs should be developed based on the needs of farmers and can be linked to research and educational institutions (e.g. universities) and private sector. Therefore, it is important to bolster innovation and investment from the private sector for adoption of agriculture technologies.

Fourth, policy makers need to develop institutional innovations to facilitate smallholder farmers to appropriate agricultural technologies as this critical to foster its adoption. For example, through institutional arrangements, smallholder farmers may be able to
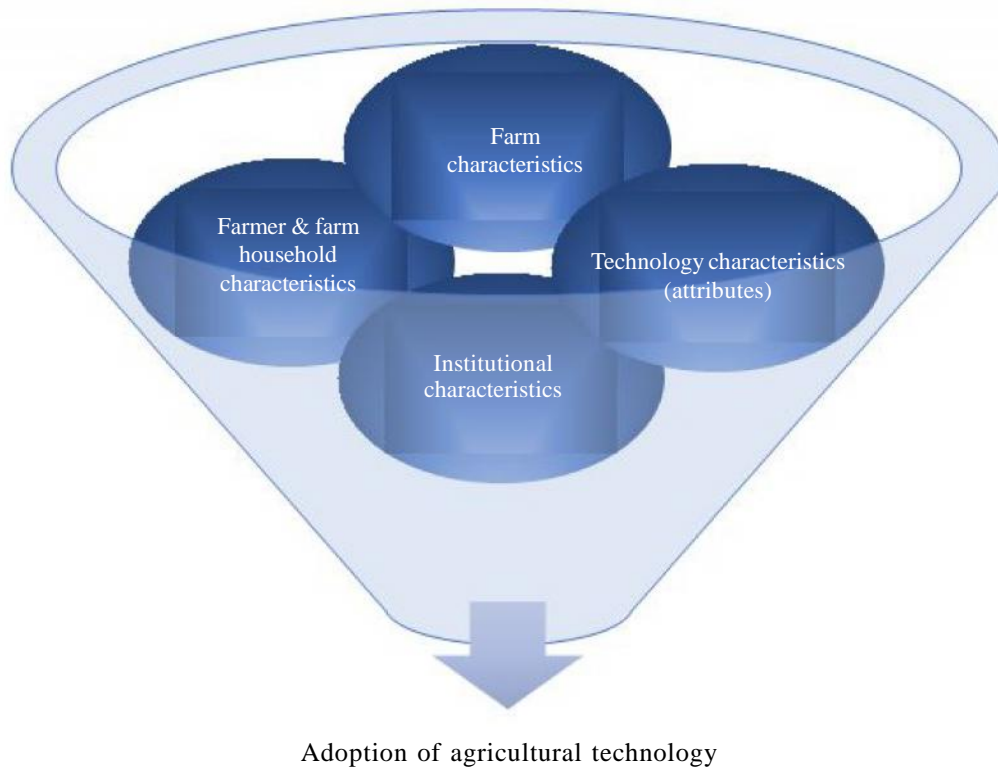
Adoption of agricultural technology

**Figure 1.** Integrating farmer, farm, institutional and technology characteristics into agricultural technology adoption's model (Sources: Adesina and Baidu-Forson 1995; Batz *et al.* 1999; Hintze *et al.* 2003; Useche *et al*. 2009).

participate in the new modern market channels which offer the opportunities to get higher productivity and income (see Narayanan 2014; Rao and Qaim 2011; Sahara *et al.* 2015).

Fifth, policy makers may consider the technology characteristics or traits (see Batz *et al.* 1999; Hintze *et al.* 2003; Lunduka *et al.* 2012; Rogers 2003) by designing incentives and information on specific technology attributes that are most likely to encourage farmers to adopt new agricultural technologies that have a high probability of offering benefits. Therefore, policy makers will have a better understanding of how to achieve sound agricultural policy for smallholder farmers and economic development as a entirety.

## CONCLUSIONS

The results of literature review show that determinant factors influencing smallholder farmer adoption of new technologies in developing countries vary from study to study based on contextual applicability and specific local condition. The results of literature study also have successfully indicated that there are four major typologies of determinant factors are identified to help explain low adoption rates of particular agricultural technology in developing countries which are technology attributes, farmer or farm household characteristics, farm characteristics and institutional factors. Furthermore, the results provide perspectives and prospects of agricultural technology adoption in Indonesia in terms of to targeting groups of farmers rather than all farmers, to promote and improve access to agricultural education and trainings for Indonesian smallholder farmers and to develop institutional innovations to facilitate smallholder farmers to appropriate agricultural technologies. For future research, empirical research may address to integrate all four determinant factors into agricultural technology adoption model. Future review may consider to use more structurally methods such as systematic review and meta-analysis with involving relatively complex statistical procedures. In addition, to conduct such an adoption review, special focus may be placed on specific type of agricultural technologies/innovations.

## CONTRIBUTION STATEMENT

Suprehatin is the main contributor in this paper.

# REFERENCES

Abdollahzadeh, G. Sharifzadeh, M. S. and Damalas, C. A. (2015). Perceptions of the Beneficial and Harmful Effects of Pesticides among Iranian Rice Farmers Influence the Adoption of Biological Control. *Crop Prot* **75**:124-131.

Abebaw, D. and Haile, M. G. (2013). The Impact of Cooperatives on Agricultural Technology Adoption: Empirical Evidence from Ethiopia. *Food Policy* **38**:82-91.

Adesina, A. A. and Baidu-Forson, J. (1995). Farmers' Perceptions and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa. *Agric. Econ.* **13**(1):1-9.

Adesina, A. A. Mbila, D. Nkamleu, G. B. and Endamana, D. (2000). Econometric Analysis of the Determinants of Adoption of Alley Farming by Farmers in the Forest Zone of Southwest Cameroon. *Agric. Ecosyst. Environ.* **80**(3):255-265.

Adesina, A. A. and Zinnah, M. M. (1993). Technology Characteristics, Farmers' Perceptions and Adoption Decisions: a Tobit Model Application in Sierra Leone. *Agric. Econ.* **9**(4):297-311.

Ainembabazi, J. H. and Mugisha, J. (2014). The Role of Farming Experience on the Adoption of Agricultural Technologies: Evidence from Smallholder Farmers in Uganda. *J. Dev. Stud.* **50**(5):666-679.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organ. Behav. Hum. Decis. Process.* **50**(2):179-211.

Arksey, H. and O'Malley, L. (2005). Scoping Studies: Towards a Methodological Framework. *Int. J. Soc. Res. Methodol.* **8**(1):19-32.

Asfaw, S. Shiferaw, B. Simtowe, F. and Lipper, L. (2012). Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia. *Food Policy* **37**(3):283-295.

Balcombe, P. Rigby, D. and Azapagic, A. (2014). Investigating the Importance of Motivations and Barriers Related to Microgeneration Uptake in the UK. *Appl. Energy* **130**:403-418.

Barham, B. L. Chavas, J. P. Fitz, D. Salas, V. R. and Schechter, L. (2014). The Roles of Risk and Ambiguity in Technology Adoption. *J. Econ. Behav. Organ.* **97**:204-218.

Barrett, C. B. Bachke, M. E. Bellemare, M. F. Michelson, H. C. Narayanan, S. and Walker, T. F. (2012). Smallholder Participation in Contract Farming: Comparative Evidence from Five Countries. *World Dev.* **40**(4):715-730.

Barrett, C. B. Carter, M. R. and Timmer, C. P. (2010). A Century-Long Perspective on Agricultural Development. *Am. J. Agric. Econ.* **92**(2):447-468.

Basu, A. K. and Qaim, M. (2007). On the Adoption of Genetically Modified Seeds in Developing Countries and the Optimal Types of Government Intervention. *Am. J. Agric. Econ.* **89**(3):784-804.

Batz, F. J. Peters, K. J. and Janssen, W. (1999). The Influence of Technology Characteristics on the Rate and Speed of Adoption. *Agric. Econ.* **21**(2):121-130.

Baumüller, H. (2013). Enhancing Smallholder Market Participation through Mobile Phone-Enabled Services: the Case of M-Farm in Kenya. Inform. 2013–Informatik angepasst an Mensch, Organ. und Umwelt.

Birol, E. Villalba, E. R. and Smale, M. (2009). Farmer Preferences for Milpa Diversity and Genetically Modified Maize in Mexico: a Latent Class Approach. *Environ. Dev. Econ.* **14**(4):521-540.

Breetz, H. L. Fisher-Vanden, K. Jacobs, H. and Schary, C. (2005). Trust and Communication: Mechanisms for Increasing Farmers' Participation in Water Quality Trading. *Land Econ.* **81**(2):170-190.

Cunguara, B. and Darnhofer, I. (2011). Assessing the Impact of Improved Agricultural Technologies on Household Income in Rural Mozambique. *Food Policy* **36**:378-390.

Demenongu, T. S. Yahaya, M. and Jiriko, R. (2018). Assessment of Farm Inputs Distribution under the E-wallet Scheme in Benue State, Nigeria. *Int. J. Agric. Food Res.* **6**(2):20-25.

Doss, C. R. (2006). Analyzing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement. *Agric. Econ.* **34**(3):207-219.

Ezeomah, B. and Duncombe, R. (2019). The Role of Digital Platforms in Disrupting Agricultural Value Chains in Developing Countries, in: International Conference on Social Implications of Computers in Developing Countries. Springer:231-247.

[FAO] Food and Agriculture Organization (2018). Small Family Farms Country Factsheet: Indonesia [WWW Document]. URL http://www.fao.org/3/i8881en/I8881EN.pdf (diakses pada 8.17.20).

Feder, G. Just, R. E. and Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: a Survey. *Econ. Dev. Cult. Change* **33**(3):255-298.

Fisher, M. dan Kandiwa, V. (2014). Can Agricultural Input Subsidies Reduce the Gender Gap in Modern Maize Adoption? Evidence from Malawi. *Food Policy* **45**:101-111.

Fliegel, F. C. and Kivlin, J. E. (1966). Attributes of Innovations as Factors in Diffusion. *Am. J. Sociol.* **72**(3):235-248.

Foster, A. D. and Rosenzweig, M. R. (2010). Microeconomics of Technology Adoption. *Annu Rev Econ.* **2**(1):395-424.

Ghimire, R. and Huang, W. C. (2015). Household Wealth and Adoption of Improved Maize Varieties in Nepal: a Double-Hurdle Approach. *Food Secur.* **7**(6):1321-1335.

Hernández, R. Reardon, T. and Berdegué, J. (2007). Supermarkets, Wholesalers, and Tomato Growers in Guatemala. *Agric. Econ.* **36**(3):281-290.

Hintze, L. H. Renkow, M. and Sain, G. (2003). Variety Characteristics and Maize Adoption in Honduras. *Agric. Econ.* **29**(3):307-317.

Hossain, S. T. Sugimoto, H. Ueno, H. and Huque, S. M. R. (2007). Adoption of Organic Rice for Sustainable Development in Bangladesh. *J. Org. Syst.* **2**(2):27-37.

Joshi, P. K. Joshi, L. and Birthal, P. S. (2006). Diversification and its Impact on Smallholders: Evidence from a Study on Vegetable Production. *Agric. Econ. Res. Rev.* **19**(2):219-236.

Kabunga, N. Dubois, T. and Qaim, M. (2012). Heterogeneous Information Exposure and Technology Adoption: the Case of Tissue Culture Bananas in Kenya. *Agric. Econ.* **43**(5):473-486.

Kariuki, G. (2017). Determinants of Intention to Adopt Maize Drying Technologies among Small-Scale Farmers in Kenya. Master's thesis, University of Cape Town.

Khonje, M. Manda, J. Alene, A. D. and Kassie, M. (2015). Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia. *World Dev.* **66**:695-706.

Knowler, D. and Bradshaw, B. (2007). Farmers' Adoption of Conservation Agriculture: a Review and Synthesis of Recent Research. *Food Policy* **32**:25-48.

Krishnan, P. and Patnam, M. (2014). Neighbors and Extension Agents in Ethiopia: Who Matters More for Technology Adoption? *Am. J. Agric. Econ.* **96**(1):308-327

Kuntariningsih, A. and Mariyono, J. (2013). Socio-Economic Factors Affecting Adoption of Hybrid Seeds and Silvery Plastic Mulch for Chilli Farming in Central Java. *SEPA J. Sos. Ekon. Pertan. dan Agribinis* **9**(2):297-308.

Laksana, S. and Damayanti, A. (2013). Determinants of the Adoption of System of Rice Intensification in Tasikmalaya District, West Java Indonesia. *Work. Pap. Econ. Dev. Stud.* No. 201306.

Lambrecht, I. Vanlauwe, B. Merckx, R. and Maertens, M. (2014). Understanding the Process of Agricultural Technology Adoption:

Mineral Fertilizer in Eastern DR Congo. *World Dev*. **59**:132-146.

Long, T. B. Blok, V. and Coninx, I. (2016). Barriers to the Adoption and Diffusion of Technological Innovations for Climate-Smart Agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy. *J. Clean. Prod*. **112**:9-21.

Lunduka, R. Fisher, M. and Snapp, S. (2012). Could Farmer Interest in a Diversity of Seed Attributes Explain Adoption Plateaus for Modern Maize Varieties in Malawi? *Food Policy* **37**:504-510.

Maertens, A. and Barrett, C. B. (2013). Measuring Social Networks' Effects on Agricultural Technology Adoption. *Am. J. Agric. Econ*. **95**(2):353-359.

Manda, J. Alene, A. D. Gardebroek, C. Kassie, M. and Tembo, G. (2015). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. *J. Agric. Econ*. **67**(1):130-153.

Mariano, M. J. Villano, R. dan Fleming, E. (2012). Factors Influencing Farmers' Adoption of Modern Rice Technologies and Good Management Practices in the Philippines. *Agric. Syst*. **110**:41-53.

Mathenge, M. K. Smale, M. and Olwande, J. (2014). The Impacts of Hybrid Maize Seed on the Welfare of Farming Households in Kenya. *Food Policy* **44**:262-271.

Matuschke, I. and Qaim, M. (2009). The Impact of Social Networks on Hybrid Seed Adoption in India. *Agric. Econ*. **40**(5):493-505.

Minot, N. and Roy, D. (2007). Impact of High-Value Agriculture and Modern Marketing Channels on Poverty: An Analytical Framework, International Food Policy Research Institute, Washington, DC.

Miyata, S. Minot, N. and Hu, D. (2009). Impact of Contract Farming on Income: Linking Small Farmers, Packers, and Supermarkets in China. *World Dev*. **37**(11):1781-1790.

Monu, E. D. (1995). Technology Development and Dissemination in Agriculture: a Critique of the Dominant Model. *Africa Dev. Développement* 21-39.

Moore, G. C. and Benbasat, I. (1991). Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation. *Inf. Syst. Res*. **2**(3):192-222.

Morrison, M. Durante, J. Greig, J. Ward, J. and Oczkowski, E. (2012). Segmenting Landholders for Improving the Targeting of Natural Resource Management Expenditures. *J. Environ. Plan. Manag*. **55**:17-37.

Morrison, M. Oczkowski, E. and Greig, J. (2011). The primacy of Human Capital and Social Capital in Influencing Landholders' Participation in Programmes Designed to Improve Environmental Outcomes. *Aust. J. Agric. Resour. Econ*. **55**(4):560-578.

Moser, C. M. and Barrett, C.B. (2006). The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar. *Agric. Econ*. **35**(3):373-388.

Narayanan, S. (2014). Profits from Participation in High Value Agriculture: Evidence of Heterogeneous Benefits in Contract Farming Schemes in Southern India. *Food Policy* **44**:142-157.

Naruka, P. S. Verma, S. Sarangdevot, S. S. Pachauri, C. P. Kerketta, S. and Singh, J. P. (2017). A Study on Role of WhatsApp in Agriculture Value Chains. *Asian J. Agric. Extension, Econ. Sociol*. 1-11.

Neven, D. Odera, M. M. Reardon, T. and Wang, H. (2009). Kenyan Supermarkets, Emerging Middle-Class Horticultural Farmers, and Employment Impacts on the Rural Poor. *World Dev*. **37**(11):1802-1811.

Ng'ombe, J. Kalinda, T. Tembo, G. and Kuntashula, E. (2014). Econometric Analysis of the Factors that Affect Adoption of Conservation Farming Practices by Smallholder Farmers in Zambia. *J. Sustain. Dev*. **7**(4):124-138.

Nkonya, E. Schroeder, T. and Norman, D. (1997). Factors Affecting Adoption of Improved Maize Seed and Fertiliser in Northern Tanzania. *J. Agric. Econ*. **48**(1-3):1-12.

Noltze, M. Schwarze, S. and Qaim, M. (2012). Understanding the Adoption of System Technologies in Smallholder Agriculture: the System of Rice Intensification (SRI) in Timor Leste. *Agric. Syst*. **108**:64-73.

Ochieng, B. J. and Hobbs, J. E. (2016). Incentives for Cattle Producers to Adopt an E. coli Vaccine: an Application of Best–Worst Scaling. *Food Policy* **59**:78-87.

Pannell, D. J. Marshall, G. R. Barr, N. Curtis, A. Vanclay, F. and Wilkinson, R. (2006). Understanding and Promoting Adoption of Conservation Practices by Rural Landholders. *Anim. Prod. Sci*. **46**(11):1407-1424.

Parsa, S. Morse, S. Bonifacio, A. Chancellor, T. C. B. Condori, B. Crespo-Pérez, V. Hobbs, S. L. A. Kroschel, J. Ba, M. N. and Rebaudo, F. (2014). Obstacles to Integrated Pest Management Adoption in Developing Countries. *Proc. Natl. Acad. Sci*. **111**(10):3889-3894.

Pingali, P. (2007). Agricultural Mechanization: Adoption Patterns and Economic Impact. *Handb. Agric. Econ*. **3**:2779-2805.

Pingali, P. (2012). Green Revolution: Impacts, Limits, and the Path Ahead. *Proc. Natl. Acad. Sci*. **109**(3):12302-12308.

Pornpratansombat, P. Bauer, B. and Boland, H. (2011). The Adoption of Organic Rice farming in Northeastern Thailand. *J. Org. Syst*. **6**(3):4-12.

Prokopy, L. S. Floress, K. Klotthor-Weinkauf, D. and Baumgart-Getz, A. (2008). Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature. *J. Soil Water Conserv*. **63**(5):300-311.

Rao, E. J. O. and Qaim, M. (2011). Supermarkets, Farm Household Income and Poverty: Insights from Kenya. *World Dev*. **39**(5):784-796.

Rogers, E.M. (2003). Diffusion of Innovations, 5th editio. ed. Simon and Schuster, NY.

Sahara, Minot, N. Stringer, R. and Umberger, W. J. (2015). Determinants and Effects of Small Chilli Farmers' Participation in Supermarket Channels in Indonesia. *Bull. Indones. Econ. Stud*. **51**(3):445-460.

Sahara, Umberger, W. J. and Stringer, R. (2013). Marketing Preferences of Small Chilli Farmers in Indonesia: an Application of Best-Worst Scaling. *ISHS Acta Hortic*. **1006**:309–315.

Suprehatin, S. (2019). Characteristics of Farmer Adopters of High Value Horticultural Crops in Indonesia. *J. Manaj. Agribisnis* **16**(2):181-190.

Tadesse, G. and Bahiigwa, G. (2015). Mobile Phones and Farmers' Marketing Decisions in Ethiopia. *World Dev*. **68**:296-307.

Teklewold, H. Kassie, M. dan Shiferaw, B. (2013). Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia. *J. Agric. Econ*. **64**(3):597-623.

Tornatzky, L. G. and Klein, K. J. 1982. Innovation Characteristics and Innovation Adoption Implementation: a Meta-Analysis of Findings. *IEEE Trans. Eng. Manag*. **29**(1):28-45.

Umberger, W. J. Reardon, T. Stringer, R. and Mueller, S. (2015). Market-Channel Choices of Indonesian Potato Farmers: a Best–Worst Scaling Experiment. *Bull. Indones. Econ. Stud*. **51**(3):461-477.

Useche, P. Barham, B. L. and Foltz, J. D. (2009). Integrating Technology Traits and Producer Heterogeneity: a Mixed-Multinomial Model of Genetically Modified Corn Adoption. *Am. J. Agric. Econ*. **91**(2):444-461.

Vermeulen, B. Goos, P. and Vandebroek, M. (2010). Obtaining more Information from Conjoint Experiments by Best–Worst Choices. *Comput. Stat. Data Anal*. **54**(6):1426-1433.

Wahida (2015). Food System Transformation in Indonesia: Factors Influencing Demand and Supply for Alternative Pest

Management Farming Systems. The University of Adelaide, Adelaide.

Wollni, M. and Andersson, C. (2014). Spatial Patterns of Organic Agriculture Adoption: Evidence from Honduras. *Ecol. Econ.* **97**:120-128.

WorldBank 2007. World Development Report 2008: Agriculture for Development. Washington, DC.

Yu, B. and Nin-Pratt, A. (2014). Fertilizer Adoption in Ethiopia Cereal Production. *J. Dev. Agric. Econ.* **6**(7):318-337.

Zhang, Y. Wang, L. and Duan, Y. (2016). Agricultural Information Dissemination using ICTs: a Review and Analysis of Information Dissemination Models in China. *Inf. Process. Agric.* **3**(1):17-29.