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A general framework incorporating knowledge, risk perception and practices to eliminate pesticide residues in food: A Structural Equation Modelling analysis based on survey data of 986 Chinese farmers

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ABSTRACT

Following a variety of incidents in China relating to food poisoning due to the presence of pesticide residues, it is crucial to correct for farmers' unsafe and improper practices towards pesticide use. Although most studies have focused on the role of external stakeholders such as government extension agencies and pesticide retailers, the attention paid to farmers' intrinsic motivations is limited. This paper applies Structural Equation Modelling to investigate psychological motivational concepts such as farmers' knowledge and risk perception, their formation mechanisms and the underlying processes of these concepts that lead to farmers' practices to eliminate pesticide residues, based on a representative survey conducted with 986 Chinese farmers from 20 counties selected from six provinces. We found both a direct and significant effect of farmers' knowledge on pesticides residue on their safe pesticide practices and also an indirect effect, i.e. knowledge influences on risk perception which in turn enhances safe pesticide practices. It was also reported that government support strategies are more effective in promoting safe pesticide practices than government regulation.

1. Introduction

China consumes an annual of 1.8 million tons of pesticides, making China world's largest pesticide user (Ministry of Agriculture, 2016). However, pesticides have been widely over-used by farmers with a surprisingly 40% of pesticides were used excessively by spraying more times than required and using higher doses than recommended (Peng, Tang, & Zou, 2009). Chinese farmers sprayed annually 14 kg/ha of pesticides, which is several-fold higher than the amounts applied in the USA (2.2 kg/ha) and France (2.9 kg/ha) (Yang et al., 2014). The over-use has caused an annual of 200,000 pesticide-poisoning accidents and also indirectly via diet-related diseases due to the accumulation of pesticide residues in food (Xu, Kuang, Pay, Dou, & de Snoo, 2008). Pesticides residues have been found to exceed the maximum residue limits in samples of vegetables and fruits in Nanjing (Wang, Liang, & Jiang, 2008), Xiamen (Chen et al., 2011) and Shaanxi (Wang, Wang, Zhang, Wang, & Guo, 2013).

Attempts have been made to change farmers' pesticide use behaviors by external stakeholders such as government extension agencies and pesticide retailers (Jin, Bluemling, & Mol, 2015; Yang et al., 2014). Other studies have blamed the commercialized agricultural extension systems which played a limited role in providing guidance on pesticide use (Hu, Yang, Kelly, & Huang, 2009; Zhang et al., 2015). Alternatively to the extrinsic stakeholder analyses, there is an increasing literature looking at intrinsic motivation which suggests that safe pesticide behaviors are based to a great extent on pesticides knowledge and perceptions of the associated pesticide risks. Based on a survey of 307 farmers from the Wei River basin, Fan et al. (2015) found that farmers' pesticide overuse is driven by limited knowledge and low awareness of pesticide risks. Similar findings were reported for Vietnamese farmers (Houbraken, Bauweraerts, Fevery, Van Labeke, & Spanoghe, 2016) and Kuwait farmers (Jallow, Awadh, Albaho, Devi, & Thomas, 2017). However, in those studies both knowledge and risk perception were independently and directly associated with behaviors. In fact,

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there exists a causal ordering from knowledge to perceived risk to safe pesticide behaviors. To the best of our knowledge, no attempt has been made to better understand the mechanism to which knowledge and risk perception of pesticide residues interact in facilitating safe behaviors. Nor has any study been conducted to address a more important research question, i.e. the psychological formation of knowledge and risk perception. In addition, the ranges of these psychological concepts that have been explored using SEM are limited. This paper tries to fill this gap.

The objective of the paper is to conceptualize a Structural Equation Modelling (SEM) framework that allows us to investigate the mediation effect of risk perception in the relationship between knowledge and practices to eliminate pesticide residues and to study the determinants contributing to the formation of knowledge and risk perception. Our study has several important advantages. First, compared with previous studies, it uses a much larger sample size surveyed from several provinces across China. Second, a SEM is used to structurally model the relationship between the determinants and knowledge, risk perception and behaviors within one framework. The rest of the paper is structured as follows. The conceptual model is presented in Section 2 and the SEM methodology is introduced in Section 3. Section 4 presents empirical results and Section 5 concludes.

2. Conceptual model

SEM allows the estimation of an integrated system of equations and has the advantage of measuring latent variables which exist but cannot be directly observed (Bollen, 1989). We constructed a SEM conceptual model in Fig. 1 which conceptualizes the latent endogenous variables, i.e. knowledge of pesticide residues (denoted by *Knowledge*), risk perception of pesticide residues (*Risk perception* thereafter) and safe pesticide use behaviors (*Behavior*), and specifies the relationships among the three endogenous variables and between the three endogenous variables and their influencing factors. Below we first define the three latent endogenous variables.

2.1. Latent endogenous variables

2.1.1. Knowledge of pesticide residues (Knowledge)

Several studies focused on farmers' knowledge on pesticides relating to their occupational health. For instance, Yassin, Mourad, and Safi (2010) defined the general knowledge of pesticide as the familiarity on the names of pesticides, health effects, methods to control pests, the mechanism pesticides affects the body, and the fate of pesticide residues. Similarly, Fan et al. (2015) measured farmers' pesticide knowledge by their understanding of pesticide toxicity, instruction manuals and pesticide labels, and the health risks posed to sprayers. Salameh, Baldi, Brochard, and Abi Saleh (2004) measured it as knowing the names of the pesticides used, and names of any dangerous pesticide and forbidden pesticides. However, our definition of knowledge differs from theirs and focuses on farmer's knowledge of pesticide residues in particular. For this purpose three questions were constructed. First, farmers' general knowledge was elicited by asking the question (*Knowledge1*): "*Do you know the concept of pesticides residues?*" on a 5-point scale "not at all", "slightly", "moderately", "very", and "extremely". Second, farmers' understanding of pesticides residues in foods was measured by the question (*Knowledge2*): "*Do you think frequent and massive use of pesticides cause residues in food products?*". Third, we measured farmers' knowledge on pesticides' waiting period (*Knowledge3*) which refers to the minimum length of time farmers must wait after the usage of pesticide before harvesting crops. The question was: "*Do you know about the waiting period of a pesticide?*" The second and third questions were on a 5-point scale ranging from "strongly disagree" to "strongly agree".

2.1.2. Perceived risk of pesticide residues (Risk perception)

Perceived risk refers to a psychological state which is formed in a way that people subjectively transform the objective risk of hazardous activities and technologies in causing immediate or long-term threats to their health and well-being (Slovic, 1987). In terms of perceived risks of pesticides, most of the existing work to date focused on farmer's perceived risks relating to farmers' own occupational health. For example, Arcury, Quandt, and Russell (2002) defined perceived risks as the health risks to farmworkers themselves, their children and unborn children. In contrast, we are interested in perceived risk with an emphasis on pesticide residues which may pose potential threats not only to crop prices but also to health risks of food consumers. For this purpose, we constructed three items that elicits respondents': (i) general perceived risk (*Risk1*), "*Do you agree that high pesticide residues impact food safety?*") (ii) perceived risk on decreased crop prices due to the

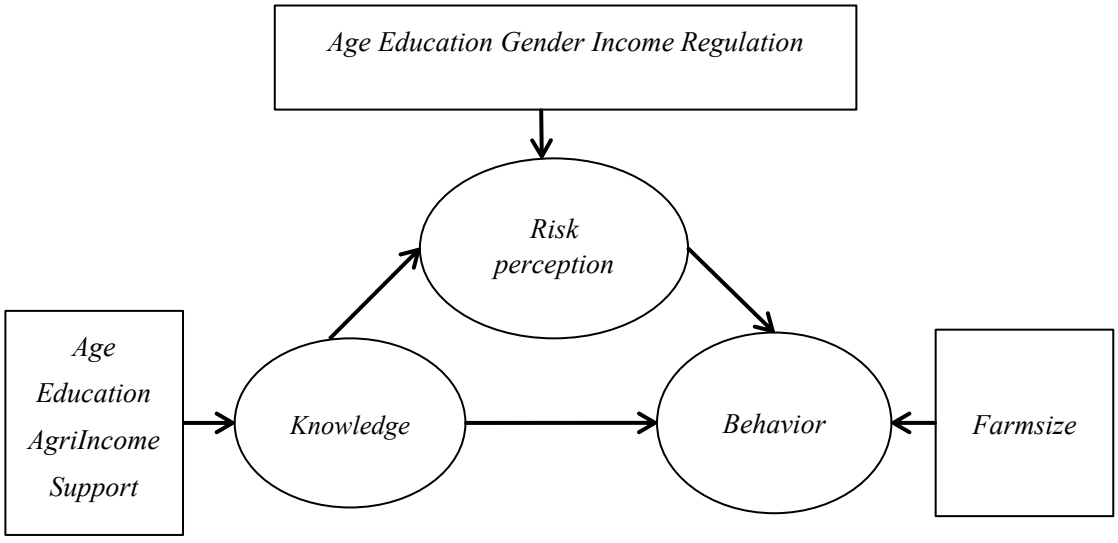

Fig. 1. Conceptual framework.