Determinants of the Extent of Technological Innovation Adoption Among Micro, Small, and Medium Food Processing Enterprises in Davao Region, Philippines

Kenneth D. Barroga1*, Agnes C. Rola2, Dinah Pura T. Depositario3, Larry N. Digal4, and Isabelita M. Pabuayon3

1Technical Services Division, Department of Science and Technology (DOST) XI
Davao City 8000 Philippines
2College of Public Affairs and Development, University of the Philippines Los Baños
Laguna 4030 Philippines
3College of Economics and Management, University of the Philippines Los Baños
Laguna 4030 Philippines
4School of Management, University of the Philippines Mindanao
Davao City 8000 Philippines

Micro, small, and medium food processing enterprises (MSMFEs) need to modernize and adopt technological innovations to stay competitive. Various factors influence MSMFEs' ability to adopt innovations. This study aimed to identify the determinants of the extent of adoption among MSMFEs in Davao Region, Philippines. Data were obtained through a census of MSMFEs in the region assisted by DOST’s Small Enterprises Technology Upgrading Program (SETUP), a government program that enables MSMFEs to adopt technological innovations to boost productivity. The analytical tools used were index construction and ordered logistic regression (LR) for quantitative analysis and case studies for qualitative analysis. The statistical or econometric packages available in R software were used in the estimation process and results generation. The adoption indices ascertained which MSMFEs did not adopt technological innovations and which ones adopted less, moderately, and highly or fully. Results showed that 4% of the MSMFEs did not or failed to adopt technological innovations. On the other hand, 21% of the MSMFEs fully adopted the innovations. The majority of them were in the highly adoptive level. Additionally, the extent of technological innovation adoption (TIA) among MSMFEs was mainly influenced by the sex of the owner, educational attainment, business scale, and type of market. Thus, male owners, those with higher educational attainment, and those who own micro-scale businesses catering to both domestic and export markets are likely to adopt more technological innovations. These findings can contribute to a policy establishing an efficient SETUP implementation strategy at the regional and national levels or developing a new program for MSMFEs.

Keywords: determinant, SME, SETUP, technological innovation adoption

*Corresponding Author: kdbarroga@up.edu.ph
INTRODUCTION

Micro, small, and medium food processing enterprises (MSMFEs) depend on the adoption of technological innovation by acquisition of upgraded equipment and diffusion of new technologies to increase their productivity, competitiveness, and efficiency. The benefits derived from TIA are well-documented in the literature (Radu 2015, Yu and Tao 2009). The issue that still needs to be addressed is the extent to which technological innovations are adopted by MSMFEs. Some MSMFEs may respond and adopt technological innovation while others may not. A common finding from MSMFE studies is that while some of them have responded by introducing technological innovation such as equipment upgrading or modernizing production, many others continue to produce without using science and technology in their operations to meet statutory and regulatory requirements and international standards (Yapp and Fairman 2005, Parrilli and Elola 2012).

Previous studies such as those of Bhoganadam et al. (2017) and Gumel (2017) revealed that MSMFEs encounter many problems due to the use of outdated machines, low levels of technology, and limited access to technological information. The utilization of old and inefficient machines, non-compliance to food safety standards, and non-adoption of innovations such as energy conservation do not necessarily indicate that MSMFE owners or entrepreneurs are unaware of the availability of better alternatives or more up-to-date production technologies in the market and food safety legislation in their locality. Some owners are aware of these, but numerous factors must be considered in deciding to adopt technological innovations. The most commonly cited barrier to TIA among MSMFEs is inadequate financial resources (OECD 2000). Access to financial assistance is necessary to implement TIA. This concern is addressed by the Philippine government through DOST-SETUP. SETUP provides financial and technical assistance to MSMFEs to enable them to adopt technological innovations to boost productivity.

Moreover, this study proposes that personal demographics, organization characteristics, and sources of information affect the degree of TIA among MSMFEs. Habaradas et al. (2014) discovered that individual, organizational and environmental factors would affect innovation activities of the firms in the Philippines. Thus, it is particularly vital to investigate what factors influence MSMFEs’ TIA: personal demographics (age, sex, years of experience, and educational attainment), organizational characteristics (business scale, organization type, and type of market), and sources of information.

The MSMFEs’ ability to adopt a technological innovation introduced by DOST-SETUP may reflect the level of their innovativeness. This innovation involves some new machineries/equipment that are considered by the Program as appropriate to enable MSMFEs to improve their performance. Some enterprises have introduced technological innovation, suggesting their ability to search for information on such innovation and their willingness to make changes in their businesses. This reflects their innovative behavior.

In this paper, innovation is defined as the adoption of a new machine or equipment – together with training support, consultancies, and ideas implemented by MSMFEs to improve their performance. In the context of Davao Region, Philippines, this study asks the following research questions: (1) what are the factors affecting TIA among MSMFEs? and (2) what is the extent of the uptake of technological innovations?

The second part of the paper presents literature on the determinants of TIA among MSMEs to ground the theoretical framework and its hypotheses. The third part discusses the methods and variables used in the analysis. The fourth part explains the findings relative to the hypotheses. Finally, the last part gives the conclusions and offers recommendations.

Literature Review

Aside from their contribution to economic growth, MSMEs are also known to be engines of innovation. McAdam and Armstrong (2001) define innovation as "the harnessing of creative ability within individuals and the workforce in response to change, by doing things differently or better across products, processes or procedures." Specifically, technological innovation activities are all those scientific, technological, organizational, financial, and commercial steps that actually or are intended to lead to the implementation of new or improved products and processes (Habaradas et al. 2014). According to Virasa and Tangjittiboon (2000), the major activities involved in TIA are acquisition of knowledge (licenses, technical services, etc.), acquisition of machinery and equipment, and various other preparations for product delivery – including staff training, marketing, and R&D. Hence, the package of assistance from DOST’s SETUP such as upgrade of machines, technology training, and consultancies – which is perceived as new by MSMEs – is technological innovation.

Acs and Audretsch, as cited in Biggs (2003), found that the rate of adoption of technological innovations is higher in MSMEs than in large enterprises in some industries. This can be explained by the MSMEs’ apparently better exploitation of university-based research compared with large enterprises. This MSME behavior can be further described by the theory of adoption.
The theory of adoption is divided into at least three general phases: initiation, adoption (decision), and implementation (Frambach and Schillewaert 2002). Initiation phase is the enterprise’s initial awareness, consideration, and attitude toward the innovation. On the other hand, the adoption decision stage involves evaluation of the innovation from technical, financial, and strategic perspectives (Damanpour and Schneider 2006). Lastly, the implementation occurs when the enterprise eventually buys the innovation and prepares to use it, favoring acceptance and continued use of the innovation until it becomes a routine feature (Damanpour and Schneider 2006).

The adoption of these technological innovations involves the uptake of something new to the enterprise, which is externally generated (Orlando et al. 2013). At the enterprise level, scholars such as Damanpour and Wischnesvsky (2006) have identified innovation adoption in the development and/or use of new ideas or behavior. This TIA does not occur as a single organizational act but as a process resolving in the assimilation of a product or practice that is new to the adopting enterprise (Damanpour and Wischnesvsky 2006).

Another strand of TIA is based on the rational model or decision theory of the enterprise, which views decision-making as a process involving the identification of goals, alternatives, and evaluation techniques. The decision of the enterprise differs from that of another because the situation can be perceived differently or the enterprise has different goals or different set of alternatives or a different way of weighing alternatives (Koropp et al. 2014). This can be modelled mathematically by loading all values into a utility function.

TIA among MSMEs is mainly influenced by their owners who play a significant part in the establishment, development, and advancement of the enterprise (Taalika 2004). Therefore, any major decisions regarding TIA would reside on them. Managers, similar to the owners, of small businesses have an exaggerated impact on the strategic direction adopted by their enterprises and their resulting performance (Hausman 2005). Hausman (2005) contends that any effort to understand the innovativeness of small businesses or MSMEs must look at the characteristics of the managers or owners. His study further reveals that the variables associated with individual innovativeness in consumer adoption are demographics such as age, gender, income, education, among others.

Thus, the determinants of TIA can be viewed at the individual and/ or organizational level. A broad part of the literature focuses on adoption as an individual process, affected by the user’s psychological characteristics, personal traits, and individual perceptions. Its foundations are in Schumpeter’s work (Schumpeter 1934) viewing entrepreneurs as innovators.

Several theories that deal with an individual’s behavioral intention to adopt have been proposed by scholars. For instance, the contributions of Moore and Benbasat’s (1991) on perceived characteristics of innovating approach, which measures the probability to adopt through three constructs that are seen as antecedents to adoption decisions: relative advantage, compatibility, and trialability. An approach in this research stream relates to Granovetter’s (1978) threshold model, which focuses on the trade-off between social value and individual benefits. Such contributions (e.g., Suarez 2005) emphasize strong tie effects where adoption is mainly the result of social pressure from network agents who have already adopted. Yet – from a sociological standpoint, among factors affecting adoption – Wejnert (2002) includes societal entity of innovators, familiarity with innovation, status characteristics, socioeconomic characteristics, relative position in social networks, and personal characteristics that are associated with cultural variables that modify personality characteristics of actors at a population level. Shaping an evolutionary model, Taylor (2010) argues that social status, information visibility, individual mobility, and cognitive belief are the main factors bearing on the adoption process.

Furthermore, it should be recognized that TIA at the organizational level is a process that is intricately connected with various determinants. Most of SMEs' TIA research has focused on analyzing the determinants of TIA. The analysis in previous literature can be categorized into three groups: factors related to enterprises that will use the technology (skill and education level), organizational characteristic (domestic or international, firm size, age, etc.), and organizational environment (country, culture, and legal system) (Oreg and Berson 2011). Small enterprises are likely to be engaged in adopting technological innovation activities than large ones (Hormiga et al. 2011).

The research gap in TIA among MSMEs reflects the fact that no integrated theoretical framework, on the determinants of the extent or the breadth and depth of applying the different technological innovations adopted into the various aspects of the MSMFE’s business in the Philippines, has been developed – one which combines both personal and organizational factors and determines its significant predictors.

**Theoretical Framework and Hypotheses**

Based on the literature, one can explain the interrelationships of factors in MSMEs' decision-making process using different theoretical approaches;
this suggests the multidisciplinary nature of TIA. The theoretical model developed in this study used three main theoretical approaches – theory of adoption, individual innovativeness theory (IIT), and decision theory of small firms or enterprises.

The TIA is the decision to acquire and utilize an innovation. Before any adoption takes place, the entrepreneur or owner has to be aware of the existence and function of the innovation. Only then can the appropriateness of the innovation to the organization be determined. It is this exposure that will shape the entrepreneur’s innovation decision. Rogers (1995) and Rogers and Shoemaker (1971) divided the innovation adoption process into five stages: (a) awareness, (b) interest, (c) evaluation, (d) implementation, and (e) adoption.

From this theory of adoption, the factors that affect their decision could be demographics of the entrepreneur or owner, organizational characteristics, and communication channels. These factors can be further explained by IIT and the decision theory of small enterprises. IIT is based on who adopts the innovation (Nutley et al. 2002). The percentage of individuals who adopt an innovation is often illustrated by a bell-shaped curve. Small enterprises’ such as MSMFEs’ culture is entrepreneurship-oriented and their ownership and management are inseparable. Thus, decisions (including TIA) are greatly influenced by the entrepreneurs’ or owners’ personal demographics. This study believes that the analysis of small enterprises' decisions to adopt an innovation is a form of dynamic decision analysis, which involves the interaction of factors which are interrelated in a complex manner.

As well as the determinants of apportionment at the individual level, Rogers (1995) pointed out that there are various external or social conditions that may accelerate or slow down TIA. These are the characteristics of decision-makers (adopters), sources of information about an innovation, be it mass media or interpersonal, and extent of change agents' (advertisers, development agencies, etc.) promotion efforts.

On the other hand, the decision theory of small enterprises describes entrepreneurs utilizing primarily a very informal approach to decision-making. As entrepreneurs operate their business with limited skills and knowledge, their decision making is very much influenced by personal and organizational characteristics (Shahadan 1996). This study therefore considers such factors for TIA.

To understand the process involved in the enterprises' innovation adoption, it is useful to examine their decision process (Figure 1), which could be affected by the owners’ personal demographics, organizational characteristics, and communication channels.

---

**Figure 1.** Factors influencing the decision to adopt among SMEs and their extent of adoption.
The characteristics of entrepreneurs or owners are influential at the following stages: awareness, interest and evaluation. At the first stage, for instance, entrepreneurs with higher levels of education or those who have upgraded their skills by attending courses or those with a higher need for achievement tend to have early awareness of the innovation (Shahadan 1996). Entrepreneurs with these characteristics usually demonstrate innovative behavior and they search for opportunities to improve their enterprises' productivity. Hence, at the interest stage, they tend to develop an interest in the innovation because they believe that – by adopting it – they will improve their business' performance.

At the evaluation stage, the entrepreneurs' level of education, skills and attitude toward risk influence their perception of the innovation. According to Shahadan (1996), those with higher levels of education, skills or knowledge of the innovation or those with greater propensity to take risks will evaluate favorably an innovation of a higher technical level.

The age of the entrepreneurs is a factor influencing innovation adoption. Korteling (1994) argued that young entrepreneurs are more innovative than older entrepreneurs due to their higher level of education. Young individuals are capable of handling complicated tasks and are receptive to change. However, it is also argued that older people are equally capable of attitude change as younger people, provided they have personal experience that leads to attitude change (Tyler and Schuller 1991). Older entrepreneurs can thus be regarded as innovative as young entrepreneurs, based on experience.

The gender of entrepreneurs also influences innovative behavior. Varyiam and Kraybill (1993) showed a relationship between entrepreneurs' gender and TIA in small enterprises. Female entrepreneurs are less mobile, less communicative, and have less opportunity to attend business courses due to their domestic commitments (Shahadan 1996, Wan Sarah et al. 1992). They venture into a business to contribute to family income (Idris and Shahadan 1991, Berma and Shahadan 1991). This study predicts that female entrepreneurs will be less innovative than male entrepreneurs.

Entrepreneurs' experience in managing their enterprises may affect their decision to adopt technological innovations. Those who have been working for many years have more experience, are very familiar with their business environment, have wider business contacts, have better access to information, and are able to seek business opportunities (Shahadan 1996). Experience makes them confident in decision-making. These entrepreneurs will likely adopt technological innovations earlier than their counterparts because they know about its existence earlier. However, new entrepreneurs with less experience in managing their business can also be innovative. They are under pressure to be competitive with existing and established enterprises. To be competitive, they have to innovate.

Business scale influences the entrepreneurs' decision at the stages of awareness, interest, evaluation, implementation, and adoption. Among small enterprises, relatively bigger enterprises have a greater tendency to become aware of the existence of the innovation earlier and show more interest in it. At the evaluation stage – according to Sahut and Peris-Ortiz (2013) – for the same level of technical complexity of an innovation, less complex enterprises will evaluate it differently from more complex enterprises.

Small enterprises, with their simple structure, are conducive to innovation (Shahadan 1996). On the other hand, other characteristics of small enterprises, such as lack of capital and lack of skilled workers act as barriers. Therefore, the influence of organizational characteristics on the innovation adoption process is worth examining. Organizational characteristics such as type of organization, business scale, and type of market (domestic and/or export) can influence TIA among MSMFEs.

The type of organization is a determinant of innovation adoption. SMEs generally have simpler organizational structure, less management hierarchy, and a more centralized decision-making process; entrepreneurs have more decision-making power. For example, a sole proprietor's buying decision will be less affected by interpersonal factors (Shahadan 1996). For SMEs with more than one owner (partnership or private limited company), decision-making is more complicated because decisions are made jointly by a group of individuals (shareholders). SME owners who are normally sole proprietors or partners are highly involved in the operation of their firms, engaging in different aspects and levels of the decision-making process (Shahadan 1996).

As mentioned by Shahadan (1996), communication also plays an important role in all stages of the adoption process. Through communication, information on innovation is accumulated from awareness to implementation stages. Having considerable information about the innovation, firms tend to develop interest in it, are able to evaluate it, and have the opportunity to try it before allowing its introduction.

To better understand the different types of technological innovation efforts in relation to each other and to MSME performance, it is important to think about the extent of innovation. The extent of TIA as the dependent variable in this study (Figure 1) is defined as the breadth and depth of using technological innovations in different aspects of the enterprise. It refers to the number of new products,
new processes, new technologies, new organizational structures, or new managerial approaches that an enterprise adopts within a given period (Damanpour 1991).

The extent of TIA varies from one enterprise to another. One might use a technological innovation (e.g., manufacturing productivity extension or MPEX) to improve productivity in the form of an efficient process flow. Another might use it in several functional areas. Therefore, MSMFEs can be categorized according to extent of TIA: “did not or failed to adopt,” “less adopted,” “moderately adopted,” “highly adopted,” or “fully adopted.” The impacts of these TIA depend on the level of MSMFE adoption. If an enterprise has fully adopted technological innovations, then that enterprise might have a greater impact on its business compared with those that did not adopt or who adopted the innovations less. This study proposes that:

**Hypothesis 1.** Males are likely to adopt more technological innovations than females.

**Hypothesis 2.** The higher the educational attainment of the owner, the more likely he/she will adopt more technological innovations.

**Hypothesis 3.** Micro enterprises are likely to adopt more technological innovations than small and medium ones.

**Hypothesis 4.** MSMFEs with ties to export markets are likely to adopt more technological innovations.

### MATERIALS AND METHODS

This study covered the proprietors of MSMFEs that received DOST’s SETUP funding in the study area from 2004–2015 based on records of DOST XI in Davao Region, Philippines. The existing SETUP data from 2004–2015 show that 52 MSMFEs in the region obtained assistance from the program. The main technological innovation is the equipment upgrading of MSMFEs. All of them have acquired upgraded food processing equipment for their business through SETUP. The technological innovations identified for adoption by MSMFEs under SETUP are the following: good manufacturing practices (GMP) assessment, plant layout, food safety training, product development, technology training, packaging and labeling, laboratory analysis, MPEX consultancy, energy audit, and cleaner production technology (CPT) consultancy. These technological innovations for adoption are additional services of DOST-SETUP’s package of assistance given to MSMFEs. All are vital to the enterprises and complement the equipment acquired from SETUP.

A complete enumeration (census) of these MSMFE-beneficiaries was done for data analysis. Relevant data collected are detailed below (Table 1):

### Data Analysis

This study utilized quantitative (index construction and ordered LR) and qualitative (case study) analyses.

The index per MSMFE for the extent of its TIA was constructed. This adoption index per respondent (say $y_t$, where $t = 1$ to $K$ respondents) is the summation of the product of technological innovations actually adopted by the said respondent (say $x$, where $x$ is 1 if adopted or 0 otherwise) and the technological innovations the population of MSMFEs viewed as important to the enterprises (say $w$, where $w$ is the weight per technological

<table>
<thead>
<tr>
<th>Table 1. Summary of indicators with corresponding variables in the analysis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator</td>
</tr>
<tr>
<td>Extent of TIA</td>
</tr>
<tr>
<td>· GMP assessment</td>
</tr>
<tr>
<td>· Technology training</td>
</tr>
<tr>
<td>· Packaging and labeling</td>
</tr>
<tr>
<td>· Laboratory analysis</td>
</tr>
<tr>
<td>· MPEX consultancy</td>
</tr>
<tr>
<td>· Plant layout</td>
</tr>
<tr>
<td>· Product development</td>
</tr>
<tr>
<td>· Energy audit</td>
</tr>
<tr>
<td>· CPT consultancy</td>
</tr>
<tr>
<td>· Food safety training</td>
</tr>
<tr>
<td>Personal demographics of MSMFEs</td>
</tr>
<tr>
<td>1. Age of owner</td>
</tr>
<tr>
<td>2. Sex of owner</td>
</tr>
<tr>
<td>3. Educational attainment of owner</td>
</tr>
<tr>
<td>4. Years of experience</td>
</tr>
<tr>
<td>Organizational characteristics of MSMFEs</td>
</tr>
<tr>
<td>5. Type of organization</td>
</tr>
<tr>
<td>6. Business scale</td>
</tr>
<tr>
<td>7. Type of market</td>
</tr>
<tr>
<td>Communication</td>
</tr>
</tbody>
</table>
innovation). The following equation details the formula to obtain the extent of adoption index:

\[ y_t = \sum_{j=1}^{K} x_{ij} w_i \]  \hspace{1cm} (1)

After computing for the indices \( y_t \)'s per technological innovation for adoption, parameters were then set and categorized according to the following fractile intervals:

1. Did not or failed to adopt
   \[ \text{if } y_t = 0 \]
2. Less adopted the technological innovation
   \[ \text{if } 0 < y_t \leq a \]
3. Moderately adopted the technological innovation
   \[ \text{if } a < y_t \leq b \]
4. Highly adopted the technological innovation
   \[ \text{if } b < y_t \leq c \]
5. Fully adopted the technological innovation
   \[ \text{if } c < y_t \leq 1.0 \]

With this classification, the MSMFEs were grouped depending on their extent of TIA. Thus, they were categorized into “did not adopt or failed to adopt,” “less adopted,” “moderately adopted,” “highly adopted,” and “fully adopted.”

The adoption indices were used to analyze the determinants of the extent of TIA among MSMFEs using the ordered multinomial model. It is expressed as follows:

\[ Y_i^* = B_1 X_{1i} + B_2 X_{2i} + \ldots + B_k X_{ki} + \mu_i \]

\[ = \sum_{n=1}^{k} B_n X_{ni} + \mu_i \]  \hspace{1cm} (2)

where \( Y_i^* \) is unobserved, the X’s are the regressors, and \( \mu_i \) is the error term. In this study, \( Y_i^* \) is the index variable from the extent of technology adoption among MSMFEs. Although it cannot be observed directly, the index variable depends on one or more regressors. In this case, the regressors or factors affecting TIA are the following:

- \( X_1 = \text{age of the owner} \)
- \( X_2 = \text{sex of the owner} \)
- \( X_3 = \text{educational attainment of the owner} \)
- \( X_4 = \text{years of experience in business} \)
- \( X_5 = \text{type of organization} \)
- \( X_6 = \text{business scale} \)
- \( X_7 = \text{type of market} \)
- \( X_8 = \text{sources of information} \)

Furthermore, this study supposed \( n \) independent MSMFEs that face \( J \)-ordered alternatives, such that

\[ Y_i = 0, \text{ if } Y_i^* = 0 \]
\[ Y_i = 1, \text{ if } Y_i^* \leq a_1 \]
\[ Y_i = 2, \text{ if } a_1 < Y_i^* < a_2 \]
\[ Y_i = 3, \text{ if } a_2 < Y_i^* < a_3 \]
\[ \vdots \]
\[ Y_i = J, \text{ if } a_{j-1} \leq Y_i^* < a_j \]

That is, MSMFE \( Y_i \) can be observed in one of the \( J \) ordered categories; these categories are being separated by the threshold parameters or cutoffs: the \( a \)'s. In other words, the threshold parameters demarcate the boundaries of the various categories. Hence, this is the fractile interval described as the index in the extent of TIA.

The method of estimation, as in all multinomial regression models, is by the method of maximum likelihood. The underlying estimation principle is as follows:

\[ \Pr(Y_i \leq j) = \Pr(B_1 X_{1i} + B_2 X_{2i} + \ldots + B_k X_{ki} + \mu_i \leq a_j) = \Pr(\mu_i \leq a_j - B_1 X_{1i} - B_2 X_{2i} - \ldots - B_k X_{ki}). \]  \hspace{1cm} (3)

The preceding equation gives the cumulative probability that \( Y_i \) falls in category \( j \) and below \( (i.e., \text{in category 0, 1, 2, \ldots, or } j) \). To compute for the probability that a random variable takes a value equal or less than a given number, the cumulative distribution function of probability distribution was used. In this study, the error term is assumed to follow the logistic distribution; hence, the estimation method used is the ordered LR model.

Regression diagnostics such as multicollinearity using the variation inflation factor (VIF) of the variables considered in the study were performed. As a rule of thumb, a variable whose VIF value is greater than 10 may merit further investigation.

The study also involved the employment of an interview schedule with a structured questionnaire administered to the MSMFEs. The regressors or factors affecting TIA are based on information taken before MSMFEs adopted the technological innovation offered by SETUP.

The major findings were analyzed and contextualized at a particular food processing enterprise to triangulate the results of the quantitative analysis. The major concerns that arose from the results were interpreted using a case study of enterprise representatives per business scale.

RESULTS AND DISCUSSION

Of the 52 MSMFEs, 41 adopted the food safety training – making this innovation the most adopted one. Product
development and CPT consultancy were the least adopted innovations with only nine MSMFEs adopting them. Table 2 shows a summary of the technological innovations adopted by enterprises per business scale.

As mentioned, the most adopted innovation was food safety training, mostly accessed by the micro food processing enterprises. Most of the micro enterprises found it difficult to get licenses to operate from the Food and Drug Administration and sanitary permits from their municipalities. This was the major area for improvement/weakness of the micro enterprises. They need to strengthen the food safety aspect of their operations as they aim to penetrate markets that require food safety certification. Half of the small and medium enterprises implemented this innovation in their operations. Overall, this innovation was adopted by enterprises regardless of the business scale.

The recommendations from GMP assessment have been adopted by 36 MSMFEs. This was the second most adopted technological innovation. Its implementation is a continuous process based on the management concept of the PDCA (plan, do, check, and act) cycle. In this study, GMP adoption of MSMFEs through this assessment accounted for 69% of the population. This was mostly adopted by micro food processing enterprises. In contrast, no medium enterprise accessed this innovation. Micro and small enterprises, unlike the medium enterprises, have yet to acquire GMP certification. DOST is focusing on the benefits of its food safety program to help MSMEs fast-track the permit and registration process.

Technology training is vital to MSMFEs because having new equipment in their production system could mean gaining mastery in operating the said technology. This innovation is needed for the enterprise to maximize its use of the upgraded equipment. Fifty-four percent (54%) of the population adopted this, mostly micro food processing enterprises. On the other hand, 70% of the small enterprises adopted this innovation. There was one medium enterprise that applied this innovation in their operation. Overall, technology training was adopted by enterprises regardless of the business scale.

Plant layout is the fourth most adopted technological innovation, implemented by 60% of the population. This was mostly adopted by micro food processing enterprises. Sixty percent (60%) of the small enterprises adopted this innovation (the second most adopted). On the other hand, no medium enterprise took up this innovation.

The next most adopted innovation was MPEX consultancy, adopted by 56% of the population and mostly accessed by the micro food processing enterprises. Sixty percent (60%) of the small enterprises adopted this innovation. No medium enterprise did so. As in other innovations, MPEX was adopted by only the micro and small enterprises.

With assistance from the energy audit team of DOST XI, 22 MSMFEs or 42% of the considered population of SETUP beneficiaries in Region XI adopted the innovation, mostly implemented by the micro food processing enterprises. Fifty percent (50%) of the small enterprises were adopters. No medium enterprise implemented this innovation in their operation.

Packaging and labeling was the next most adopted innovation offered by SETUP. With the help of in-house experts of DOST XI, 42% of SETUP MSME beneficiaries adopted this innovation. This was mostly accessed by micro food processing enterprises. Only 30% of the small enterprises and none of the medium

<table>
<thead>
<tr>
<th>Category</th>
<th>Rank</th>
<th>Frequency</th>
<th>Percent</th>
<th>Business scale (%)</th>
<th>Micro</th>
<th>Small</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food safety training</td>
<td>1</td>
<td>41</td>
<td>79</td>
<td>88</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>GMP assessment**</td>
<td>2</td>
<td>36</td>
<td>69</td>
<td>73</td>
<td>70</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Technology training</td>
<td>3</td>
<td>34</td>
<td>65</td>
<td>65</td>
<td>70</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Plant layout</td>
<td>4</td>
<td>31</td>
<td>60</td>
<td>63</td>
<td>60</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MPEX**</td>
<td>5</td>
<td>29</td>
<td>56</td>
<td>58</td>
<td>60</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Energy audit</td>
<td>6.5</td>
<td>22</td>
<td>42</td>
<td>43</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Packaging and labeling</td>
<td>6.5</td>
<td>22</td>
<td>42</td>
<td>48</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laboratory analysis</td>
<td>8</td>
<td>20</td>
<td>38</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Product development</td>
<td>9.5</td>
<td>9</td>
<td>17</td>
<td>20</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CPT consultancy**</td>
<td>9.5</td>
<td>9</td>
<td>17</td>
<td>18</td>
<td>10</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

*Multiple responses
**GMP – good manufacturing practices, MPEX – manufacturing productivity extension, CPT – cleaner production technologies
enterprises adopted this innovation. Packaging and labeling was adopted by micro and small enterprises only.

In spite of its importance and being required of MSMFEs, only 38% of the MSMFEs had subjected their products to laboratory analyses in DOST XI's Regional Standards and Testing Laboratory. This is the third least adopted innovation. It was mostly accessed by micro food processing enterprises. Forty percent (40%) of the small enterprises adopted this innovation. No medium enterprise submitted their products for testing and analysis in the laboratory of DOST XI.

The product development innovation has been adopted by only nine MSMFEs from a total of 52. This was one of the two least adopted innovations. It was mostly accessed by micro food processing enterprises. Ten percent (10%) of the small enterprises adopted this innovation. Again, there were no adopters among medium enterprises. Thus, product development under SETUP was adopted only by micro and small enterprises.

CPT consultancy was also the least adopted innovation from SETUP. Only 17% of the population adopted this innovation, mostly accessed by micro food processing enterprises. Ten percent (10%) of the small enterprises adopted this innovation. Although this was the least adopted, there was one medium enterprise that took up this innovation. Overall, CPT was adopted by enterprises regardless of business scale.

It was found that the most adopted combination of technological innovations was food safety training, GMP assessment, and MPEX. Interestingly, these three innovations are interrelated. Most of the recommendations of the MPEX consultants pertain to the implementation of food safety training and GMP assessment in the enterprises.

As previously described, the frequency in adopting each technological innovation does not imply the depth and breadth of its adoption. It further needs an evaluation of how important every innovation is to the MSMFE to determine the extent of TIA. Results show that 11 MSMFEs fully adopted the said innovations. Meanwhile, two MSMFEs did not or failed to adopt the technological innovations offered by SETUP. The majority of the MSMFEs were in the highly adoptive level. Table 3 summarizes the extent of TIA among the 52 MSMFEs.

All the medium enterprises were in the less-adopted level. The majority of the micro enterprises highly adopted the innovations. In the case of small enterprises, most of them were moderate to high adopters.

The ‘Fully Adopted’ MSMFEs
Fully adopting the technological innovations of SETUP is the highest and most desirable level of adoption. However, only 21% of the MSMFEs were able to fully adopt such innovations, implying that DOST efforts to encourage more MSMFEs to adopt these technological innovations still need to be improved. One hundred percent (100%) of the MSMFEs have adopted three technological innovations: GMP assessment, MPEX, and food safety training. This was followed by technology training, packaging and labeling, and plant layout, all at 91%. Only 36% adopted CPT, making it the least adopted technology. The micro enterprises under this category adopted, on average, all 10 innovations; while small enterprises only adopted, on average, eight innovations. They did not adopt laboratory analysis and product development.

The ‘Highly-adopted’ MSMFEs
The characteristics of MSMFEs with high TIA were quite different from those of the other adoption groups. The MSMFEs under this category have adopted GMP assessment the most (100%). This was followed by food safety training and technology training. The least adopted innovation was product development and CPT consultancy. Thirty-three percent (33%) of the MSMFEs were at this level. In this category were 13 micro food processing enterprises and four small. Thus, one-third (33%) of all the micro enterprises, 40% of all the small enterprises, and none among the medium enterprises ‘highly adopted’ the technological innovations of SETUP. The degree of adoption in this category was higher than the previously discussed adoption levels. The micro

Table 3. The extent of TIA among MSMFEs, by business scale (N = 52).

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>Percent</th>
<th>Business scale (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Micro</td>
</tr>
<tr>
<td>Fully adopted</td>
<td>11</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Highly adopted</td>
<td>17</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Moderately adopted</td>
<td>16</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Less adopted</td>
<td>6</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Did not or failed to adopt</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
enterprises under this category adopted, on the average, all technological innovations; whereas small enterprises also adopted, on average, all except for CPT.

The ‘Moderately-adopted’ MSMFEs
Sixty-one (61%) percent of MSMFEs in this level produced new products in the last three years. Unlike the ‘less-adopted’ enterprises that adopted seven out of 10 technological innovations, there was at least one ‘moderately-adopted’ MSMFE that adopted at least one of 10 innovations from SETUP. Hence, this category has the characteristic that it can adopt 10 out of 10 technological innovations on the average, but the degree of innovation still varies from one enterprise to another. Among these innovations, food safety training was adopted the most (63%), followed by GMP assessment and technology training. The least adopted was product development and CPT, both at 6%. Thirty-one percent (31%) of the MSMFEs belonged to this category; 12 micro food processing enterprises and four small. Thirty percent (30%) of the micro enterprises, 40% of the small enterprises, and none of the medium enterprises adopted technological innovations moderately. The micro enterprises under this category adopted at least one technological innovation, while small enterprises also adopted all except for product development, plant layout, and CPT.

The ‘Less-adopted’ MSMFEs
The MSMFEs belonging to this category only adopted five innovations: technology training, MPEX, plant layout, CPT, and food safety training. Among these innovations, they adopted food safety training the most (67%), followed by plant layout and technology training (33%). Those belonging to this group were three micro food processing enterprises, one small, and two medium. This means that 8% of all micro enterprises, 10% of all small enterprises, and 100% of all medium enterprises had less adoption of technological innovations. As per validation, the medium enterprises only ‘less adopt’ these innovations because they are already well-established, and they see no value in them being added. For instance, they already have food technology experts in-house who help them meet the technological needs of the enterprise. The micro enterprises under this category only adopted technology training, plant layout, and food safety training; whereas small enterprises adopted only MPEX and plant layout. On the other hand, medium enterprises adopted technology training, food safety training, and CPT. This makes CPT the only innovation adopted by all enterprises regardless of business scale.

The ‘Did-not-adopt’ MSMFEs
The two enterprises that did not or that failed to adopt the technological innovations of SETUP had similar characteristics. Both were micro enterprises and were SETUP proponents with terminated projects or whose projects were subject to termination. Both enterprises were devastated by Typhoon Pablo in 2012. One of them stopped operating after the typhoon and did not use the funding from SETUP for its intended use. This enterprise did not believe that technological innovations from SETUP would have a positive impact on their business. Conversely, the other enterprise did use the fund properly but did not inform DOST XI immediately that their company was already bought by a foreign investor (Korean) in 2013. The enterprise’s management decided to sell the company because they cannot afford the major repair needed after the typhoon. Their product, banana chips, was most affected in the aftermath of the typhoon. Hence, both enterprises violated the terms and conditions in the duly signed memorandum of agreement between the enterprise and DOST XI. These enterprises are now subject to legal action.

The adoption level was affected by eight factors: personal demographics of the owner, organizational characteristics, and sources of communication. Among the factors, this study found significant determinants of TIA among MSMFEs using ordered LR.

The results of the ordered logistic estimation are given in Table 4. Ordered LR was used because the dependent variable (level of adoption) has more than two meaningful orders. As shown in the table, several results immediately stood out. Four variables (sex, business scale, educational attainment, and type of market) had highly significant coefficients at the 5% level of significance and are considered significant predictors of the extent of TIA among MSMFEs.

Table 4. Results of logit regression analysis (N = 52).

| Variable             | Coefficient | Std. error | Wald  | Prob. (> |e|)  |
|----------------------|-------------|------------|-------|----------|------|
| Age                  | 0.0270      | 0.0354     | 0.76  | 0.4458   |
| Sex                  | −1.1295     | 0.5610     | −2.01 | 0.0441*  |
| Organization type    | 0.2133      | 0.7756     | 0.27  | 0.7833   |
| Experience           | −0.0015     | 0.0283     | −0.05 | 0.9580   |
| Business scale       | −1.2832     | 0.6390     | −2.01 | 0.0446*  |
| Education            | 1.4316      | 0.7231     | 1.98  | 0.0477*  |
| Type of market       | 0.9467      | 0.4755     | 1.99  | 0.0465*  |
| Information source   | −0.6375     | 0.6927     | −0.92 | 0.3574   |

Observations (no.) = 52
Degree of freedom (df) = 8
LR chi-square (df) = 19.83
Prob (> chi-square) = 0.0110**

**Significant at 5% level
All the medium enterprises were in the less-adoptive level. The majority of the micro enterprises highly adopted the innovations. In the case of small enterprises, most of them were moderate to high adopters.

The first statistically significant factor was the sex of the owner. The gender dimension of MSME development is evident in this study. Sixty percent (60%) of the adopters were female owners. According to Zarina and Mohd (2014), there are more female entrepreneurs than male entrepreneurs because the former are already oriented in making money and willing to create new markets. Their participation in entrepreneurial activities was encouraged as another way to improve family income. Within the Asia-Pacific region, the share of women SME owners is evident, with 35% of all SMEs being headed by women.

Although there were more female MSMFE owners as shown in the descriptive statistics, MSMFEs run by male owners were more likely to extensively practice TIA. This can be attributed to the fact that more male owners highly and fully adopted the innovations than did female owners. This confirms the findings of Wan Sarah et al. (1992) that female entrepreneurs are less likely to adopt more technological innovations as they are less mobile, less communicative, and have less opportunity to attend business courses because of domestic commitments.

As observed, the variable “sex of the owner” had a negative coefficient (–1.13), which suggests that an increase in the number of females adopting technological innovations will result in lesser adoption extent; furthermore, a 1.13 decrease in the log odds of females being in a higher level of adoption is observed, given that all of the other variables in the model are held constant. It was noted that the majority of the female owners ‘less adopted’ or only ‘moderately adopted’ the innovations, in contrast to majority of the male owners who had high and full adoption. Hence, this study reveals that males are more likely to adopt more technological innovations of SETUP. Cross-tabulating the gender dimension with another statistically significant predictor of technological innovation, educational attainment, it was discovered that there were more male owners with higher educational attainment who highly and ‘fully adopted’ the innovations than female owners.

The business scale, which is a statistically significant predictor of the model, also had a negative estimated effect (–1.28) on the level of adoption. If the business scale is increased by a unit (say, from micro to small), the ordered log-odds of adopting technological innovations decreases by about 1.28, holding all other regressors constant. This simply means that micro enterprises have a greater chance to adopt more technological innovations compared with small and medium enterprises. As observed, 77% of the MSMFEs that adopted technological innovations were micro enterprises. These findings confirm the study of Sahut and Peris-Ortiz (2013). The validation visits further found that micro enterprises have a less developed R&D capability than their larger counterparts and that they rely more heavily on R&D results from outside research institutions. Also, micro enterprises have lesser hierarchy or line of authority; thus, decisions here are made faster compared with larger enterprises. This explains their greater likelihood to adopt technological innovation.

Unlike the first two significant predictors, educational attainment was found to have a positive effect on the level of adoption. As MSMFE owners earn a degree one step higher (say, from high school to college), the ordered log-odds of adopting technological innovations increase by about 1.43, holding all other regressors constant. It was also found that majority of the owners who adopted the innovations were college graduates – most of them moderate to full adopters. Overall, this implies that the higher the level of education of the owner, the more likely he/she will extensively adopt the technological innovations of SETUP. At a higher level of education, owners were already knowledgeable as they have had 14 years of formal education and they have the potential to be trained. This result is supported by the literature. GEM (2010) reported that enterprises with healthy and educated owners are more competitive, productive, and likely to adopt technological innovations.

Similarly, the type of market – a significant predictor of the model – turned out to have a positive effect on the extent of adoption. If MSMFE owners were to increase their type of market by one point (from domestic only to export), their ordered log-odds of being in a higher level of adoption would increase by 0.95, with other variables held constant. MSMFEs that cater to both export and domestic markets were found to more likely adopt more technological innovations offered by SETUP. The type of market is a significant predictor as MSMFEs supplying the export market would tend to adopt more to conform with international standards, which validates the study of Bleaney and Wakelin (1999). As reflected in the survey data, 75% of the MSMFEs with export products have high to full adoption.

The other four variables, however, all failed to achieve the 5% level of statistical significance: age, organization type, years of business experience, and source of information of SETUP. This implies that the said factors are not significant predictors of the extent of technological innovation, showing an inconsistent trend in the ordered logistics model. This information can help DOST management in choosing potential SETUP beneficiaries.
Given these outputs, this study further tested for multicollinearity of the predictors. This may be the reason these four independent variables did not achieve statistical significance.

To test for multicollinearity of the variables, the variance inflation factor (VIF) was computed. The VIF (1/tolerance) is an appropriate tool for multicollinearity ordered LR diagnostic. As a rule of thumb, a variable whose VIF value is greater than 10 may merit further investigation. This study shows that all the VIF values of the variables were less than 10, meaning that multicollinearity is not an issue among the variables considered.

Under the null hypothesis that all regressor coefficients are zero, LR follows the chi-square distribution with degrees of freedom (df) equal to the number of regressors, eight in this case. The results show that the chi-square value was about 20.61. If the null hypothesis were true, the chances of obtaining a chi-square value of as much as 20.61 or greater are 0.0082, which is less than the 0.05 level of significance. Despite all these observations on the coefficients – which might be due to a small sample size – collectively, all regressors have a strong influence on the extent of TIA. This simply tells us that the model as a whole is statistically significant compared with the null model with no predictors.

Fitting all the predictors in the model using ordered LR, there is a 4% chance that MSMFEs do not adopt the technological innovations of SETUP, an 11% chance for them to adopt the innovations less, 31% chance to moderately adopt, 34% chance to highly adopt, and 20% chance to fully adopt. Hence, the majority of the MSMFEs adopted the package of assistance on technological innovations of SETUP. In summary, the owners or MSMFEs with the following characteristics have a greater chance of adopting more technological innovations: male, micro enterprise, higher educational attainment, and catering to the export market. The strongest determinants of the extent of TIA among MSMFEs were sex of owner and business scale.

These key results were validated through case studies to Enterprise K (micro enterprise engaged in coco sugar business), Enterprise A (small enterprise engaged in rice milling), and Enterprise M (medium enterprise engaged in chocolate-making).

Case Study of Enterprise K
Three out of the four significant determinants from the quantitative results (educational attainment, business scale, and type of market) are reflective to Enterprise K.

Enterprise K is a single-proprietorship-type of micro-scale business that engages in coco sugar production. The enterprise was established by a female owner who has a Master of Business Administration degree and a diploma in Research and Development Management. Even from the start, the owners were oriented toward making money and were willing to create new markets to improve family income. She admitted not having much experience in business before adopting the technological innovations of SETUP. She took the risk because she wanted to make their business grow the soonest time possible, and wished to be able to penetrate the national and international markets. It was then new in the business industry; thus, the product and its health benefits were only known to a few people. In fact, they forged a contract with an international distributor of coco sugar in Belgium. This was one of the driving factors why they decided to adopt more technological innovations of SETUP. They need to innovate to comply with international standards. Their machinery and equipment were upgraded through SETUP.

Aside from that, Enterprise K has fully adopted the technological innovations of SETUP. Specifically, the enterprise has adopted eight out of the 10 technological innovations: food safety training, plant layout, GMP assessment, MPEX consultancy, laboratory analysis, energy audit, product development, and technology training. The owner admitted that their enterprise has less developed R&D capability than their larger counterparts. With this constraint, they have relied more heavily on external R&D output of research institutions. The owner strongly believed that the technological innovations adopted from SETUP have brought significant changes in their business. Particularly, it has increased their annual gross sales by Php 2,402,863.52 after TIA, increased income by 1,118%, generated more employment by 157%, increased daily wage rates of their direct workers by Php 115.94 on the average, enabled them to qualify for international certification, improve their products, and increase their market reach. The quantitative data were further confirmed through success stories shared by the owner and his workers.

CONCLUSION
A modified theoretical framework focusing on the “extent” of TIA among MSMFEs was developed in this study. Using the framework, this study predicts that the extent of TIA among MSMFEs is influenced by several factors: personal demographics of the owner (age, sex, years of experience, and educational attainment), organizational characteristics (business scale, organization type, and type of market), and sources of communication. It was discovered that only four or half of the factors considered were highly significant predictors (sex of owner, educational attainment, business scale, and type
of market) of the degree of uptake of technological innovations among MSMFEs. MSMFE owners who are normally sole proprietors or partners in this study were highly involved in the operation of their enterprises and, thus, were involved in different aspects and levels of the decision-making process.

MSMFEs are entrepreneurship-oriented and their ownership and management are inseparable; thus, decisions (including TIA) are greatly influenced by entrepreneurs' personal demographics, as likewise noted by Sajilan et al. (2015). The extent of TIA among these enterprises was mainly influenced by the sex of the owner [consistent with the findings of Wan Sarah et al. (1992)] educational attainment (Korteling 1994), business scale (Mishra 2016), and type of market (Bleaney and Wakelin 1999).

It is the goal of SETUP to assist more MSMFEs in the country through technological innovation. Hence, DOST should put emphasis on these highly significant factors to achieve program efficiency in identifying their beneficiaries: male, higher educational attainment, micro enterprise, and caterer to both domestic and export markets.

The type of market was found to be a significant factor related to TIA. Thus, enterprises engaged in both local and export markets could be potential SETUP beneficiaries. The results showed that only the micro enterprises have highly significant predictors of the extent of TIA, which were similar to the overall analysis: sex of the owner (male), educational attainment (higher educational attainment), and type of market (domestic and export).

This study confirms what previous research (Mishra 2016) has found that, among enterprises of different sizes, the micro enterprises are generally more flexible, can adapt themselves better, and are better placed to develop and implement new ideas. The flexibility of micro enterprises considered in this study, their simple organizational structure, their low risk, and their receptivity are the essential features that facilitate the adoption of more technological innovations. Therefore, micro enterprises among MSMFEs have the unrealized innovation potential that needs to be tapped.

RECOMMENDATIONS

This study suggests that DOST should formulate additional measures or improve existing guidelines on SETUP to encourage more MSMFEs to fully adopt technological innovations. To develop an efficient program or to improve SETUP, DOST should focus on the micro enterprises with characteristics suggested by the significant predictors. MSMFEs – should there be a need for them to hire a manager or a new team member or set a strategic direction of their business – can use this study as a reference, emphasizing on the said significant determinants of the extent of TIA.

This study was done on a specific time setting or area to determine the extent of TIA among MSMFEs. It will be more promising if the following were considered: (1) increasing the number of samples; (2) scaling up the analysis to national level; (3) extending the comparative analysis to the sector level and not only to food processing; (4) considering other variables such as training status, entrepreneurial motivation, attitude toward technological innovation, expected net gain/ profit that can be derived from TIA, among others, to have a comprehensive analysis; and (5) extending the analysis to other forms of innovation such as market and organizational innovation.

ACKNOWLEDGMENT

This paper was a part of a Ph.D. dissertation. We are grateful to our family and friends for encouraging us to publish the results of this dissertation. Funding and related support from the Southeast Asian Regional Center for Graduate Study and Research in Agriculture and the DOST – Human Resources Development Program is gratefully acknowledged.

REFERENCES


837


ORLANDO B, RENZIA, VAGNANI G, VOLPE L. 2013. Determinants of innovation adoption: A literature review and future avenues of research. Sapienza Research Unit, Sapienza University of Rome, Ancona, Italy.


