Impact of Farm Size and Uncertainty on Technology Disadoption

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Abstract

For policies that promote use of new technologies by farmers to be successful, it is important that farmers continue to use these technologies. Technology disadoption has not been analyzed in the literature widely and there is no theoretical model that analyzes technology disadoption. The objective of the current study is to provide a theoretical framework that explains the impact of farm size and uncertainty with respect to production technology on farmers' decision to disadopt a new technology. Current study found that a negative relationship between farm size and disadoption technologies that were complement to other technologies that are used by larger farms. Also, the current study predicted that larger farmers are more likely to disadopt a new technology if a fixed replacement cost is required, where average replacement cost decreases with farm size. For the impact of technological uncertainty, the current paper found that if the variance of the profit from current technology or pratice increases, farmers become more likely to disadopt the current technology or the practices.

Key Words: Technology Disadoption, Farm Size, Uncertainty, Environmental Quality

According to the National Water Quality Inventory, animal feeding operations are significant sources of water pollution in the U.S (Environmental Protection Agency 1998). Livestock production produces manure as a by-product, which contains nutrients such as nitrogen and phosphorous and without proper management, these nutrients can degrade water sources (Aillery et al. 2005). The National Water-Quality Assessment Program found that the highest concentration of nitrogen and phosphorus in streams occurred in basins with extensive agricultural production and that high nitrogen and phosphorus concentrations in these streams were mostly due to livestock wastes and manure and fertilizer used for crop production (U.S. Department of Interior 1999).

Nitrogen is found in the environment and it is crucial for living organisms, especially as a nutrient for crops. The elemental nitrogen gas in the atmosphere is not hazardous to environmental quality. However, ammonia and the nitrate form of nitrogen are dangerous to environmental quality, as they can combine with other compounds and create environmental problems (Aillery et al. 2005). Nitrate is an important plant nutrient but in water sources it can cause over growth of plants, which causes the amount of dissolved oxygen required by fish and other organisms to decrease, causing the death of living organisms in water sources (a situation known as eutrophication). Livestock production contributes to emission of nitrate to water sources through the run-off or leaching of nitrate in manure, which is spread on fields, or through the leakage of manure storage facilities (Aillery et al. 2005). Phosphorus content of animal waste is also a concern for water sources (Environmental Protection Agency, 2006). Phosphorus can reach surface water through runoff from land application of manure and direct disposition (Environmental Protection Agency 2006).

Animal Feeding Operations (AFOs) that are not classified as Concentrated Animal Feeding Operation (CAFOs) are not federally regulated and are treated as non-point source polluters, therefore adoption various manure management practices is voluntary. Since almost 95 percent of animal feeding operations are not classified as CAFOs, a majority of the animal feeding operations are not required to implement nutrient management practices. To minimize the pollution from AFOs, the U.S. Department of Agriculture and the Environmental Protection Agency promote the use of nutrient management practices by AFOs (U.S. Department of Agriculture and Environmental Protection Agency 1999). For policies to be successful, it is important that farmers continue to use these practices.

Technology adoption has been extensively analyzed in the literature. The adoption studies involved theoretical and empirical studies that analyzed the factors that impact farmers' adoption of new technologies. Since there are many different factors that impact adoption of a new technology, studies mostly analyzed a subset of factors and developed theories that combine this small set of factors and adoption behavior. Therefore, instead of a one big theory that explains all aspects of technology adoption, it is possible to see different theories that explain a part of adoption behavior. The historical order of the development of adoption theories had been roughly in order of profitability (Griliches 1957 ; Mansfield 1961), farm size (Feder, Just and Zilberman 1985), risk and uncertainty (Feder, Just and Zilberman 1985; Sunding and Zilberman 2001), information gathering (Hiebert 1974 ; Feder and O'Mara 1982 ; Feder and Slade 1984), human capital (Schultz 1972; Huffman 1974; Wozniak 1984) and labor supply (Huffman 1980). Hence, there are well-established theoretical models that explain factors that impact adoption of new technologies by farmers.

For policies to be successful, it is important that farmers continue to use new technologies and practices. Recent studies found that farmers do not continue to use the technologies that they initially adopted (An 2008; Barham, Smith and Moon 2002; Moser and Barrett 2002; Cornejo, Alexander and Goodhue 2002; Bravo-Ureta, Cocchi and Solis 2006). Hence, recently disaoption of practices and technologies by farmers received the attention of researchers and policy makers. Altough technology adoption has been analyzed intensively in the literature, there is little known about technology disadoption.

Among the few studies that investigated disadoption of new technologies by farmers, farm size was found to be a significant factor that impacts technology disadoption(An 2008; Bravo-Ureta, Cocchi and Solis 2006). However, some of these studies found positive, while others found negative relationship between farm size and disadoption of new technologies. Hence, the impact of farm size on technology disadoption is not clear. Uncertainty with respect to production technology was also found as an important factor, but there is no conceptual framework that explains the relations between technological uncertainty and disadoption of a new technology (Moser and Barrett 2002; Cornejo, Alexander and Goodhue 2002; Bravo-Ureta, Cocchi and Solis 2006).

Overall, previous studies do not provide an explanation to why farmers would disadopt a new technology. The objective of this paper is provide a conceptual framework that explains the impact of farm size and technological uncertainty on the dsiadoption decision.To our knowledge, this is the first study that explains the technology disadoption by farmers. This knowledge can be used by policy makers to promote longer use of technologies such as conservation practices by farmers.

Model

The farmer's problem is to maximize the expected value of discounted streams of profits over a finite time horizon. Farmer's problem can be represented using dynamic optimization as;

$$(1) \qquad \max_{x \in \{0,1\}} E_0 \sum_{t=0}^{T} \beta^t \pi_t$$

where $0 < \beta < 1$ is the discount factor and famer's choice is $x = 0$ if the farmer continues to use the existing technology in which case the current profit is $\pi_t = \pi^C$. If the farmers disadopts the current technology $x = 1$ in which case the current profit is $\pi_t = \pi^D$, where π^D is the profit from an alternative technology that replaced the current technology. For the solution of the farmer's problem, the value function $v(\pi^D)$ that satisfies the Bellman equation can be shown as;

$$(2) \qquad v(\pi^D) = \max_{x \in \{0,1\}} \left(\frac{\pi^D}{1-\beta} - C(L), \pi^C + \beta \int_0^B v\left(\pi^{D'}\right) dF\left(\pi^{D'}\right) \right)$$

where C(L) is the one time cost of shifting from one technology to another C(L). There exists a level of $\bar{\pi}^D$, which makes the value functions from continue to adopt the existing technology and disadopting the existing technology be equal.

$$(3) \qquad \bar{\pi}^D = (1-\beta) \left[C(L) + \pi^C + \beta \int_0^B v\left(\pi^{D'}\right) dF\left(\pi^{D'}\right) \right]$$

Hence, the farmer's choice can be represented as;

$$(4) \qquad x = \begin{cases} 0 \text{ if } \pi^{\mathrm{D}} \leq \bar{\pi}^{D} \\ 1 \text{ if } \pi^{\mathrm{D}} > \bar{\pi}^{D} \end{cases}$$

To see the impact of farm size and uncertainty, the solution in equation is used. Any factor that increases $\bar{\pi}^{D}$ will cause farmers to be less likely to disadopts the current technology, *ceteris paribus*. If cost of replacing the current technology *C*(.) increases as the farm size *L* increases,

$$(5) \qquad \frac{dC(L)}{dL} > 0 \Rightarrow \frac{\partial \bar{\pi}^{D}(.)}{\partial L} > 0$$

then the reservation level of profits $\bar{\pi}^{D}$ increases, which means that larger farms are less likely to disadopt the current technology. This explains why the previous studies found negative relationship between farm size and disadoption technologies that were complement to other technologies that are used by larger farms. The model predicts that larger farmers are more likely to disadopt a new technology if a fixed replacement cost is required, where average replacement cost decreases with farm size.

For the impact of uncertainty, if π^{C} is replaced by its certainty equivalent $E(\pi^{C}) - Var(\pi^{C})$, then it is seen that as the variance of π^{C} increases, farmers become more likely to disadopt the current technology. However, if the variance of π^{C} decreases, the farmers become less likely to disadopt the current technology.

Conclusions

As the concerns about environemntal quality increases, farmers use of technologies that conserve the environmental quality becomes more important. As more government policies developed to promote use of technologies and practices to conserve the environmental quality, farmers continues of these technologies and practices become important. Recent studies found farmers can stop using a technology or practice that they initally adopted. Farm size and tecnological uncertainty found as important factors that impact disadoption of technologies and practices by farmers, but previous studies did not incorporate a conceptual framework that explains the relationship between farm size, technological uncertainty and the disadoption decision. Henc,e the current study provided the conceptual framework that analyes the disadoption decision of farmers.

Current study found that a negative relationship between farm size and disadoption technologies that were complement to other technologies that are used by larger farms. Also the current study predicted that larger farmers are more likely to disadopt a new technology if a fixed replacement cost is required, where average replacement cost decreases with farm size. For the impact of technological uncertainty, the current paper found that if the variance of the profit from current technology or pratice increases, farmers become more likely to disadopt the current technology or the practices.

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