Population Aging and Growth of Developed Countries' Agricultural Sector: Focusing on the Inverse Relationship between Aging and Cognitive Abilities

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1. Introduction

In most parts of the world, population aging is a common phenomenon (Cai and Stoyanov, 2016) and closely related to the establishments of competitiveness (Göbel and Zwick, 2012). The speed of population aging is faster in developed countries since the average birth rate in developed countries is lower than developing countries (see. Figure A1). Among industries in developed countries, the agricultural sector is one of fast aging industries due to the industrialization and urbanization, accompanied with migration of young people from rural area to urban area for better job opportunities. In 2014, the average population concentration in urban areas reached to the average 76% among all high-income countries.[1]

Extensive literature have paid attentions on the relationship between aging and certain abilities of labor force. Aging is closely related to productivity-linked to factors such as strength, stamina, and health (Skirbekk, 2008). Studies such as Albert and Heaton (1988) and Salthouse (2009) provide evidence of negative relationship between age and cognitive skills.[2] Recently, Cai and Stoyanov (2016) find that age-depreciating cognitive skills are closely related to the low skilled workers. Many cognitive and physical skills, which are age dependent, affect on quality of labor force; thus, aging is one of determinants to explain productivity. Rapidly growing ageing

[1] Countries with per capita GDPs above $12,736 in 2015 are defined high income by the World Bank. The rural or urban population concentration are calculated based on the World Bank dataset available at http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS.

[2] Salthouse (2009) finds that age and cognitive skills have a negative relationship only based on cross-section data.

in rural area is expected to change the structure of agricultural production as well as farm efficiency.

Empirical studies such as Abdulai and Eberlin (2001) and Li and Sicular (2013) find the evidence that efficiency increases by age of farmer up to a certain inflection point and decreases after the inflection point. Both studies focus on developing countries rather than developed countries with certain products or regions. Even though the aging problem is severe in developed countries compared to developing countries, most studies on the farm productivity in developed countries do not take into account the age effect on the technical efficiency based on our best knowledge.

This study focuses on South Korea (hereafter "Korea") as an extreme case of developed countries because Korea is one of rapid ageing nations in the agricultural sector. According to farm household economic survey (FHES), the average age of farmers in Korea has increased from 59.9 to 68.3 during the periods 2003-2015.[3] Rapidly growing age of farmers can be explained by the fast economic growth from the industrialization. Furthermore, the population migration in Korea is severe since Korea has a comparative disadvantage in the agricultural sector and agricultural imports have increased due to the reduced trade barrier based on the free trade agreement (FTA).[4]

Main objective of this study is to investigate the impact of aging on farm efficiency in Korea by utilizing FHES dataset. We examine what factors are important to improve or deteriorate farm efficiency by exploring the impact of farmer characteristics on efficiency. To be

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[3] http://kostat.go.kr/portal/eng/surveyOutline/1/6/index.static

[4] Based on Revealed Comparative Advantage (RCA) results of Yoon and Kim (2006), Korea has a comparative disadvantage in the agricultural sector.

specific, we capture different marginal effect of age on farm efficiency by assuming a non-monotonic effect on farm efficiency suggested by Wang (2002).

2. Literature Review

Aging can have an impact on the productivity of workers due to several reasons such as cognitive abilities, strength, stamina, and health (Skirbekk, 2008). Salthouse (2009) well summarizes previous studies for the aging effect on cognitive abilities. Based on previous literature, most of studies find that cognitive skills are significantly affected by age with different thresholds. In other words, most previous studies show that there is a non-linear relationship between age and cognitive skills. . Studies such as Allen, et al. (2005), Del Tredici and Braak (2008), Erixon-Lindroth, et al. (2005), Hsu, et al. (2008), Kadota, et al. (2001), Kruggel (2006), Pieperhoff, et al. (2008), Salat, et al. (2004), Salthouse (2009), and Sheline, et al. (2002) find that the cognitive abilities begin to decline around the age of 20's.[5] On the other hand, literature such as Aartsen, et al. (2002), Albert and Heaton (1988), Plassman, et al. (1995), Rönnlund, et al. (2005), and Schaie (1989) find that the cognitive abilities begin to decline at the age more than 50 years old.[6]

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[5] Studies such as Allen, et al. (2005), Kruggel (2006), and Pieperhoff, et al. (2008) suggest that the regional brain volume is main factor to cause the cognitive skills to decline in the age of 20's. Salthouse (2009) summarizes other neurobiological factors that start the cognitive skills to decline in 20's: Myelin integrity (Hsu, et al., 2008), cortical thickness (Salat, et al., 2004), serotonin receptor binding (Sheline, et al., 2002), striatal dopamine binding (Erixon-Lindroth, et al., 2005), accumulation of neurofibrillary tangles (Del Tredici and Braak, 2008), and concentrations of various brain metabolities (Kadota, et al., 2001).

[6] Aartsen, et al. (2002) find that cognitive abilities begin to decline in the middle age, and the most frequency part is found in higher ages (70 or higher). Albert and Heaton (1988) find that the performance of people does not decline much until about 50 years old. According to Plassman, et al. (1995), cognitive abilities do not change until 60 years old. The results of Rönnlund, et al. (2005) represent that performance of people do not change or little drop before age 55. Schaie (1989) find that cognitive abilities decline in the age of late 50's or early 60's.

Medical, physiological, or economic analyses have investigated the relationship between aging and productivity (Li and Sicular, 2013). Gelderblom (2005) and Skirbekk (2008) mention that some economic literature investigate the relationship between aging and earning, and other studies examine the impact of age of workers at firm, industry, or national productivity. Most economic empirical researches on aging and productivity find the nonlinear relationship that productivity begins to decline at age 40 or later. However, Göbel and Zwick (2009) find slightly different results that negative impact of age on productivity varies by the nature of data, sector or level of analysis, and methodology.

Even though the effect of age on the productivity of manufacturing firm is well documented in previous studies, there is a lack of studies to investigate the relation between age and farm productivity. (Li and Sicular, 2013). In addition, there are only few studies that investigate the relationship between aging and farm efficiency based on the stochastic frontier model. The stochastic frontier model has been extensively used to investigate technical efficiency in agricultural farm production across the countries in the past two decades.[7] Liu and Zhuang (2000) investigate the impact of age, which is one of efficiency variables to capture the physical strength and farm experience, on-farm efficiency by employing farm-level data in China from rural household sample survey in 1990. They find that farm efficiency increases until the household head reaches the age of 40 and declines afterwards. Abdulai and Eberlin (2001) measure technical efficiency of maize and bean based on a cross-section survey of 120 households in Nicaragua during April 1994 and March 1995. They find that improvement of technical efficiency based on estimated coefficients in the inefficient model is explained by the

[7] Please see Bravo-Ureta et al (2006) who review 167 farm level technical efficiency studies to examine the impact of various attributes on technical efficiency estimates using meta-regression analysis.

factors of education, age, access to credit, family size. Especially for age effect, they find that increase in household head's age results in less efficiency of the household after the age of 38.7 years for maize and 39.5 years for beans. Fuwa, et al. (2007) utilize farm-level and plot-level rice data in eastern India to estimate a translog stochastic frontier production function. They incorporate the age of the household head as both potential sources of technical inefficiency and proxy for farming experience, and find that learning from experience plays an important role in increasing farm efficiency. A recent study by Li and Sicular (2013) employs a translog stochastic frontier production function to estimate the impact of age on the technical efficiency of crop production in China by using a panel survey data from 2004 to 2008. They find that technical efficiency increases until the age of a farmer is 45 and declines after 45 years old. They explain this inflection effect of age on efficiency by old farmers' lack of incentive, less motivation, risk-averse tendency, and less adaptable new technology.

Based on our best knowledge, most of the literature that examine age effect on technical efficiency using stochastic frontier model focus only on developing countries. Due to rapid population ageing in developed countries especially in the agricultural sector, we hypothesize that the age effect on farm efficiency might be different between developing and developed countries. It is because the developed countries are expected to have more capitals and older farmers compared to developing countries. Therefore, findings from this study will fill a gap in existing studies for age and technical efficiency in developed countries. Among developed countries, this study focuses on South Korea (hereafter "Korea") since Korea is one of the ageing nations in the agricultural sector. In 2015, the average age of Korea farm head reached 68.3 years old due to young population migration from rural to urban areas based on rapid economic growth from the manufacturing sector. Our paper also examine the effect of income subsidy on farm efficiency in Korea. Previous literature find both positive and negative effect of the income subsidy on farm efficiency (Zhu and Lansink, 2010). The subsidy has a positive effect on farm efficiency if farmers use the income subsidy for improving technology or on-farm organization. The subsidy, however, has a negative effect on farm efficiency if farmers have less motivations to improve their productivity due to increased incomes. Therefore, it is a testable hypothesis whether the effect of income subsidy in Korea is negative or positive on farm efficiency.

3. Data

This study utilizes the Korean Farm Household Economic Survey (FHES) that is the annual based national survey conducted by the Statistics Korea. Its randomly selected sample, which is replaced every five year, is composed of about 3,000 farm households, each representing a number of similar households. The FHES contains detailed information about managerial characteristics and agricultural economic activities such as farm resources, financial conditions, revenues and expenses of sample households.[8] This paper employs sample periods from 2008 to 2012 to capture the most recent information.

To estimate farm efficiency using the stochastic frontier production model that is suggested by Battese and Coelli (1995), we need to consider functions of production and inefficiency simultaneously. In farm production function, we use farm sales as output and land, labor (family and employed), capital, and intermediate as inputs. In order to investigate the inefficiency sources in farm production, we consider the following as explanatory variables; age,

[8] The FHES, originally started in 1953, is designed to improve agricultural management and to establish agricultural policies. FHES is similar with the Agricultural Resource Management Survey (ARMS) in United States Department of Agriculture (USDA) in terms of the overall survey procedure, survey questions, and data generating system.

gender, educational attainment, farm household's family size, the proportion of employed labor to total labor hours, agricultural liabilities ratio, the ratio of non-agricultural revenue on agricultural revenue, and share of decoupled income support in farm income.

Table 1 shows the descriptive statistics of all variables that used to estimate both farm production and inefficiency functions during the sample period from 2008 to 2012. Farm outputs and inputs do not vary much; however, the data provides the evidence that there exist decreasing and increasing trends for labor usage and intermediate materials, respectively. Farms with large families may have less problems in labor supply, and higher probability for finishing their operational tasks in limited time compared to farms with small families (Abdulai and Eberlin, 2001). Family labor force for a farm operation might also be important since the average ratio of employed labor in Korea farm is less than 30% with decreasing trend.

<Insert Table 1>

There are two main schemes of agricultural supports that is separately reported to the FHES. Reported direct schemes of agricultural supports include environment-friendly farming, landscape conservation, and disadvantaged region. Fixed payment schemes are the other type of agricultural supports reported to FHES. Among fixed payment schemes, the support for paddy fields is a representative decoupled direct payment in Korea.[9] Estimating the impact of income

[9] In 2005, Korea established an income support program and abolished Rice Purchase Program that is one of market price support program. An income support program is composed of fixed payment scheme for paddy fields and efficiency payment for the targeted rice price. From recent Korea notifications (2011) for domestic agricultural supports to World Trade Organization (WTO), the average fixed direct payment for paddy fields was 984 billion

subsidy on farm efficiency in Korea is the testable hypothesis since Zhu and Lansink (2010) point out that the income subsidy can have both positive and negative effects on farm efficiency. The ratio of average income subsidy is 28.4% in our study period.

The main variable of age is expected to have a relationship with production efficiency since the age is related with skills (physical or cognitive) and experience. The age in general is negatively correlated with skills (either physical or cognitive). To be specific, the age dependent physical and cognitive skills are not expected to change much until a certain age, however, these skills are expected to decline after a certain age. On the other hand, the experience is expected to have a positive relationship with farm efficiency. However, the increasing rate of experience effect on efficiency is expected to decrease in additional year of experience. Therefore, the combined effect of age dependent skills and experience on farm efficiency may have a non-linear relationship with certain inflection point. As shown in Table 1, the average age of farm operators in the sample is 66 years old with increasing trend.

Figure 1 illustrates how the age distribution of Korean farm operators has changed. It shows that the average age has clearly increased in recent 15 years. According to the census of agriculture, the proportion of population aged 65 and older in farm households was 38.4 percent in 2015, more than three times as compared to 13.2 percent for Korea as a whole.[10] A super-aged agricultural sector is supported by the fact that the proportion of farm operator aged 70 and older already reached 30.9% in 2010 and increased by 6.9 percent points until 2015.

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won during the period between 2008 to 2011. That amount of direct payment occupies 14.5% of the average total domestic support and 2.4% the average total agricultural production at the same period.

[10] Among 2.57 million person of farm household, 0.99 million persons are 65 and older in 2015.

<Insert Figure 1>

Educational attainment of a farm operator, generally representing human capital, is expected to be positively associated with the farm efficiency. It is due to the fact that human capital is expected to enhance the reallocation of farm resources in response to changes in relevant information, technology, or economic conditions. The average education years of farm operators are about 8 years and do not change much during the sample period.[11] The 8 years of maximum education for farmers are much lower than the total average education years of Korea.[12] Table 2 shows how aging and education are inversely related. In our sample, most farmers under age 50 have more than a high school education, whereas most farmers over 50 have less than a middle school education.

<Insert Table 2>

4. Methodology

4.1. Stochastic Frontier Model

Aigner, et al. (1977) and Meeusen and van Den Broeck (1977) independently propose the stochastic frontier production function that has two random components with a random error and

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[11] Year of public education level in Korea for elementary, middle, high school is 6, 3, and 3 years, respectively. Year of education attainment after high school is same as the U.S.

[12] The total average of maximum education years in Korea is 11.8 in 2010.

technical inefficiency. The stochastic frontier production function that is proposed by Aigner, et al. (1977) and Meeusen and van Den Broeck (1977) can be estimated upon both data structure with cross-section and panel (Battese and Coelli, 1992). However, most previous theoretical literature for stochastic frontier production function do not formulate a model for the effect of explanatory variables on technical efficiency (Battese and Coelli, 1995). To come up with estimation problem in technical efficiency, Battese and Coelli (1995) propose the method to estimate stochastic frontier production and technical efficiency functions at the same time for the panel dataset.

The panel stochastic frontier production function, that is proposed by Battese and Coelli (1995), is specified by the equation (1):

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \tag{1}$$

where, *Y* represents the farm production, *x* is a $(1 \times \mathrm{k})$ vector of inputs, β is a $(1 \times \mathrm{k})$ vector of parameters, *i* is *i*-th farm, *t* is time, V_{it} is supposed to follow *i.i.d* $\mathrm{N}(0, \sigma_v^2)$, and U_{it} is non-negative random variables for technical efficiency.

The technical inefficiency term, U_{it}, is specified by the following equation:

$$U_{it} = z_{it}\delta + W_{it} \tag{2}$$

where, U_{it} is the mean, $z_{it}\delta$, and the variance, σ^2, with the truncated normal distribution at zero, z_{it} is $(1 \times \mathrm{m})$ vector of technical inefficiency explanatory variables, δ is $(1 \times \mathrm{m})$ vector of parameters, W_{it} follows the truncated normal distribution with zero mean and variance of σ^2. If all vector of $\delta's$ is zero, then *z* variables do not explain the technical inefficiency and Aigner, et al. (1977) has to be utilized for the analysis.

The technical efficiency of farm production according to farm *i* and time *t* is defined by the following equation:

$$TE_{it} = \exp(-U_{it}) = \exp(-z_{it}\delta - W_{it}) \quad (3)$$

The conditional expectation method is utilized to predict the technical efficiencies based on the model assumptions.

4.2. Non-Monotonic Efficiency Effect

To figure out the possible non-monotonic effect of explanatory variables on farm efficiency, this study utilizes the non-monotonic efficiency effects method that is suggested by Wang (2002). The non-monotonic efficiency effect allows us to assume that z_{it} can have both positive and negative effects on farm efficiency according to values of z_{it}. For example, age can have a positive (negative) effect on farm efficiency within a certain range of age, but opposite in the outside of a certain range of age. Age also can have a different (positive or negative) effect on farm efficiency even though individuals are the same age.

Wang (2002) start from Hadri (1999) that extend random error (V_{it} ~ $\mathrm{N}(0, \sigma_v^2)$) to address the problem of heteroscedasticity as V_{it} ~ $\mathrm{N}(0, \sigma_{vi}^2)$, where, $\sigma_{vi}^2 = \exp(h_i'\emptyset)$ and h_i does not necessarily appear in z_i. In the next step, Wang (2002) define the first two moments (mean and variance) of U_{it}:

$$m_1 = f(\mu_{it}, \sigma_{it}) = \sigma_{it}[\Lambda + \frac{\phi(\Lambda)}{\Phi(\Lambda)}]$$
$$m_2 = f(\mu_{it}, \sigma_{it}) = \sigma_{it}^2[\Lambda - [\frac{\phi(\Lambda)}{\Phi(\Lambda)}] - [\frac{\phi(\Lambda)}{\Phi(\Lambda)}]^2] \quad (4)$$

where, $\Lambda = {}^{\mu_{it}}/_{\sigma_{it}}$, ϕ is probability density function of standard normal distribution, and Φ cumulative density function of standard normal distribution.

Combining the equation (2) and the condition for $\sigma_{vi}^2 = \exp(h_i'\emptyset)$ with two moments, we can derive marginal effect of z[k] (k-th explanatory variables for farm efficiency) on $E(U_{it})$:

$$\frac{\partial E(U_{it})}{\partial z[k]} = \delta[\mathrm{k}]\left[1 - [\frac{\phi(\Lambda)}{\Phi(\Lambda)}] - [\frac{\phi(\Lambda)}{\Phi(\Lambda)}]^2\right] + h[k]\frac{\sigma_{it}}{2}\left[(1+\Lambda)^2[\frac{\phi(\Lambda)}{\Phi(\Lambda)}] + \Lambda[\frac{\phi(\Lambda)}{\Phi(\Lambda)}]^2\right] \quad (5)$$

where, $\delta[\mathrm{k}]$ and $h[k]$ are corresponding coefficients for the equation (2) and $\sigma_{vi}^2 = \exp(h_i'\emptyset)$, respectively. The equation (5) represents that the summation of the adjusted slope coefficients from functions of mean and variance is the marginal effect.

5. Empirical Model

Our empirical model is composed of a stochastic frontier function with the translog form:

$$\ln(Y_{it}) = \beta_0 + \beta_T T + \sum_{j=1}^{5}\gamma_j + \sum_{k=1}^{15}\theta_k + \sum_{l=1}^{5}\beta_l \ln(x_{lit}) + \sum_{m=1}^{5}\sum_{n=1}^{5}\beta_{mn}\ln(x_{mit})\ln(x_{nit}) + \sum_{m=1}^{5}\alpha_{Tm}Tln(x_{mit}) + V_{it} - U_{it} \quad (6)$$

where, *Y* is output of farm, *i* is *i*th farm household, *t* is time, *T* is the time trend with coefficient β_T, γ_j is dummy coefficient for farmtype *j*, θ_k is dummy coefficient for region *k*, x is input, $V_{it} \sim$ *i.i.d* $\mathrm{N}(0, \sigma_v^2)$, and U_{it} is non-negative random variables for technical efficiency.

Farm inefficiency function is defined as the following equation:

$$U_{it} = \delta_0 + \delta_1 age_{it} + \delta_2 edu_{it} + \delta_3 age_{it} edu_{it} + \delta_4 sfs_{it} + \delta_5 agdebt_{it} + \delta_6 noagrate_{it} + \delta_7 subsidy_{it} + W_{it} \quad (7)$$

where, δ are parameters to be estimated, *age* is age of farm household, *edu* is the maximum education year of farm household, *sfs* is standardized farming size, *agdebt* is debt/assets, *nonagrate* non-agricultural revenue/total revenue, and *subsidy* is income subsidy/agricultural income.

6. Results

The estimated results of the stochastic frontier function are presented in Table 3. Based on the results of likelihood ratio test (LR test), we find that the translog functional form is more adequate than the general Cobb-Douglas functional form.[13] Even though the Cobb-Douglas function is nested in the translog function, the estimated input elasticities from the two production frontiers are quite different mainly due to the strict assumptions embedded in the Cobb-Douglas function.[14] The translog, which is one of the flexible functional forms, captures

[13] The LR test statistics is $\chi^2(15) = 883.4$with p-value of 0.000, which indicates that the tranglog functional form is preferred to the Cobb-Douglas functional form.
[14] The Cobb-Douglas functional form assumes that all farms have the same production elasticities, and substitution elasticities between production inputs are equal to one.

possible substitutions among inputs. Furthermore, the translog form considers different input elasticities across individual farms. For the translog, the estimated output elasticities for family labor, employed labor, capital, land, and intermediate are 0.04, 0.43, -0.07, 0.40, and 0.18, respectively.[15] Employed labor has the largest elasticities followed by land and intermediate input while the elasticities of family labor and capital are insignificant. The insignificance of labor on farm production is consistent with previous literature such as Battese and Broca (1997), Fuwa, et al. (2007), and Sharif and Dar (1996). They find that family labor in developing countries has relatively small or insignificant elasticities since family labor has a predetermined characteristic compared to the other inputs. The predetermined characteristic of labor input from family is well shown in Korea since the family share on total labor inputs in our sample is more than 70%. The insignificant capital elasticities on production is not consistent with previous studies such as Battese and Broca (1997), Fuwa, et al. (2007), and Sharif and Dar (1996). It might be explained by the excessive investments on capital inputs such as farm facilities, which are triggered by the large scale of financial support plans in Korea. The policy plans are originated from the trade liberalization since early 1990s' WTO regime.[16] With the accumulated policy funds from both central and local governments, rapid aging and gradually proceeded hollowing out phenomenon of local communities recently result in lots of unused agricultural facilities and equipment in rural areas.

[15] Since transformed data where the output and 5 inputs are measured relative to their sample means, the translog elasticities evaluated at means would simply be the parameter estimates (β_i) themselves.

[16] In the 2000s, the financial supports has reinforced since Korea prepare the implementation of multiple FTAs such as Korea-Chile FTA (2004), Korea-EU FTA (2011), Korea-USA FTA (2012), and Korea-China FTA (2015).

<Insert Table 3>

Based on the LR test result, we only focus on the results of efficiency estimators in the translog function. The estimated value of 4.33 ($\lambda = \sigma_u/\sigma_v$) represents the relative ratio between the truncated standard errors in the inefficiency function and the standard errors in random errors of stochastic frontier function. This result indicates that the variation in technical inefficiency is a significant component in the total variation of output (Battese and Coelli, 1995).

Since efficiency and inefficiency have an opposite meaning, we need to put a negative (-) sign on the estimators of farm inefficiency function. Our empirical results reveal that variables of the age, education, gender, the debt ratio, and the share of decoupled income support have negative impact on efficiency. On the other hand, family size appears to have a positive effect on efficiency. The interaction between age and education has a positive effect on farm efficiency. This finding implies that the negative effect of age and education on farm efficiency is attenuated by the interaction effect.

The variable of age is used to capture the effect of cognitive and physical abilities of leading farmers on farm efficiency since these abilities are age dependent. There are two methods to find the possible inflection point of age on farm efficiency. First, studies such as Abdulai and Eberlin (2001) and Li and Sicular (2013) use variables of age and age square simultaneously and find that the age begins to decline farm efficiency. Second, Wang (2002) suggest the model with the non-monotonic effect of age on farm efficiency. This paper utilizes the method proposed by Wang (2002) that is more flexible form compared to the quadratic structure of age. In addition, the average age of farm head is 66 in our sample, and 94% of the sample is older than 50, which is higher than the investigated inflection age range, 35-45, by Abdulai and Eberlin (2001) and Li and Sicular (2013).

The negative effect of education on farm efficiency is contrary to Abdulai and Eberlin (2001), Battese and Broca (1997), and Liu and Zhuang (2000) that use the data of developing countries. On the other hand, it is consistent with recent studies for China (Chen, et al., 2009; Li and Sicular, 2013) and U.S. (Goodwin and Mishra, 2004). Our result is contradictory to the human capital theory, which is partially attributed to very low level of education.[17] Another possible explanation of the negative effect of education is a job switching from agriculture to non-agriculture.[18] Considering Korea as one of the developed and industrialized countries, the probability of job switching appears to be high compared to developing and less-industrialized countries.

Larger families seem to be more efficient than smaller families since larger families could use enough family labor for farm operations than others. However, the positive gain of family size on efficiency will be attenuated over time because the average family size is gradually decreasing, and other members except farm operator and its spouse do not tend to join farming any longer in recent years. We also find that female farm managers, occupying only 6% in our sample, are less efficient than male.

[17] 41.7% of farm leaders experienced only primary school education, and 9.1% of them have no schooling at all in our sample.
[18] As found at in Goodwin and Mishra (2004), the higher educational attainment of farmer may cause more job switching from agriculture to non-agriculture.

The liabilities ratio is negatively associated with farm efficiency. The farm household, who faces with a credit restriction, is less likely to purchase additional inputs in response to new technology, machinery, equipment, seed, and so on. Moreover, the higher debt ratio may hinder desirable reallocation of resources to keep up with the change of internal abilities in farm management. Therefore, the higher debt ratio results in negative consequences for farm productivity.

The ratio of non-agricultural to agricultural revenue, implying the income dependence of household on non-farm work, shows a negative relationship with farm efficiency. This result is in the same context of previous literature such as Abdulai and Eberlin (2001) and Huffmann (1999) while it is contrary to Li and Sicular (2013) and Zhengfei and Oude Lansink (2006). The negative effect indicates that opportunities of non-farm income in the rural area of Korea reduce agricultural labor force in input portfolio to maximize a household disposable income rather than induce to reinvest non-farm income in enhancing farm efficiency.

The share of decoupled income subsidies in total farm income is negatively associated with farm efficiency. It is supported by the findings from Hennessy (1998), Sckokai and Moro (2006), Serra, et al. (2005), and Zhengfei and Oude Lansink (2006). They find that an increased income from decoupled subsidies lowers the motivation for enhancement efforts toward farm productivity.

<Insert Table 4>

As shown in the 2nd column of Table 4, farm efficiency was 72.5% in 2008 and 72.9% in 2009 but thereafter slightly decreased each year, falling to 70.9% in 2012. Table 4 also presents mean efficiency scores by several subgroups and year, which can be interpreted as the average performance of each subgroup relative to the national frontier in a given period. The rice farms, which account for 37.9% of the sampled farms, on average, have been more efficient than other farms producing non-rice crops, even though the rice market of Korea is relatively more protected by the delayed tariffication (1995-2014) and income subsidies for rice farmer. One possible explanation for the higher performance of rice farms in productivity is that all resources for irrigation, readjustment, and mechanization of arable land in Korea had been concentrated on rice paddy fields by the middle of the 2000s.[19]

To implement agricultural budget in an effective way, the Korea government has designated specialized farm households as operators, whose agricultural sales exceed non-farm receipts, having more than 3ha of cultivated lands or raising more than 20 million won of agricultural sales. These specialized farms, which currently comprise 35 % of the sampled farm, are explicitly more efficient than others since they have been targeted for various competitiveness-enhancing policy programs in recent 10 years in the stream of trade liberalization in Korea agriculture.[20]

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[19] The share of readjusted paddy fields in total paddy fields reached 64.7% in 2004 when the related policy program finished, while the policy-targeted area of dry field for readjustment in 2015 is just 23.3% of total dry fields (180 vs. 771 tho. ha).

[20] For fruit and livestock sector, product specific subsidies or policy loans for farm facilities had been extensively distributed with farmers' own matching funds before and after implementations of Korea-Chile FTA (2004) and Korea-USA FTA (2012). The relatively higher level of debt ratio in fruit and livestock farms is partly attributed to these loans and matching funds. In our analysis, fruit farms and livestock farms comprise 14% and 8% of the sampled farms, respectively.

Finally, farms near the metropolitan area appear to be less technically efficient than those located in rural areas. It is probably because the arable land price is too high to take advantage of agglomeration effects and knowledge spillovers associated with improvement of productivity and thus farm efficiency.

<Insert Table 5>

To focus on our interest point, the non-monotonic efficiency effects of aging, we present the sample mean of $\partial\, \mathrm{E}(U_{it})/\partial Age_{it}$ in table 5 calculated from equation (5) based on Wang (2000). Along with the average efficiency score, the table 5 also reports the average marginal effects of the categorized age groups in each year. Negative effect of aging on efficiency is clearly observable as the average marginal effect is increasing over time and age group.

During the sample period, the average marginal effects of age in the youngest group (30s) and the oldest group (80s) are 0.0014 and 0.0159, respectively. Since $\partial\, \mathrm{E}(U_{it})/\partial Age_{it} = -\partial\, \mathrm{E}(\ln Y_{it})/\partial Age_{it}$, the effects translate into decreases of output by 0.14% and 1.59%. In other words, additional increase in age for older farm managers tend to be more counterproductive, leading to much increases in inefficiency compared to younger managers. The loss in the output growth for oldest farmer is about 100 times bigger than youngest one.

Figure 2 shows the results of Kernel-weighted local polynomial smoothing. First graph represents the average efficiency according to the age of farmers, and we find that the average farm efficiency is decreasing in age and a rate of decrease begins to wide at the age around 60.

Second graph indicates the average marginal effect of age on farm inefficiency by age. It shows that the average marginal effect of age on farm inefficiency has an increasing trend and a rate of increase begins to wide at the age around 60.

<Insert Figure 2>

7. Conclusion

This paper investigates the impact of age on farm efficiency in Korea using FHES longitudinal dataset from 2008 to 2012. This paper employs tanslog stochastic frontier model based on Battese and Coelli (1995) that allows us to estimate functions of farm production and efficiency simultaneously. Utilizing non-monotonic assumptions by Wang (2002), this study examines different marginal effects of age on farm efficiency by individual farmers.

The results indicate that the age of farmer is negatively associated with the farm efficiency. More specifically, our result shows that the marginal effect of age on farm efficiency rapidly decreases after age 60. This results implies that the large share of low farm efficiency and competitiveness in Korea is explained by the old age structure in agricultural sector.

We find the negative relationship between the income subsidy and farm efficiency. This result is not surprising due to the high age structure in the agricultural sector. The average age of farmers in Korea reached 68.3 in 2015, which may reduce an impact on the use of income subsidy. Old farmers have a less motivation to use income subsidy effectively compared to young farmers; therefore, the income subsidy has a negative effect on farm efficiency.

Our findings provide some contributions and implications to previous and existing studies. First, this study fills a gap on studies related to age and farm efficiency since previous studies do not focus on developed countries. The age of farm household in developed countries especially in rural areas is much higher than developing countries due to the industrialization. Thus, the effect of age on farm efficiency is expected to have different impacts between developing and developed countries. Our finding provides evidence that the age effect on farm efficiency in Korea is negative whereas previous literature for developing countries find the inverse U-shape. Second, this paper suggests that Korea can support the competitiveness in the agricultural sector by providing or implementing the incentive policy for young people migration from urban to rural areas. Considering current high unemployment rate in Korea especially in young people, not only the incentive policy is expected to increase farm efficiency, but also reduce the unemployment rate. It is because the increased farm efficiency from the government policy can reinforce the competitiveness of farm, which eventually leads the growth of agricultural sector.

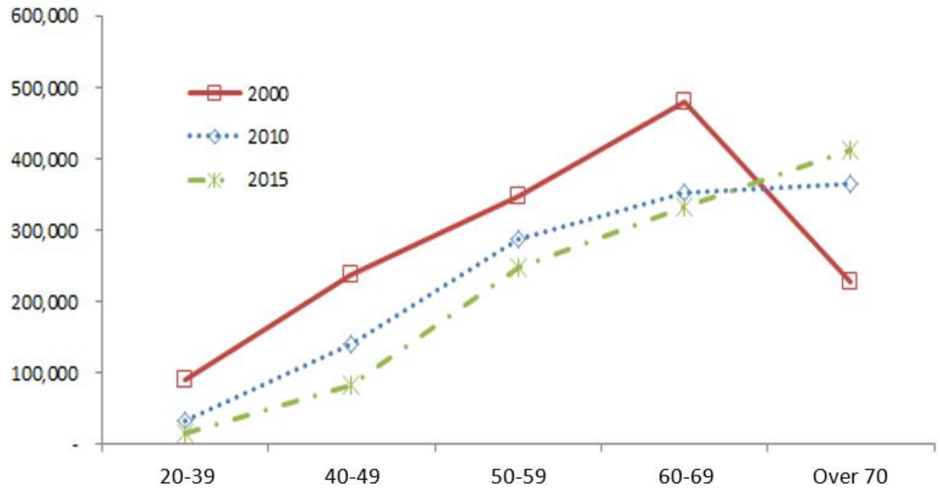

Figure 1. Average Age Distribution of Korean Farm Operators in 2000, 2010, and 2015
Source: Census of Agriculture, Statistics Korea, 2000 2010 2015

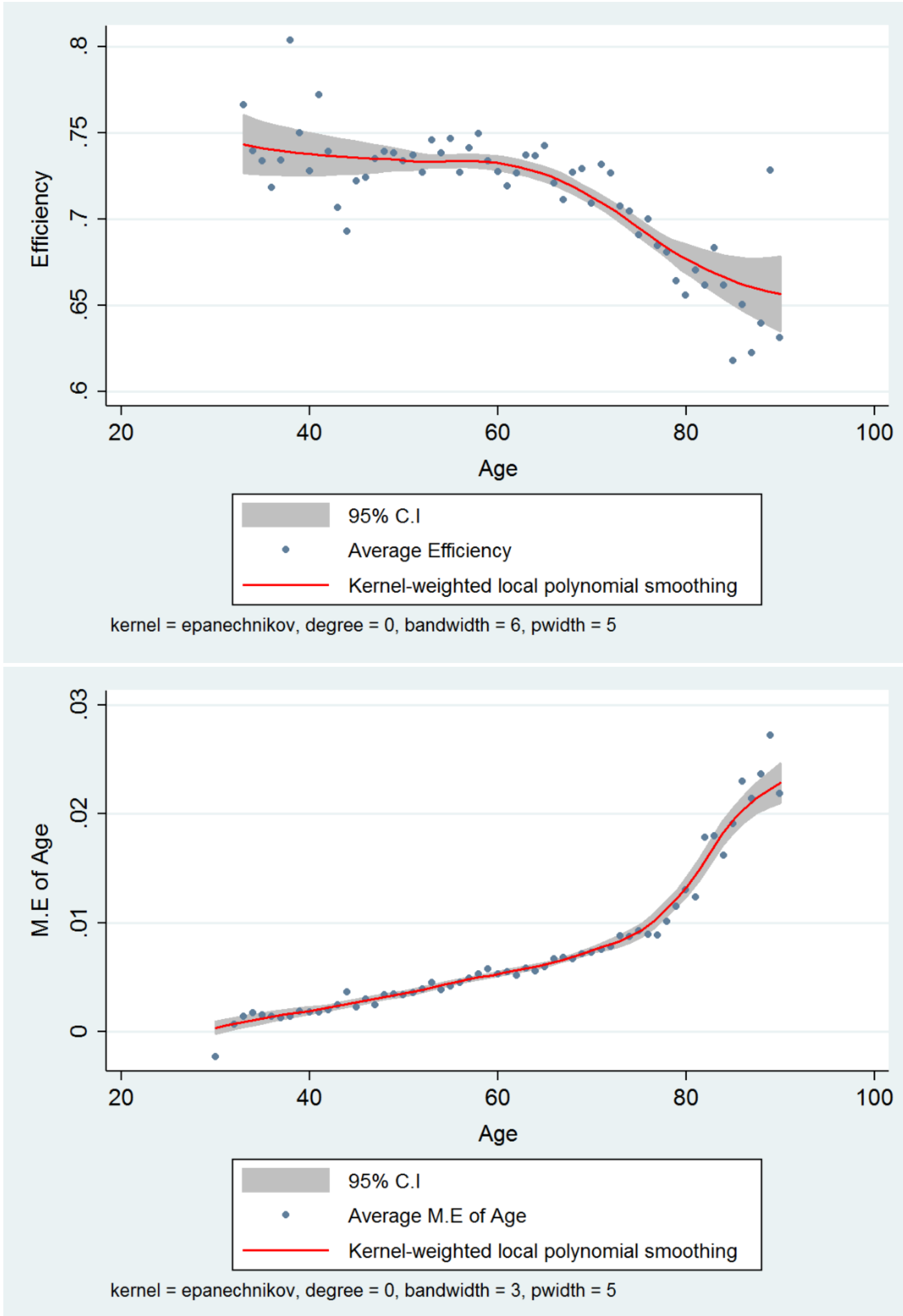

Figure 2. Estimated Efficiency Score (top) and Marginal Effect of Age on Inefficiency (bottom), by Age

Table 1. Dependent and Independent Variables and Their Descriptions

	Variable	Description	Mean	Std. Err.
Frontier	*Y*	Farm Sales (in thousand Won)	25,801	351
	FL	Family Labor (in hour)	998	7.8
	EL	Employed Labor (in hour)	385	7.6
	K	Agricultural fixed assets (in thousand Won)	273,438	3432
	A	Cultivated arable land (a)	191.7	2.2
	M	Intermediate input expenditures (in thousand Won)	4,632	66
Inefficiency	*Age*	Age of farm operator (in year)	66.03	0.09
	Edu	Maximum education year of farm operator (in year)	7.98	0.03
	Family Size	Number of household members (in person)	2.71	0.01
	Gender	= 1 if farm operator's gender is female; otherwise 0	0.075	-
	Debt rate	Total Debts/Farm Assets	5.95	0.36
	Share of NF. Rev.	Non-farm revenue/Total Revenue	34.07	0.31
	Share of Subsidies	Income Subsidy/Farm Income	28.39	6.46

Notes:

Table 2: Number of observations in each group of age and education

Age	**Education Attainment**							
	No School	Elementary	Middle	High	Associate	Bachelor	Advanced	**Total**
30 and less	0 (0.00)	0 (0.00)	8 (0.07)	47 (0.41)	12 (0.11)	7 (0.06)	1 (0.01)	75 (0.66)
40 to 49	0 (0.00)	32 (0.28)	101 (0.89)	412 (3.63)	57 (0.50)	74 (0.65)	1 (0.01)	677 (5.97)
50 to 59	39 (0.34)	556 (4.90)	598 (5.27)	867 (7.65)	69 (0.61)	55 (0.49)	3 (0.03)	2187 (19.29)
60 to 69	169 (1.49)	1,662 (14.66)	927 (8.18)	657 (5.79)	51 (0.45)	91 (0.80)	10 (0.09)	3567 (31.46)
70 to 90	570 (5.03)	2,108 (18.59)	683 (6.02)	609 (5.37)	41 (0.36)	82 (0.72)	1 (0.01)	4094 (36.11)
80 and older	254 (2.24)	375 (3.31)	46 (0.41)	43 (0.38)	4 (0.04)	16 (0.14)	0 (0.00)	738 (6.51)
Total	1,032 (9.10)	4,733 (41.74)	2,363 (20.84)	2,635 (23.24)	234 (2.06)	325 (2.87)	16 (0.14)	11,338 (100.00)

Note: Parentheses represent the proportion of observation in percentage

Table 3: Estimates of the parameters between the Cobb-Douglas and Translog functions

		Cobb-Douglas		Translog	
		Coeff.	Std. Err.	Coeff.	Std. Err.
Frontier	*ln FL*	0.300***	0.008	0.041	0.114
	ln EL	0.185***	0.004	0.431***	0.065
	ln K	0.071***	0.005	-0.079	0.056
	ln A	0.200***	0.007	0.397***	0.102
	ln M	0.302***	0.007	0.182*	0.095
	$(ln\ FL)^2$			0.099***	0.008
	$(ln\ EL)^2$			0.041***	0.002
	$(ln\ K)^2$			0.002	0.002
	$(ln\ A)^2$			0.003	0.006
	$(ln\ M)^2$			0.048***	0.005
	ln FL × ln EL			-0.061***	0.007
	ln FL × ln K			0.009	0.007
	ln EL × ln K			-0.008**	0.004
	ln FL × ln A			-0.060***	0.011
	ln EL × ln A			0.022***	0.005
	ln FL × ln M			-0.038***	0.011
	ln EL × ln M			-0.055***	0.006
	ln A × ln K			0.017***	0.006
	ln K × ln M			0.002	0.006
	ln A × ln M			-0.013	0.008
	ln FL × T			0.005	0.005
	ln EL × T			0.011***	0.003
	ln K × T			-0.010***	0.003
	ln A × T			-0.007	0.004
	ln M × T			-0.001	0.005
	T			0.094**	0.045
	T^2			-0.003	0.003
	Constant			2.844	0.583
Inefficiency	*Age*	0.176***	0.022	0.230***	0.032
	Edu	0.842***	0.125	1.174***	0.186
	Age × Edu	-0.011***	0.002	-0.015***	0.002
	Gender	0.961***	0.181	1.352***	0.274
	Family Size	-0.468***	0.065	-0.547***	0.088
	Debt rate	0.0004	0.001	0.001**	0.001
	Share of NA. Rev.	0.052***	0.005	0.066***	0.007
	Share of Subsidy	0.00004	0.00004	0.0001**	0.0001
	Constant	-17.254	2.097	-23.851***	3.171
	σ_u	1.211***	0.072	1.495***	0.096
	σ_v	0.379***	0.005	0.345***	0.004
	λ	3.198***	0.072	4.330***	0.097
	Log likelihood		-8,178.535		-7,692.945
	Obs.		11,338		11,338

Notes: A positive sign of a parameter of the inefficiency model indicates that the associated variable has a negative impact on technical efficiency, and vice versa. Significance levels are indicated by *, **, *** for 10, 5, and 1 percent significance level, respectively.

Table 4. Average technical efficiency by the overall sample and different groups

Year	Total Efficiency	Subgroup 1: Rice	Subgroup 1: Non-Rice	Subgroup 2: S Farm	Subgroup 2: NS Farm	Subgroup 3: Urban	Subgroup 3: Rural
2008	0.7250	0.7419	0.7113	0.7984	0.6903	0.7085	0.7279
	(0.0003)	(0.0038)	(0.0051)	(0.0036)	(0.0043)	(0.0090)	(0.0035)
2009	0.7291	0.7499	0.7147	0.8058	0.6890	0.7071	0.7329
	(0.0033)	(0.0036)	(0.0049)	(0.0034)	(0.0043)	(0.0091)	(0.0035)
2010	0.7131	0.7133	0.7129	0.7934	0.6717	0.6845	0.7179
	(0.0034)	(0.0046)	(0.0047)	(0.0041)	(0.0044)	(0.0096)	(0.0037)
2011	0.7106	0.7221	0.7042	0.7890	0.6693	0.6774	0.7164
	(0.0035)	(0.0050)	(0.0047)	(0.0041)	(0.0046)	(0.0094)	(0.0038)
2012	0.7089	0.7399	0.6934	0.7818	0.6680	0.7086	0.7089
	(0.0036)	(0.0050)	(0.0048)	(0.0043)	(0.0048)	(0.0093)	(0.0040)
Total	0.7173	0.7343	0.7068	0.7934	0.6778	0.6972	0.7208
	(0.0015)	(0.0019)	(0.0022)	(0.0018)	(0.0020)	(0.0041)	(0.0016)

Note: Standard errors are reported in parenthesis

Table 5. Average marginal effect of age on inefficiency by age group and year

AGE	Total Efficiency	**Marginal Effect of Age**					
		2008-2012	2008	2009	2010	2011	2012
30s	0.7473	**0.0014**	0.0017	0.0014	0.0016	0.0011	0.0010
	(0.0195)	(0.0002)	(0.0003)	(0.0004)	(0.0005)	(0.0005)	(0.0005)
40s	0.7292	0.0029	0.0024	0.0025	0.0026	0.0041	0.0030
	(0.0067)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0010)	(0.0005)
50s	0.7386	0.0045	0.0041	0.0044	0.0044	0.0047	0.0048
	(0.0036)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0004)
60s	0.7279	0.0061	0.0058	0.0061	0.0061	0.0060	0.0066
	(0.0026)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0004)
70s	0.7045	0.0086	0.0079	0.0086	0.0087	0.0086	0.0092
	(0.0025)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
80s	0.6606	**0.0159**	0.0177	0.0184	0.0153	0.0146	0.0154
	(0.0065)	(0.0008)	(0.0029)	(0.0002)	(0.0014)	(0.0013)	(0.0014)

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Appendix

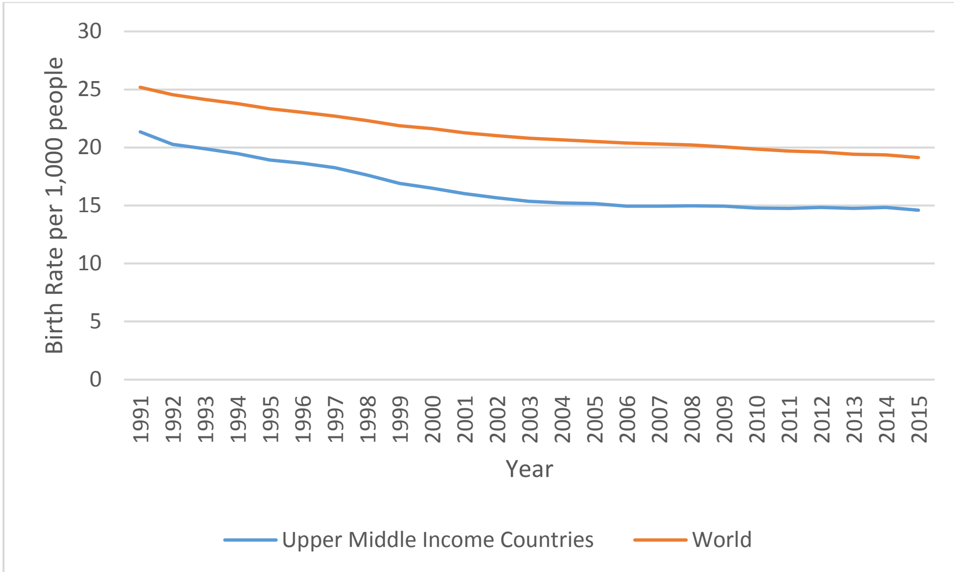

Figure A1. Birth Rate Comparison between Upper Middle Income Countries and World

Note: Upper Middle Income Countries are defined by World Bank
Source: Author's calculation based on World Bank Database