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Essays on the Elderly Labor of Korea

한국의 고령자 노동 연구

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경제학부 경제학 전공

정 종 우

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이 논문을 경제학 박사 학위논문으로 제출함

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정종우의 경제학 박사 학위논문을 인준함

2021년 7월

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Abstract

The dissertation contains three essays on labor economics of the elderly in Korea. Specifically, I investigate how elderly labor responds to the following three factors: 1) housing wealth, 2) technological change, and 3) minimum retirement age policy.

Chapter 1: Housing Wealth, Home Ownership, and Retirement Behavior

Using a longitudinal data set from South Korea, I estimate the impact of housing wealth on the labor supply of elderly workers. Estimation results from my model suggest that house wealth variations significantly influence labor force participation, working hours, and expected retirement age of older workers. The housing wealth effect is bigger for people nearing retirement, which influences their retirement behavior. Additionally, this study suggests a mechanism of the housing wealth effect in which home-owning retirees tend to liquidate their housing wealth to finance their retirement. Retirees tend to move to a less-expensive house and utilize the profits from the housing values as a financial cushion to fund their retirement.

Chapter 2: Technological Change, Job Characteristics, and Employment of Aged Workers (with Chulhee Lee)

We investigate how the adoption of a new production technology differently affects the risk of job separation of young and old employees in South Korea by analyzing establishment-level panel data linked with administrative employment insurance records on individual workers. To address potential endogeneity associated with a firm's technology adoption, we conduct instrumental variable estimations with a two-stage residual inclusion (2SRI) approach. The results suggest that technological changes (indicated by newly adopted automation, increased investment in IT, and increased purchase of IT equipment) positively affect the overall employment of incumbent workers. However, the employment of aged workers is less favorably affected by newly adopted technologies compared to that of younger workers. In some conditions, technological changes increase the retirement risk of older workers absolutely as well as relative to that of younger workers. Newly adopted automation negatively affects the employment of aged male workers who are engaged in the manufacturing industry. Investment in IT or IT equipment raises the probability of voluntary retirement of older workers employed in the service industry.

Chapter 3: The Impact of the Minimum Retirement Age and Labor Substitutability

Since 2016, workplaces in South Korea have been required to set the minimum retirement age at 60 by the amendment of the Act on aged workers' employment. Using a set of data combining establishment-level panel data with individual-level employment records, I examined whether the delayed retirement age would increase older workers' employment and how it affects the younger generations. A simple analysis shows that birth cohorts affected by the policy are 25.1 percentage points less likely to retire from their original retirement age than the other cohorts. The estimation results suggest that the policy reduces the employment of mid-aged (aged 30-54) workers. Much of the reduction in employment can be accounted for by the changes in male workers working for more than two years. The degree of labor substitution between older and young workers depends on the implementation of a wage-peak system. Firms adopting the wage-peak system tend to show 1) the low proportion of old workers and 2) the existence of a labor union. I found that firms having at least one of these characteristics show lower labor substitutability between generations.

Keywords: Elderly Labor, Housing Wealth, Technological Change, Retirement Age, Labor Substitutability
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Chapter 1. Housing Wealth, Home Ownership, and Labor Supply of Older Workers

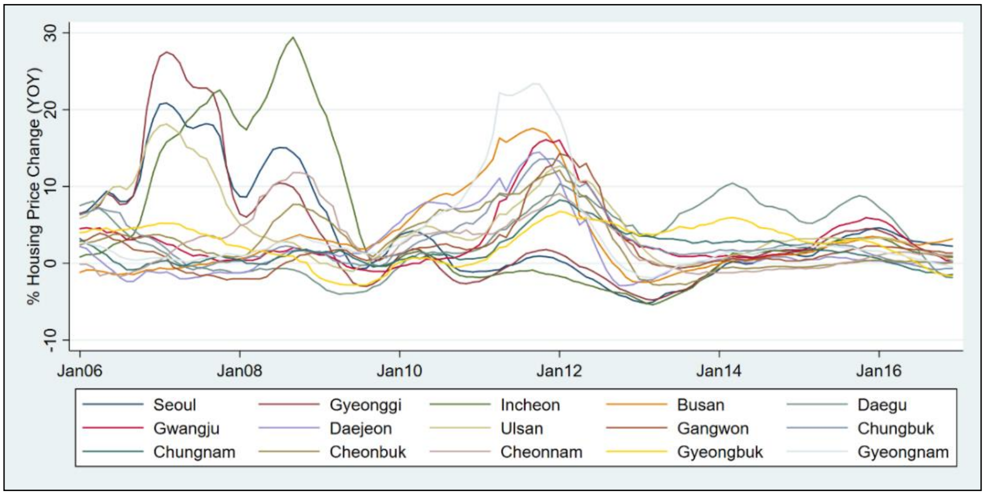
1.1. Introduction

Since the relative size of the elderly population has been increasing, examining the labor decisions of elderly workers has become more important due to its influence on modern society and its economic structure. Therefore analyzing the elderly labor trend would be helpful in solving social problems such as labor shortages, aging labor force, and a rising burden of social security taxes.

Researchers have highlighted key determinants of labor supply, such as financial wealth, social security, and health (Dwyer and Mitchell 1999; Gruber and Wise 2002; McGarry 2004). As housing markets in the U.S. and other developed countries have fluctuated over recent decades, studies have also examined the effect of housing wealth of elderly households on labor supply and their retirement decision based on the following questions: When experiencing housing wealth shock that results in increasing/decreasing the wealth of the elderly, do elderly people reduce/increase their labor supply; Is the effect limited to only homeowners; Which mechanism drives the elderly to change their labor supply? While housing wealth constitutes a large fraction of the retirement portfolio of old households, relatively small evidence has been proved the housing wealth effect and its mechanism.

This study uses the Korean Longitudinal Study of Aging (KLoSA, hereafter) to examine the effect of housing wealth on elderly labor supply and retirement. There are several interesting points to consider regarding this issue in the context of South Korea. First, households in South Korea have experienced a number of housing price shocks in the last 15 years. Figure 1.1 shows the housing pricing data published by the Korea Appraisal Board between 2006 and 2016, a period of time when the annual house price change varied from -5% to 30%. There are various views to explain what happened, but the consensus is that a huge amount of floating money originating from a low interest rate was concentrated in the real estate market rather than the financial market due to long-term low economic growth.

Figure 1.1. Housing Price in South Korea



Note: Housing Price Indexes are provided by Korea Appraisal Board. Three kinds of first-level divisions in South Korea are reported: one special city (Seoul), eight provinces (Gyeonggi, Gangwon, Chungbuk, Chungnam, Cheonbuk, Cheonnam, Gyeongbuk, and Gyeongnam), and six metropolitan cities (Incheon, Busan, Daegu, Gwangju, Daejeon, and Ulsan).

Second, In South Korea, real estate assets constitute the primary wealth component of the elderly household. In comparison, financial assets are the main wealth component of the elderly household in (most) developed countries. In 2017, real estate accounted for 69.8% of South Korean household assets. Moreover, the homeownership rate increases as households get older. This suggests that elderly Korean household wealth is possibly more vulnerable to housing market crises compared to other countries: older people may highly depend on their housing wealth to financially support retirement.

Third, the elderly labor market in South Korea is more active than in any other country. Although the statutory retirement (pensionable) age in South Korea is around 60, most people who retire at around 60 seek a secondary job or switch to being self-employed. Thus, the effective retirement age in South Korea is the highest among Organization for Economic Co-operation and Development (OECD, hereafter) countries. In 2017, 67.5% of Koreans between the ages of 55 and 64 were employed (including self-employed). However, the average effective retirement age for older workers in South Korea is 72 (OECD, 2017; the average for all OECD countries is 65), and the public pension system of South Korea is still at an early stage. Since the income replacement ratio on the current pension system in South Korea is just 24.2%, many older people who receive a pension remain in the labor market. This situation explains why the gap between the effective retirement age and the pensionable age in South Korea is also the highest among OECD countries.

Based on this background, we conduct our study across two stages. In the first stage (Section 1.4), we use an individual fixed-effects approach to examine whether changes in housing wealth level affects labor supply with capturing individual heterogeneity. In the second stage (Section 1.5), we elaborate the literature by suggesting a channel of utilizing housing wealth where retirees tend to move to a less expensive house. To examining the channel, meanwhile, we use a 20% sample of the 2015 Population and Housing Census (20% PHC, hereafter) released by Korea Statistics to investigate the moving pattern of retirees.

The paper is organized as follows: Section 1.2 reviews the previous literature and suggests a theoretical framework; Section 1.3 presents the data and the empirical strategy; Section 1.4 reports the baseline regression results along with robustness checks; Section 1.5 reports the extended analysis of the mechanism; and Section 1.6 concludes this study.

1.2. Literature Survey and Theoretical Framework

Previous studies have found a variety of determinants that influence the elderly labor supply. In terms of policy-related factors, benefits from social security wealth, Medicare eligibility, disability insurance, and work or tax incentives are widely acknowledged to be important variables for labor participation as well as financial well-being in retirement. (Coile and Gruber 2007; Kostol and Mogstad 2014; Krueger and Pischke 1992; Liebman, Luttmer, and Seif 2009). In terms of individual labor supply, wealth, income, health, job characteristics, job satisfaction, and labor supply of other household members play an important role in influencing labor supply of older workers (Dwyer and Mitchell 1999; French 2005; Gruber and Wise 2002; Haveman et al. 2006; Lee and Lee 2013; McGarry 2004).

Another consensus of research on the household survey is that large capital gains lead workers to reduce labor force participation. The magnitude of the reduction of the labor force is larger among old workers who are close to retirement age: they are at the margin of their working life, and their retirement is more easily induced by capital gains (Hurd et al. 2009; Imbens, Rubin, and Sacerdote 2001; Zhao and Burge 2017). A channel of large capital gain may be from housing wealth, the primary component of household assets for the elderly. Considering that a higher proportion of the elderly own their home than younger people, capital gains from the housing market are more likely to increase rest-of-lifetime resources in older households.

The relationship between housing wealth and labor supply has attracted relatively little attention until recent years. Generally, in the economic literature, there is a skeptical view that most elderly households regard housing wealth as an illiquid asset. However, the development of financial products such as reverse mortgages enables older households to more conveniently liquidate their homes. Moreover, a strong boom and bust cycle of the housing market over the last 20 years has emphasized the importance of housing wealth.

Previous studies have suggested two methodologies to measure the housing wealth effect: changes in housing wealth level and unexpected capital gains from the housing market boom. Both of two examine capital gains but differ in their theoretical framework. First, the effect of housing wealth level is based on consumption theory, which has suggested that leisure consumption, like other normal goods and services, would increase if an individual experiences capital gain. Skinner (1996) and Engelhardt (1996) suggested the importance of housing wealth; however, considerable literature has documented a relationship between housing wealth and consumption levels (Aladangady 2017; Angrisani, Hurd, and Rohwedder 2019; Bhatia and Mitchell 2016; Bostic, Gabriel, and Painter 2009; Cristini and Sevilla 2014; Engelhardt 1996; Kishor 2007). Campbell and Cocco (2007) find that the effect is largest for older homeowners.

The precautionary saving hypothesis also suggests that older households would increase their consumption if their wealth level met the saving goals for an emergency or bequest (Campbell and Cocco 2007; Case, Quigley, and Shiller 2005; Skinner 1996); however, people do not report the level of their saving goals or how an increase in housing wealth would raise the probability of retirement when they are close to the goal. Fu et al. (2016) investigate older workers in China and find a significant relationship between housing wealth and female labor supply. In contrast, Disney et al. (2015), using UK data, find little evidence of the effect and suggest that the local labor market situation is more important.

Based on the theoretical background, we set out a simple model of leisure consumption.

$$L_i = W(h_i, f_i \mid X_i, N_i, M_i) \quad (1)$$

The length of leisure, L is determined by W_i, an individual $i's$ wealth given a set of demographical characteristics including health (X); income (N); and macroeconomic situations (M). W includes housing wealth (h) and non-housing wealth (f): that is, renters only have f. Anticipating the length of rest-of-life, i determines W_{it}^G, the saving goal before retirement at time t. In the data, we observe the binary of retirement decision,

$$R_{it} = 1 \text{ if } W_{it} > W_{it}^G \quad \text{and} \quad R_{it} = 0 \text{ if } W_{it} \leq W_{it}^G,$$

where $R_{it} = 1$ means that an individual i retires at time t.

We next point to examine the mechanism of the housing wealth effect: how retirees use their housing wealth to finance retirement consumption? Two channels are suggested-collateral borrowing and downsizing channels. In the case of the collateral borrowing channel, a highly appraised housing price makes reverse mortgage loans more attractive to retired homeowners. The advantage of the collateral borrowing channel is that borrowers can continue to live in their homes and do not have to redeem the loan before termination. Cocco and Lopes (2020) suggest that a reverse mortgage loan may enhance old homeowners' utility not only due to financing retirement but also fulfilling their need to reside in their current place. Haurin et al. (2018) find evidence that the elderly tends to overvalue their housing asset and that the upward bias becomes stronger even when the market value of the house is decreasing. Using a multi-period optimization model with cohort-specific life table in Korea, Yang and Yuh (2019) also suggest that reverse mortgage loan is beneficial for homeowners who are 67 and older.

On the other hand, the disadvantage of reverse mortgage loan is that retirees should lose their home ownership. A strong preference for home ownership may make the collateral borrowing option less attractive to old households. Nakajima & Telyukova (2017) suggest that precautionary saving and bequest motives explain a (low) demand on the reverse mortgage loan. Statistics also show little evidence of the channel in Korea. Since the Korean government implemented a reverse mortgage loan in 2007, the coverage rate of old households is less than one percent (Lee, An, and Sung 2018).

The downsizing channel can be an alternative option: retirees move to lower value homes and keep their home ownership. Moreover, if retirees lived in an urban area with a high cost of living, they could move to a suburban area where not only the house is cheaper but also the living expenses are low. The channel might become a more preferred option if a housing market experiences boom for a considerable period. If a retiree expects that local housing price continues to increase in the future, so the present price, the size of a reverse mortgage, seems to be undervalued, he or she would move into the less expensive house and expect the house price to go up.

Meanwhile, it is worth noting to summarize studies on elderly labor and the housing price trend in South Korea. Many studies have explored the characteristics and determinants of retirement behavior in South Korea. Representatively, Lee and Lee (2015) show that poor health and a higher hourly wage correlate with a greater retirement hazard[①]. Using the 2006–2008 KLoSA, Lee and Lee (2013) report the importance of quality of matching between worker and job characteristics as a determinant of retirement. They show that self-employed workers who are able to adjust the amount they work to their own needs tend to work longer than waged workers. These papers show relatively less attention to the effect of housing wealth, a potentially important factor which may

① According to the Korean Longitudinal Study of Ageing (KLoSA), the most frequently reported reason for retirement is poor health (Lee and Lee 2013). There is an argument that this self-reported health measure is potentially endogenous because retirees tend to use their health as an excuse to justify their retirement. For example, Anderson and Burkhauser (1985) show that retirees jointly decide to report their poor health and retirement. In the case of South Korea, however, there might be the different interpretation that older workers in South Korea have to work as long as their health allows it due to their low income.

be directly related to retirement plans of old households or affect their labor decisions.

The housing market in South Korea has been uncertain in recent decades. For example, the housing market in metropolitan areas (Seoul special city, Incheon metropolitan city, and Gyeonggi province) had an unprecedented boom in the 2006–2008 periods[②]. The government had announced housing policies to stabilize the housing market every three months but failed to reach the goal[③]. Since then, the entire housing market experienced a bust in the aftermath of the Great Recession of 2008. House price growth stagnated during this period. The government implemented policies to revive the housing market (and the construction industry) in order to encourage an economic rebound. The housing market, however, responded only after two years. The market has gradually revived since 2010, and house prices have significantly increased again. This historical background suggests that the housing market trend is hard to anticipate.

1.3. Data and Empirical Strategy

1.3.1. Data

This study uses four different sources of data: the KLoSA, the Korea Housing Price Index, macroeconomic variables from Korea Statistics, and 20% of the sample of the 2015 Population and Housing Census (20% PHC, hereafter). The first three data sets are used for estimating the baseline regression. The 20% PHC provides auxiliary data in order to investigate a downsizing channel of the housing wealth effect. This section focuses on the first three data set, and more details on the 20% PHC will be discussed in section 1.5.

② Xiao and Park (2010) suggest that the combination of sluggish housing supply and speculative demand added to the demand to live in a decent place (i.e., an apartment located in Seoul) led to rapid price increases. In a macroeconomic view, Cerutti et al. (2017) suggest that account surpluses after an economic boom are associated with the housing market boom in South Korea.

③ Park et al. (2010) argue that regulation on bank lending for anti-speculation doesn’t affect metropolitan areas due to the strong belief of households that house prices in metropolitan areas will continue to increase.

The main data of this study, the KLoSA is a survey of people who are over 45 years old and have lived in metropolitan cities and provinces of South Korea[4]. The KLoSA began its first survey in 2006 and has re-interviewed households every two years. The survey interviews each member of a household (normally husband and wife). If the survey fails to interview a subject in one wave, the KLoSA tries to interview him or her in the next survey. Due to the use of individual-level data, we are able to estimate the response of labor supply to housing price variation at a local level, and keep track of changes in their demographics, assets, income, and job characteristics. The survey also contains detailed individual-level information on demographics, labor, assets, income, and health. Employment information includes current employment status, occupational classification, and earnings.

This study uses the KLoSA from waves 1 to 6 of the survey (2006–2016 biennial panel data). Samples include respondents from 55 to 70 years of age. Measures of labor supply are labor-force participation, weekly working hours, and expected retirement age. The expected retirement age was surveyed only for those currently working. They responded to the age at which they anticipated retiring. Some of them replied that they wanted to work as long as they could; we coded them equal to the maximum of answers from people of the same age, gender, and occupation.

Asset variables include housing, financial assets (checking, savings, stocks, bonds, and pensions), and other assets, including non-housing real estate assets. We define housing wealth as a housing asset minus housing-related debt (the net value of home equity). While every respondent reports their own assets, the representative respondent in a household can report their housing value only if the house they are currently residing in is under their name.[5] To estimate house price

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[4] There are five kinds of first-level divisions in South Korea: eight provinces, six metropolitan cities, one special city (Seoul), one special self-governing province (Jeju Island), and one special autonomous city (Sejong, first settled in 2012). People lived in the last two divisions are not surveyed by the KLoSA due to the small population (1.6% of total population). Thus, our study covers all of the provinces, the metropolitan cities, and the special city. In terms of total area, provinces are the broadest divisions in South Korea. The average is about 12,000km^2 in area, which is about the half of New Jersey, the fourth-smallest among the U.S. On the other hand, the average of area of metropolitan cities (including special city, Seoul) is about 770km^2, which is about 60% of New York City. About 45% of populations in South Korea live in the metropolitan cities and the special city.

[5] Due to a strong Confucian influenced (mainly patriarchal) culture and men constituting a higher rate

effects on both husbands and wives, we assume that each household member pools the housing wealth. Non-housing wealth is defined as non-housing assets minus non-housing liabilities. As wealth variables are logged for conducting the regression, we change people with negative financial wealth value (2.4% of the sample) to zero.

A few filters are used. First, we drop respondents who do not report demographic or asset information. Second, we also drop respondents who were already retired in the first survey or reported they had never had a paid job. Third, samples are restricted to respondents who have been surveyed at least two times to meet conditions where every specification requires. Table 1.1 summarizes the construction of samples. 1,601 respondents remained, which constitute 8,758 of sample size.

Two auxiliary datasets are merged to the KLoSA. First, we use the city/province-level housing price index (HPI, hereafter) published by Korea Appraisal Board. The Korea Appraisal Board collects all the housing sales records in South Korea and reports price index every month. In addition, there is a concern that some macroeconomic changes may have an impact on the labor demand and house market prices and change the equilibrium. Thus, we merge the average local wage and the unemployment rate of 55 and older individuals from Korea Statistics to the KLoSA panel adjusting to survey year and month. All the macroeconomic variables are city/province level values.

Table 1.2 displays descriptive statistics of variables used for our study. Respondents are surveyed 5.42 times (out of 6) on average for 10 years. In 2006, four out of five respondents were homeowners. According to HPIs, housing prices annually increase by 3.41% on average. The average value of housing wealth is 132.1 million KRW and constitutes 73% of total wealth. 77% of the samples were working at the first wave, and 53% of them are self-employed. While previous studies exclude self-employed from the sample, we included them because many old workers in South Korea move to self-employed after their main occupation,

of labor force participation than women in Korea, household assets (especially the elderly) are often under the patriarch's name. Since 75.6% of homes are under the name of men, in the first wave male respondents (husbands) normally reported information on their housing wealth.

and also, our goal of this study is how old households continue/stop their labor supply.

Table 1.1. Sample Selection

Sample for retirement transitions	Sample Size
People ages 55-69 in 2006	21,303
+ Has no missing data	20,307
+ Has a career history	8,896
+ At least interviewed twice 2006-2016	8,758

Source: Korea Longitudinal Study of Aging 2006-2016

Table 1.2. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Basic Information				
Number of Surveyed	5.42	1.16	2	6
Female (=1)	0.32	0.47	0	1
Age	61.13	4.26	55	69
Elementary school (=1)	0.44	0.50	0	1
Middle school (=1)	0.20	0.40	0	1
High school (=1)	0.27	0.44	0	1
>Some college (=1)	0.10	0.30	0	1
Number of unmarried children	0.59	0.80	0	4
Self-reported health (Bad =1)	0.22	0.42	0	1
Assets				
Homeowner (=1)	0.80	0.40	0	1
Housing Price Index (2016 HPI=100)	75.11	5.20	63.90	85.10
Housing assets (Homeowners only, 1M KRW)	138.16	204.9	0	1870
Housing wealth (Housing assets - housing liability, 1M KRW)	132.08	200.8	0	1870
Non-housing wealth (1M KRW)	47.08	263	0	7194
Annual labor income (1M KRW)	18.92	21.8	0	324
Annual non-labor income (including pension, 1M KRW)	2.94	12.6	0	396
Labor				
Wage worker (=1)	0.37	0.48	0	1
Self-employed (=1)	0.41	0.49	0	1
Working Hours (Workers only, Weekly)	41.92	25.22	0	126
Retired by 2016 (=1)	0.86	0.35	0	1
Collateral Borrowing and Moving	72.99	7.96	55	104
Personal annuity (1M KRW)	0.14	1.32	0	23.9
Have moved during the survey (=1)	0.18	0.38	0	1
Local Market				
Local Average Wage (City-Province Level, 1M KRW)	2.11	0.19	1.8	2.5
Local Unemployment rate (City-Province level)	3.30	1.04	1.3	4.6
Observations	8,758			

Note: Sample includes observations on workers 55-70 years old in 2006 (The KLoSA 1st wave). Housing wealth, Non-housing wealth, and income are deflated by CPI. Property tax is calculated by reported housing and other real-estate assets. The exchange rate used for Dec. 2006 is US$ 1 = KRW 925.26.

1.3.2. Empirical Strategy

We employ individual fixed-effects models to examine the housing wealth effect on labor supply. The model can capture unobserved and individual-specific heterogeneity: for example, people have a different preference for wealth accumulation and leisure consumption. The model can also mitigate the bias if self-reported housing wealth is consistently over/undervalued. Specifically, we estimate:

$$Y_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 X_{it} + \beta_3 W_{it} + \beta_4 M_{jt} + \gamma_t + \delta_j + \mu_i + \omega_{ijt} \qquad (2)$$

The outcome variable, Y_{it}, is the labor supply of individual i (living in region j) at t. Specifically, labor force participation (dummy), working hours (logged value), and expected retirement age (logged value) are used. Since the impact of housing wealth on retirement can be heterogeneous based on the definition of retirement, we define retirement in several ways. The strictest definition is the one used by the KLoSA (as explained in Section 1.3). In addition to this, we define a partial retirement where a respondent said they quit the job and does not search for another job but is not considered as being in permanent retirement. In the third definition of retirement, we consider involuntary retirement. If a respondent declares retirement, the KLoSA survey asks the reason for retirement. Retirees can choose one of the following: 1) my non-labor income is enough to retire, 2) my spouse's income is enough to retire, 3) I do not want to work anymore, 4) I want to spend my leisure time, 5) for volunteer or hobby activity, 6) poor health, 7) my spouse's health problem, 8) other family's health problem, 9) housekeeping and childcare, 10) I can't find a job anymore, 11) I have reached the retirement age of my company, 12) other reason. Among reasons for retirement, we exclude involuntary reasons (from 7) spouse's health problem to 11) reaching the retirement age of their company). H stands for housing wealth and β_1 is our interest. X, a set of demographic and personal information, includes age, gender, education level, family (number of children), and health. W, a set of other assets, includes non-housing wealth (real estate being excluded in the residential homes and other financial assets minus liabilities). M is a set of macroeconomic statistics. γ_t, δ_j, and μ_i are time, region, and individual fixed effect, respectively.

We use two alternative measures of housing wealth: self-reported housing wealth (housing price minus debt related to house) and housing price indexes (HPIs, hereafter). Since renters only had non-housing wealth, HPI is used as a proxy variable for comparing homeowners and renters.

HPI is also used to make up for the weakness of self-reported housing wealth. Of course, the primary benefit of self-reported value is that the value itself is a perceived housing price: it is natural to judge that consumption level is based on his or her perceived wealth. However, the self-reported wealth has a possibility of measurement error. The reported values are not guaranteed to be the most recent price: it may be the purchase price, updated but not up-to-date price, or the price they just hope, the willingness to sell. The error may have a substantial problem of offsetting the estimates of the housing wealth effect. In addition, changes in housing wealth may reflect individual preference, which is correlated with labor supply decisions. It is possible that an individual who wants to retire early would hasten to pay back their mortgage loan or save more during his/her working periods (Hurd et al., 2009). Although the individual fixed effect can address the heterogeneity issue, estimating equation (2) using self-reported housing wealth still remains an endogeneity issue as a result.

Not only being a proxy variable, HPI can be employed as an instrumental variable. HPI carries exogenous shock of regional housing markets: the indexes are not biased to very local characteristics. Lovenheim (2011) argued the validity of the housing price index as an instrument for endogenous household assets. He suggested that short-term housing wealth changes could be exogenous shocks of household wealth variation and showed a strong relationship between house price indexes and household wealth. In a similar vein, Fu et al. (2016) used the average capital gains from the neighborhood as an instrumental variable.

In the first stage, we regress housing wealth on the housing price index and other covariates. Specifically, we estimate:

$$H_{it} = \beta_0 + \beta_1 HPI_{jt} + \beta_2 X_{it} + \beta_3 W_{it} + \beta_4 M_{jt} + \gamma_t + \delta_j + \mu_i + \varepsilon_{ijt} \qquad (3)$$

The definitions of variables are the same as equation (2). In the second stage, the explanatory variable is $\widehat{H}_{it}$ as estimated by the first stage:

$$Y_{it} = \beta_0 + \beta_1\widehat{H}_{it} + \beta_2 X_{it} + \beta_3 W_{it} + \beta_4 M_{jt} + \gamma_t + \delta_j + \mu_i + \omega_{ijt} \qquad (4)$$

where ω_{ijt} is the residual and $Cov(HPI_{jt}, \omega_{ijt}) = 0$ is assumed.

1.4. Results

1.4.1. Baseline Results

Table 1.3 reports the estimation results of the individual fixed-effects models. Columns 1–3 present the estimation results based on Equation (2). The results show that variation in self-reported housing wealth is not significantly associated with labor supply. As explained in Section 1.3, this may suggest that measurement error or any endogenous characteristics of reported wealth offset the effect. Conversely, for columns 4–6, the estimation results using the HPI as an instrument suggest a significant relationship with retirement behavior. The first stage of the instrumental variable estimation is reported in Table 1.A.1. The elasticity between HPI and reported housing wealth is 0.87, which indicates a high correlation between the two variables. The F statistic for the weak instrument test, based on Stock and Yogo's (2002) criteria is 22, indicating the HPI instrument is not a weak one. For the second stage, housing wealth has a significant impact on all the outcomes indicating labor supply. Results from column 4 indicate that a 10% increase in housing wealth is associated with a 3.1% decrease in labor force participation. It also decreases working hours and expected retirement age by 11 and 0.4%, respectively. Like the housing wealth effect, non-housing wealth also has an impact on labor supply, but the magnitude is much less than housing wealth. This difference could be explained by housing-biased asset portfolios in Korean households.

The estimated effects of other control variables show similar significance and magnitude across the specifications. As previous literature has found, age, health, and the number of unmarried children are other determinants of labor supply. Although health status is an important factor in any labor market, the result includes another meaning in the Korean labor market. As explained in Section 1.1, due to the unmatured pension system, many old workers in Korea want to work as long as their health allows. Under the background, we conjecture the health status only affects the current working status, but not working plans such as expected retirement age. The change in the number of unmarried children is also an important issue in Korean culture. Since parents tend to give their child financial support to prepare a house or furniture when the child gets married, they would feel less burdened after the child moves out. Among the macroeconomic variables, the effect of the local average wage is statistically significant if the expected retirement age is an outcome variable.

Table 1.3. Housing Wealth Levels and Labor Supply

	(1)	(2)	(3)	(4)	(5)	(6)
	Fixed Effects Model			IV-Fixed Effects Model		
Dependent Variable	Labor Force Participation (=1)	Work Hours (log)	Expected retirement age (log)	Labor Force Participation (=1)	Work Hours (log)	Expected retirement age (log)
Housing wealth (log)	-0.0023	-0.0055	-0.0013	-0.3073***	-1.0784***	-0.0431***
	(0.0040)	(0.0154)	(0.0010)	(0.0975)	(0.3595)	(0.0165)
Non-housing wealth (log)	0.0087***	0.0295**	0.0011	-0.0374**	-0.1328**	-0.0045*
	(0.0033)	(0.0125)	(0.0008)	(0.0154)	(0.0567)	(0.0024)
Age	0.3321***	1.1736**	-0.0614***	0.2986*	1.0555*	-0.0637**
	(0.1214)	(0.4636)	(0.0234)	(0.1634)	(0.6027)	(0.0276)
Age squared	-0.0009***	-0.0033***	-0.0001**	-0.0011***	-0.0039***	-0.0001**
	(0.0001)	(0.0005)	(0.0000)	(0.0002)	(0.0006)	(0.0000)
Bad Health (=1)	-0.0763***	-0.3169***	-0.0013	-0.0797***	-0.3292***	-0.0014
	(0.0114)	(0.0434)	(0.0029)	(0.0153)	(0.0565)	(0.0034)
Number of unmarried children	0.1277	0.6190	-0.0219	-0.2050	-0.5518	-0.0726**
	(0.1014)	(0.3871)	(0.0256)	(0.1727)	(0.6369)	(0.0362)
Local average wage (log)	0.0253**	0.0620	-0.0055**	0.0389***	0.1100**	-0.0056**
	(0.0103)	(0.0394)	(0.0024)	(0.0145)	(0.0536)	(0.0028)
Unemployment rate (%)	0.0062	-0.0034	-0.0049*	0.0142	0.0247	-0.0030
	(0.0117)	(0.0447)	(0.0028)	(0.0159)	(0.0587)	(0.0034)
Individual Fixed Effects	Y	Y	Y	Y	Y	Y
Time Fixed Effects	Y	Y	Y	Y	Y	Y
Regional Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	8,758	8,758	6,203	8,758	8,758	6,203

Note: Sample includes observations from the KLoSA 2006–2016 of individuals who were aged 55–70 years old in 2006. The HPI (city-province level) is used as an instrument variable in columns 4–6. Macroeconomic variables (local wage and unemployment rate) are obtained from Korea Statistics. Housing wealth and non-housing wealth are deflated by CPI. Robust standard errors in parentheses. *** Denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

1.4.2. Robustness Checks

Possible concerns arise as to whether the results are robust with regards to housing wealth, instruments, or the age cohort in the baseline regression. First, an anticipated criticism of the baseline results is that the increase in housing wealth on a small scale could not affect labor supply: the housing wealth effect is not linear, and the only large capital gains would matter. To solve this issue, we changed the measure of housing wealth as an indicator. Since the standard deviation of housing wealth is about 100 million Korean won among homeowners, 100 million Korean won is chosen for large capital gains from housing wealth. Conversely, as a representative measure of the small gains, housing wealth increase by 10 million Korean won is chosen. We conduct the same regressions using the two measures. The estimation results are reported in Table 1.4. We do not find significance in every specification, which is already expected by the characteristic of self-reported housing wealth. However, the magnitudes of the large capital gain effects are much larger than the small capital gains, as we assumed. For column 6, the estimation result suggests that the large capital gains from housing wealth shock significantly decrease the expected retirement age.

Second, we use more refined HPI as an instrumental variable. The exclusion restriction of HPI would be flawed if certain classes of people, including newlyweds and retirees, could affect both housing prices and the labor supply. To solve the problem, we derive a new housing price index that excludes a part explained by population movement from the original index. Specifically, we conduct a regression analysis for explaining the housing price index by population movement. We use net movement data for each generation (from the 20s to 60s) and city/province published by Korea Statistics. Predicted residuals obtained after conducting the regression (year and regional fixed effects controlled) were used as an instrumental variable. Table 1.5 reports estimation results using the new instruments. The impact of housing wealth appears to be weaker than those estimated from the baseline results, which indicates a moving trend that significantly affects the relationship between house price and labor supply. Also, the housing wealth effect is consistent for samples restricting only homeowners (refer to columns 4-6).

Third, we conducted a sensitivity test that examines how the regression results change with an alternative age cohort ranging from the set of 51–65 to the set of 60–74 years old by increasing one year in the first wave. Thus, ten sets of samples are used to conduct our baseline analysis. Figures 1.2.A to 1.2.C plot the estimated coefficients for housing wealth with A) labor force participation, B) working hours, and C) expected retirement age, respectively. For Figures 1.2.A to 1.2.C, downward trends are shown, suggesting that the wealth level's influence increases on the worker's decisions concerning labor supply as they get old. Since ages around 70 are the effective retirement age in Korea, these reductions in labor supply would gradually lead to retirement. The trend suggests that housing wealth shock affects older people more, who are more likely to be on the verge of retirement.

Table 1.4. Large Capital Gains and Labor Supply

Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Labor Force Participation (=1)		Working hours (log)		Expected Retirement Age (log)	
ΔHousing wealth>10M KRW	-0.1146		-0.4980		-0.0402	
	(0.1138)		(0.4362)		(0.0304)	
ΔHousing wealth>100M KRW		-0.4211		-1.5228		-0.1180**
		(0.2622)		(0.9942)		(0.0583)
Non-housing wealth (log)	0.0062	0.0038	0.0180	0.0112	0.0001	-0.0003
	(0.0043)	(0.0048)	(0.0165)	(0.0181)	(0.0011)	(0.0011)
Age	0.3377***	0.2061	1.1975**	0.7174	-0.0595**	-0.0965***
	(0.1232)	(0.1526)	(0.4723)	(0.5786)	(0.0243)	(0.0319)
Age squared	-0.0010***	-0.0009***	-0.0035***	-0.0034***	-0.0001**	-0.0001**
	(0.0001)	(0.0001)	(0.0005)	(0.0005)	(0.0000)	(0.0000)
Bad Health (=1)	-0.0764***	-0.0754***	-0.3176***	-0.3138***	-0.0005	-0.0023
	(0.0115)	(0.0123)	(0.0442)	(0.0465)	(0.0031)	(0.0034)
Number of unmarried children	0.0469	-0.0170	0.2626	0.0926	-0.0428	-0.0598*
	(0.1319)	(0.1425)	(0.5057)	(0.5403)	(0.0314)	(0.0351)
Local average wage (log)	0.0257**	0.0211*	0.0641	0.0470	-0.0055**	-0.0085***
	(0.0105)	(0.0114)	(0.0402)	(0.0433)	(0.0025)	(0.0031)
Unemployment rate (%)	0.0082	-0.0001	0.0055	-0.0262	-0.0042	-0.0054*
	(0.0120)	(0.0132)	(0.0461)	(0.0500)	(0.0030)	(0.0032)
Other controls	Y	Y	Y	Y	Y	Y
Individual Fixed Effects	Y	Y	Y	Y	Y	Y
Time Fixed Effects	Y	Y	Y	Y	Y	Y
Regional Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	8,758	8,758	8,758	8,758	6,203	6,203

Note: Sample includes observations from the KLoSA 2006-2016 on individuals who are 55-70 years old in 2006. The dependent variable is binary equal to one when individual i retired at time t. Macroeconomic variables (local wage and unemployment rate) are provided from Korea Statistics. Housing wealth and non-housing wealth are deflated by CPI. Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

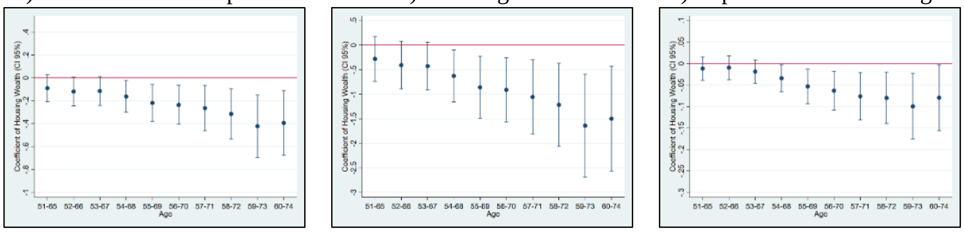
Table 1.5. Estimation Results using the New Instrumental Variable

	(1)	(2)	(3)	(4)	(5)	(6)
	Full Sample			Homeowners		
Dependent Variable	Labor Force Participation (=1)	Work Hours (log)	Expected retirement age (log)	Labor Force Participation (=1)	Work Hours (log)	Expected retirement age (log)
Housing wealth (log)	-0.2214**	-0.7820**	-0.0690**	-0.2195***	-0.8630***	-0.0594***
	(0.1057)	(0.3952)	(0.0270)	(0.0826)	(0.3174)	(0.0205)
Non-housing wealth (log)	-0.0244	-0.0880	-0.0080**	0.0115***	0.0383**	0.0028***
	(0.0164)	(0.0615)	(0.0038)	(0.0042)	(0.0162)	(0.0010)
Age	0.3080**	1.0881**	-0.0652*	0.2511*	0.8663*	-0.0738***
	(0.1449)	(0.5419)	(0.0333)	(0.1286)	(0.4943)	(0.0259)
Age squared	-0.0010***	-0.0037***	-0.0001**	-0.0007***	-0.0027***	-0.0001**
	(0.0002)	(0.0006)	(0.0000)	(0.0001)	(0.0005)	(0.0000)
Bad Health (=1)	-0.0788***	-0.3258***	-0.0014	-0.0668***	-0.2876***	-0.0018
	(0.0136)	(0.0508)	(0.0041)	(0.0134)	(0.0515)	(0.0034)
Number of unmarried children	-0.1113	-0.2283	-0.1040**	-0.0414	-0.0118	-0.0485
	(0.1668)	(0.6238)	(0.0489)	(0.1252)	(0.4812)	(0.0316)
Local average wage (log)	0.0351***	0.0967**	-0.0056	0.0193	0.0427	-0.0060**
	(0.0132)	(0.0492)	(0.0034)	(0.0119)	(0.0458)	(0.0029)
Unemployment rate (%)	0.0119	0.0169	-0.0019	0.0137	0.0233	-0.0052
	(0.0142)	(0.0530)	(0.0042)	(0.0137)	(0.0526)	(0.0035)
Individual Fixed Effects	Y	Y	Y	Y	Y	Y
Time Fixed Effects	Y	Y	Y	Y	Y	Y
Regional Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	8,758	8,758	6,203	7,278	7,278	5,214

Note: Sample includes observations from the KLoSA 2006-2016 on individuals who are 55-70 years old in 2006. Macroeconomic variables (local wage and unemployment rate) are provided from Korea Statistics. Housing wealth and non-housing wealth are deflated by CPI. Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Figure 1.2. Coefficient Plots

1) Labor Force Participation   2) Working hour   3) Expected Retirement Age



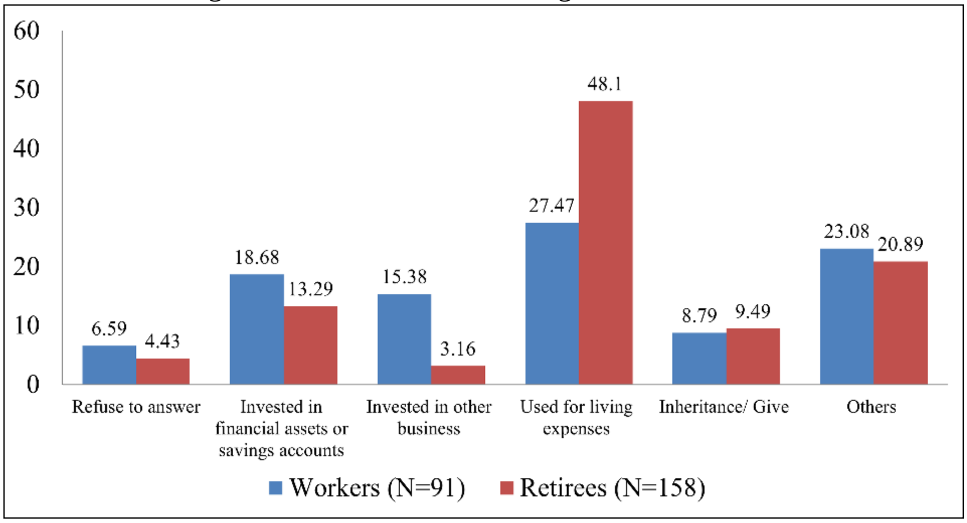
Note: Each plot is derived from the KLoSA 2006-2016 on individuals ranging from the set of 51–65 to the set of 60–74 years old by increasing one year in the first wave.

1.5. Downsizing Channel of Housing Wealth Effect

We next examine how retirees use their housing wealth to finance retirement consumption. Descriptive statistics (Table 1.2) reports that 18 % of our samples have moved at least once during the survey periods. The KLoSA also provides us some interesting statistics for movers implying the possibilities for the downsizing effect. If the value of their current residence is less than 80% of that in the previous interview, the movers are automatically asked what the difference has been used for the most. Figure 1.3 reports that 48% of retired movers stated that they mainly used the difference for living expenses, and 27% of working movers gave the same answer. These comparisons show that retirees are more likely to liquidate their housing wealth to finance retirement.

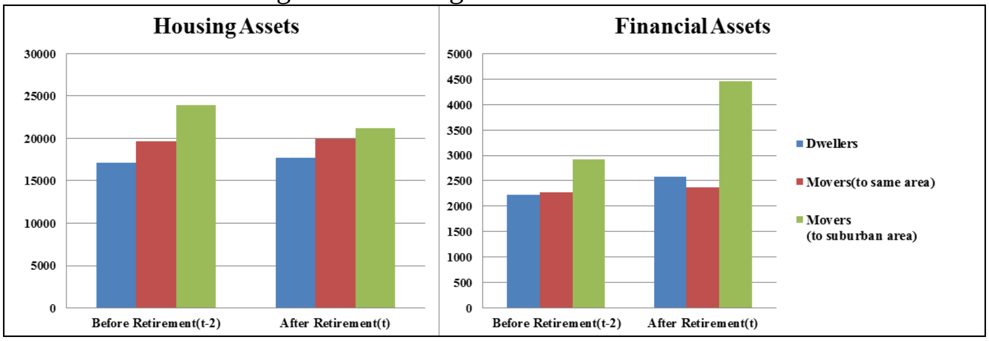
The KLoSA provides additional evidence. We calculate the difference of assets between the three groups: 1) retirees who had lived in urban areas (and had also worked there) and lived in the same house ('Dwellers' in Figure 1.4); 2) retirees who had moved to another house but in the same area; or 3) retirees who had moved to suburban (rural) areas after retirement. Figure 1.4 shows that only the housing value of suburban area movers decreases, whereas their financial assets greatly increase after they move to suburban areas. In the case of retirees who had lived in Seoul, about 30 million KRW (about $32K) of housing wealth decreased, whereas 20 million KRW (about $21K) of their financial wealth increased.

Figure 1.3. Main Use of Housing Value Difference



Source: the KLoSA 2006-2016

Figure 1.4. Changes in Assets of Retirees



Note: the KLoSA 2006-2016 used. All samples are respondents who had lived in an urban area (Seoul, Incheon, Daejeon, Daegu, Ulsan, Busan, and Gwangju), worked at t-2, and retired at t. 'Dwellers' did not move during the period. 'Movers (to the same area)' moved in the same area, and 'Movers (to the suburban area)' moved to a suburban (rural) area during the period. Every asset is measured in 10K KRW. Every asset value is deflated by the Consumer Price Index.

To discuss moving trends of retirees more deeply, we consider that a 20% sample of the 2015 Population and Housing Census (20% PHC, hereafter) released by Korea Statistics. The census is conducted every 5 years, and the total sample size of the 20% PHC is about 9.5 million. This study focuses on respondents between the ages of 60 to 80 (1.8 million households), which are similar ages to those in the main sample of the baseline regression.

Two questions in the 20% PHC are useful for examining the downsizing channel: migration within five years and the main source of living expenses for the elderly. Since the 20% PHC did not identify retirees, we define as retirees those who responded that they were not employed. Table 1.6 shows that retirees are more likely to move in three directions: first, from Seoul special city to non-Seoul areas; secondly, from metropolitan areas (Seoul special city, Incheon metropolitan city, and Gyeonggi province) to non-metropolitan areas; and thirdly, from Seoul and six metropolitan cities (Incheon, Daejeon, Daegu, Ulsan, Busan, and Gwangju) to other areas. The housing value of the former is commonly higher than the latter. Statistics also show that retirees are more likely to depend on their real estate assets for living expenses. The 20% PHC surveys older people about their main channel of living expenses. Compared to workers (1.54%), a higher ratio of retirees responded that they depend on real estate for living expenses (6.21%).

Using the sample of the 20% PHC data, we estimate a linear probability model, which is specified in equation (5):

$$Y_i = \beta_0 + \beta_1 Moving_i + \beta_2 Rural_i + \beta_3 Retire_i + \beta_4 Moving_i * Retire_i + \beta_5 Rural_i * Retire_i + \beta_6 X_i + \varepsilon_i \qquad (5)$$

where Y_i is the binary equal to 1 if elderly i's main channels of living expenses include real estate. Here, $Moving_i$ means that individual i has moved in the last five years; $Rural_i$ means that i has moved from an urban city (or region) to a suburban or rural area. We define three kinds of $Rural_i$ variables-1) from Seoul to non-Seoul, 2) from MP to non-MP, 3) from Seoul and six metropolitan cities to others and regress them separately.

β_5 is the main interest of the equation (5), which is the estimator of interaction term. Since $Rural_i$ is a sub-concept of $Moving_i$, $E[Y_i|Moving_i = 0, Rural_i = 1]$ does not exist. From equation (5), we get:

$$[Y_i|Moving_i = 1, Rural_i = 1, Retire_i = 1] - E[Y_i|Moving_i = 1, Rural_i = 0, Retire_i = 1] = \beta_2 + \beta_5 \quad (6),$$

which means the difference between Urban → Rural movers and other retired movers, and

$$E[Y_i|Moving_i = 1, Rural_i = 1, Retire_i = 0] - E[Y_i|Moving_i = 1, Rural_i = 0, Retire_i = 0] = \beta_2 \qquad (7),$$

which means the difference between Urban → Rural movers and other working movers.

Using both equations (6) and (7), we get the coefficient of β_5.

$$\{E[Y_i|Moving_i = 1, Rural_i = 1, Retire_i = 1] - E[Y_i|Moving_i = 1, Rural_i = 0, Retire_i = 1]\} - \{E[Y_i|Moving_i = 1, Rural_i = 1, Retire_i = 0] - E[Y_i|Moving_i = 1, Rural_i = 0, Retire_i = 0]\} = \beta_5.$$

Table 1.7 shows the regression results. Retirees who move from Seoul to non-Seoul, from MP to non-MP, and from Seoul and six metropolitan cities to other areas are 2.1, 0.9, and 1.3 percentage points, respectively, more likely than workers to depend on their real estate assets as living expenses. The magnitudes of interaction terms are, respectively, 48%, 20.6%, and 29.8% of the mean of the dependent variable.

Table 1.6. Descriptive Statistics (20%PHC)

Sample	Full Sample (Obs=1,783,666)		Retiree (Obs=1,076,590)		Worker (Obs=707,076)		t-test (Retiree vs Worker)
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Female(=1)	0.548	0.498	0.633	0.482	0.419	0.493	>290***
Age(60 to 80)	68.811	6.043	70.026	6.002	66.961	5.622	>340***
Move within 5 years(=1)	0.233	0.423	0.262	0.440	0.188	0.390	>120***
Seoul→NonSeoul(=1)	0.018	0.132	0.020	0.142	0.014	0.116	33.921***
MP→NonMP(=1)	0.013	0.112	0.013	0.115	0.012	0.108	9.144***
Seoul and 6 cities→Other area(=1)	0.026	0.160	0.029	0.168	0.022	0.146	30.151***
Use real estate assets as living expenses(=1)	0.044	0.204	0.062	0.241	0.015	0.047	>150***

Note: 20% sample of 2015 Population and Housing Census is used. Sample includes elderly people from 60 to 80 years old.

Table 1.7. Moving, Retirement, and Living Expenses

	(1)	(2)	(3)
Dependent Variable	Use Real Estate Assets as Living Expenses(=1)		
Retired(=1)	0.057***	0.057***	0.057***
	(0.000)	(0.000)	(0.000)
Migration*Retired	-0.025***	-0.024***	-0.025***
	(0.001)	(0.001)	(0.001)
Seoul→NonSeoul * Retired	0.021***		
	(0.002)		
MP→NonMP * Retired		0.009***	
		(0.003)	
Seoul and 6 cities→Other area * Retired			0.013***
			(0.002)
Gender and Age controls	YES	YES	YES
Constatnt	0.059***	0.060***	0.059***
	(0.002)	(0.002)	(0.002)
Mean of Dependent variable	0.044	0.044	0.044
Observations	1,783,666	1,783,666	1,783,666
R-squared	0.015	0.015	0.015

Note: Dependent variable is binary equal to one if an elderly person uses their real estate assets as living expenses. Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

1.6. Conclusion

South Korea became an aging society (people aged 65+ constitute over 7% of the population) in 1999 and an aged society (65+ constitute over 14%) in 2017. Due to the rapid aging, South Korean society has suffered the highest poverty rate in elderly people among OECD countries. In addition, baby boomers born between 1955 and 1963 have begun to retire from their main jobs and reach pensionable age. According to Korea Statistics, South Korea is expected to become a super-aged society (65+ constitute over 20%) in 2025. With such an explosive increase in the older population underway, the situation is expected to get worse.

Since the 2010s, South Korea has experienced remarkable changes in the demographic composition and variations in the housing market concurrently. The unanticipated fluctuations in the housing market over the past decades have led researchers to examine the impact of housing wealth variations on elderly labor supply. This study uses KLoSA data from 2006 to 2016 to examine the effects of housing wealth changes on older workers' retirement plans.

Our findings may contribute to the literature in various ways. First, this study is the first to examine the relationship between housing wealth and the labor supply of elderly workers using South Korean data. Second, this study provides clear and consistent evidence of the housing wealth effect by several empirical strategies to find evidence that housing capital gains affect homeowners' decision to stay/exit the labor force. Last but not the least, this study reveals a mechanism of the housing wealth effect where home-owning retirees are likely to liquidate their housing wealth and to rely on liquidated housing wealth to finance their retirement. The findings may contribute to enhancing our understanding of the elderly labor market.

Currently, boosting labor force participation of the elderly is an urgent national task. The findings of this study also suggest that understanding the housing market may help policymakers anticipate elderly labor supply. In other words, housing market shocks such as radical real estate policy may distort older workers' retirement decisions.

Overall, the findings of this study can be used to help society cope with the massive change of the labor force in South Korea. Developing countries experiencing rapid aging can also benefit from the findings of this study.

1.A. Appendix

Table 1.A.1. First Stage of Instrumental Variable Estimation

	(1)
Dependent Variable	Housing Wealth (1M KRW)
Housing Price Index	0.8662***
	(0.1846)
Non-housing wealth	-0.1516***
	(0.0094)
Age	-0.1160
	(0.3565)
Age squared	-0.0004
	(0.0004)
Bad Health	-0.0108
	(0.0334)
Local average wage	0.0433
	(0.0303)
Unemployment rate	-0.6367**
	(0.3127)
Individual Fixed Effects	Y
Time Fixed Effects	Y
Regional Fixed Effects	Y
F-statistic	22.02
Observations	8,758
R-squared	0.0638

Note: Sample includes observations from 2006-2016 on individuals who are 55-70 years old in 2006. The dependent variable is binary equal one when individual i retired at time t. Housing price index is measured in city-province level. Macroeconomic variables (local wage and unemployment rate) are provided from Korea Statistics. Wealth variables are deflated by CPI. Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Chapter 2. Technological Change, Job Characteristics, and Employment of Aged Workers

2.1. Introduction

How will new advances in technology, often symbolized by artificial intelligence (AI) and automation in production, change the labor market in the future? A few studies have investigated and predicted the labor market consequences of the technological changes of the *Fourth Industrial Revolution*. Debates are ongoing on whether newly invented machines such as robot adoption will radically replace human labor (Acemoglu and Restrepo 2020; Chung and Lee 2020; Graetz and Michaels 2018) and on what kinds of jobs will be vulnerable to the effects of technological change (Autor 2015; Autor, Levy, and Murnane 2003; Fonseca, Lima, and Pereira 2018; Goos and Manning 2007).

Growing evidence suggests that the labor-market consequences of technological changes, if any, will probably be heterogeneous across jobs with disparate human capital requirements and workplace characteristics. Given that aged workers tend to have more obsolete skills, to be less efficient in learning, and to be less mobile across jobs compared to younger workers, their labor market status could be affected differently by technological advances in production and managerial practices. As for the mechanism, which will be covered below in detail, technological changes can affect the employment of older workers by changing their relative productivity and by altering the quality of the matching between the workers and their jobs. However, only a few studies have empirically investigated how technological changes affect young and old workers differently (Aubert, Caroli, and Roger 2006; Bartel and Sicherman 1993; Friedberg 2003; Lee 2015), compared with the attention given to the differences across workers with disparate human capital or skills. No evidence regarding the issue has been suggested for Korea.

The primary purpose of this study is to investigate how the adoption of new production technology[⑥] affects the employment of older South Korean workers by using establishment-level panel data that were newly linked with administrative records. The Workplace Panel Surveys (WPS), conducted by the Korea Labor Institute since 2005, provide detailed information on each establishment, including variables pertaining to workplace innovations in production, organization, and human resource management. The Korean Employment Insurance records, matched with WPS data, offer information on labor market transitions and personal characteristics of the individuals employed in the workplaces included in WPS.

Using the data, we investigated how indices of new technology adoption affected the risk of employees leaving their jobs and how the effects differed between older and younger workers. For constructing variables on technological change, we utilized responses to the following three questions: 1) whether new automation was adopted by the firm, 2) how much investment in information technology (IT, hereafter) sectors increased, and 3) how much IT equipment purchases increased. These changes may substitute jobs or take over tasks that workers used to perform.

We conducted survival analyses (Cox proportional hazard model) that included each of the indices of technological change and its interaction with a variable indicating if the worker is an aged person, along with variables pertaining to personal and job characteristics. The decisions on adopting new technology, however, could be endogenously influenced by unobservable factors related to the retirement risk of aged and younger workers. We addressed this problem by relying on an instrumental variables estimation using a set of instruments: 1) small group activities for innovation geared toward productivity and 2) a code of conduct regarding internet use. We employed the two-stage residual inclusion (2SRI) approach, a preferred method to obtain a consistent estimator when using instruments in non-linear models (Terza, Basu, and Rathouz 2008).

The paper is organized as follows: In section 2.2, we discuss the conceptual framework of this paper and review previous studies on the subject. In

⑥ In this paper, terms referring to technological changes such as "the adoption of (production) technology," "technological advances," and "new technology" have the same meaning. We will use these expressions interchangeably when considering the context.

section 2.3, we introduce the data and empirical strategy used in the study. Section 2.4 presents the results of baseline and additional regression analyses. The final section concludes the study.

2.2. Conceptual Framework and Related Literature

Technological changes can affect the overall employment of workers through several different pathways. Acemoglu and Restrepo (2018c; 2019) identified three distinct labor market effects of a newly adopted technology, namely, displacement effect, productivity effect, and reinstatement effect. First, technological progress can diminish labor demand and salary equilibrium by taking over tasks previously conducted by human labor (*displacement effect*). Second, the adoption of a new technology may increase the demand for labor by improving labor productivity (*productivity effect*). Finally, technological progress can create new tasks and, if labor has comparative advantages in the newly created tasks, increase demand for labor (*the reinstatement effect*).

The overall employment effect of technological change would be determined by the balance among these three effects. Based on analyzing a theoretical model, Acemoglu and Restrepo (2018d) proved that the displacement effect would dominate the other two if the cost of capital was sufficiently small. Otherwise, there is a long-run equilibrium with balanced growth in which technological progress and the creation of new tasks can go hand-in-hand.

A few studies have provided empirical evidence suggesting that the displacement effect dominates the productivity effect. Prettner (2019) found that increased automation explains 14% of labor share reduction in the US during the 1970–2016 period. He also reported that automation might accelerate the inequality between capital owners and job-losing workers over the last decades. Using cross-country data covering four decades (from 1970 to 2007), Autor and Salomons (2018) examined the impact of automation (industry-level) on employment and labor's share of value added in total productivity. They found that automation reallocates employees across industries and has a negative impact on labor's share of productivity value for decades. Agrawal, Gans, and Goldfarb (2019) found that artificial intelligence (AI) could be labor-replacing technology in a prediction task, such as demand forecasting and legal judgment prediction.

Using variations in robot exposure across US industries between 1990 and 2007, Acemoglu and Restrepo (2020) examined the impact of industrial robots on local labor markets. They found that robot adoption lowered both employment-to-population ratio and average wages across the commuting zones. Based on using data for 21 OECD countries, Arntz, Gregory, and Zierahn (2016) estimated that about 9% of jobs on average could be replaced by automation. They additionally suggested that the workplace environment, investment in technologies, and the education level of workers are the main factors in the differences in the extent of substitution between automation and labor across countries.

Other studies have found evidence that the positive (productivity and reinstatement) effects may offset the negative (displacement) effect. Chung and Lee (2020) conducted an analysis similar to Acemoglu and Restrepo (2020) using updated US data for the period from 2005 to 2016. They showed that the effects of robot exposure employment changed over time, being negative prior to 2010 but turning positive thereafter. Graetz and Michaels (2018) examined the economic contributions of robot adoption using industry-country level panel data. They found that robot adoption did not significantly affect labor hours and total employment, whereas it reduced the employment of low-skilled workers.

Acemoglu and Restrepo (2018a) suggested that the displacement effect of adopting new technology reduces labor demand and wages in the short run, but it can be counteracted by capital accumulation, productivity improvements, and the creation of new tasks. Autor (2015) supported the idea and predicted that, even though current middle-skilled jobs are at risk of automation, technological progress would require new tasks and create new middle-skilled jobs. However, researchers commonly agree that low-skilled jobs (Graetz and Michaels 2018) and routine tasks (de Vries et al. 2020) are more susceptible to the negative effects of increased robot exposure.

As the labor force is aging over time, the relationship between aging and technological change has received increasing attention. Using the US commuting zone data, Acemoglu and Restrepo (2018b) examined how robot adoption affected the employment of middle-aged and older workers. They found that robot adoption reduced the employment and earnings of middle-aged workers but had no effect on those of older workers. The negative employment effect found among middle-aged workers was attributed to their greater concentration in blue-collar jobs that can be more easily automated by robots. The study also found that countries experiencing rapid aging are more likely to invest in robots. Their estimates suggested that aging explains 40% to 65% of the cross-country variations in robot adoption.

Even within the same industry, the employment effect of technological progress may differ by the age of workers. Any technological change with disparate effects on productivity depending on the age of workers would affect young and aged employees differently. If the tasks of old workers can be automated more easily, for example, the technological change would be associated with a relative decrease in demand for the elderly. As marginal workers in the labor market, aged people may likely be vulnerable to radical economic changes, such as the emergence of new technology. As noted by Lankisch et al. (2019), the potential disadvantages associated with aging may stem from the lower level of skills possessed by the elderly compared with the young.

Even with the same quality of human capital, the labor market effects of technological changes could be more strongly felt among the elderly than the young. For example, technological changes could affect the employment of aged workers by deteriorating the quality of matching between workers and their jobs. Technological progress is often associated with radical changes in job requirements and working conditions. Adoption of new technology can make it increasingly costly for aged workers to continue working as the speed and intensity of work, as well as the requirements for skills, increases, possibly beyond their physical and mental capacities. Given their deteriorated physical strength and health, obsolete skills and knowledge, and lack of education compared with young cohorts, aged workers have lower capabilities (or incentives) to learn to meet new work requirements. A return to training generally decreases with age; thus, employers would be unwilling to invest in the training of aged workers, thereby increasing the severity of their disadvantages.

Only a few studies have empirically investigated how technological changes affect young and old workers differently, compared with the attention given to the differences across workers with disparate human capital or skills. Hurd

(1996) demonstrated that labor rigidities, such as the inability to change working hours, could become a greater burden to old workers as their preference shifts from work to leisure. According to Lee (2015), technological changes in the course of the "Second Industrial Revolution" during the early 20th century increased the intensity of work and diminished job flexibility. Lee suggested that these changes negatively affected the employment of aged US manufacturing workers. Lee and Lee (2013) found that older workers engaged in a more flexible job show a lower probability of retirement than others when other conditions are equal.

Acquiring a new skill to adjust to a technological change could be costlier for older workers. Bartel and Sicherman (1993) demonstrated that unexpected changes in the rate of technological changes provoked disutility for working and induced older workers to retire earlier. To show these effects empirically, several studies have examined the impact of IT innovations on the employment of older workers. Friedberg (2003), using the US data, found that the spread of computers in a workplace had a negative impact on the employment of old workers, but only for workers close to the timing of their mandatory retirement. Aubert, Caroli, and Roger (2006) offered firm-level evidence that the use of computers and the internet tended to reduce the wage bill share of older workers. Peng et al. (2017), using a dataset of European countries from the 1970s to the 2000s, suggested that the impact of IT on labor demand is skill-biased; it reduced wage shares of low-skilled workers. Jerbashian (2019) showed that a reduction in the price of IT induced an increase in the share of employment in high-wage occupations but a decrease in the share of middle-wage occupations.

In the present study, we attempt to investigate how a technological change affects the overall employment and the relative employment of the young and the old. More specifically, we analyze the technological change variables and their interaction with the variable for older workers. If the conceptual framework discussed above is applied, the estimated coefficient for the interaction term captures how a newly adopted technology alters the productive efficiency and the quality of job matching of older workers relative to those of younger ones, whereas the coefficient for the technology variable shows how it changes the overall productivity of all employees in the establishment.

2.3. Data and Empirical Strategy

2.3.1. Data

It is difficult to obtain data containing information on both technological changes adopted by firms and the employment of individual workers in the firms. Thanks to the cooperation and support of the Korea Labor Institute, we obtained and used a unique dataset that has been produced by linking firm-level panel data with administrative employment records for the individuals employed in the firms. More specifically, the following micro datasets were linked and used: the workplace panel surveys (referred to, hereafter, as the WPS) and the Korean Employment Insurance records.

The WPS, conducted by the Korea Labor Institute since 2005, provides detailed information on each establishment included in the survey, such as variables pertaining to workplace innovations in production, organization, and human resource management. As WPS started to ask questions regarding technological changes adopted by each firm since 2015, we largely use the 2015 survey, which includes 3,431 firms.

The Korean Employment Insurance records matched with WPS offer information on labor market transitions and personal characteristics of the individuals who were employed in the workplaces included in the WPS. The significant advantage of the linked data is that it includes all workers employed at least once in these firms, which allows us to follow up on labor market changes of the individuals, including the exact timing and reason for job separations. A drawback of the linked data is that it provides only a limited set of variables regarding the information on each individual, especially his or her job characteristics (e.g., full/part-time job).

We restricted our sample to individuals who met the following conditions: (1) employed in the WPS firms at the beginning of 2015, (2) aged 25 to 69 in 2015, and (3) working in a firm with more than ten employees.[7] As a consequence of the selections, we ended up with a sample of 962,404 persons employed in 3,033

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[7] Given the poor business circumstances of small-scale firms in Korea, we hardly expect a tangible effect of a technological change on employment among firms with less than ten employees.

firms, and the size of each birth cohort ranged from 13,734 (those aged 25) to 1,320 (those aged 69). We classified individuals aged 50 and older in 2015 as aged workers in the baseline analysis. In the additional analysis, we use various age cutoffs for defining older workers as a robustness check.

2.3.2. Empirical Strategy

The 2015 WPS includes questions regarding newly adopted technological changes. The following indices of technological changes were considered in the present study: (1) newly adopted automation, (2) increased investment in information technology (IT), and (3) the increased purchase of IT-related equipment. New automation refers to the circumstance that any process or part of work for a product or service is newly automated and is considered along with the extent of automation already completed. Measures of IT investment and IT-related equipment are obtained from responses using a five-point Likert scale ("Not at all," "Not much," "Neutral," "Somewhat," and "Very much do"). We constructed a dummy variable that has a value of one if a firm selected "Somewhat" or "Very much do."

We investigated how the adoption of new technological changes in a firm affects the probability that an employee will leave the firm. The 2015 WPS was linked to the employment insurance records from 2015 to 2017, which allowed us to follow up on individuals employed in the firm in 2015 for two years. Taking advantage of the longitudinal features of the data, we examined the effect of technological changes on the retirement hazard by estimating a Cox proportional hazard model. Hereafter, we use job separation, departure, and retirement (from the 2015 job) interchangeably. The retirement risk for workers is specified as:

$$\lambda_i(t) = \lambda_0(t) exp(\beta_1 T_j A_i + \beta_2 T_j + \beta_3 A_i + \gamma X_i + \delta F_j) \quad (1)$$

In equation (1), $\lambda_0(t)$ denotes the baseline retirement risk of workers at time t. Subscripts *i* and *j* denote individual and firm, respectively. *T* stands for the dummy variable for technological change. *A* indicates a dummy variable for aged workers (aged 50 and older). X denotes a set of a matrix that includes each worker's personal characteristics, such as age, gender, job tenure, and being subjected to extending mandatory retirement.[8] These are proxy variables for the worker's productivity in the labor market. *F* indicates variables pertaining to firm characteristics, including size (the number of employees) and industry. These variables are expected to be associated with labor market conditions, institutional features, and work environment that could affect decisions on job separation.

The variable of primary interest to us is the interaction between variables for technological change and aged workers. As explained in section 2.2, the estimated coefficient for the interaction term (β_1) is expected to capture how a newly adopted technology changes the productive efficiency and the quality of job matching of older workers relative to those of younger ones. If the sign of the parameter is estimated to be positive (negative), it indicates that the employment effect of the technological change is more unfavorable (favorable) for older workers as compared to the effect for younger employees. The coefficient for the technology variable (β_2) shows how the adoption changes the overall productivity of the employees in the establishment. If the estimated parameter is positive (negative), it tells us that the overall effect of the technological change is unfavorable (favorable) for the employment of incumbent workers. The sum of the two coefficients ($\beta_1 + \beta_2$) shows the overall employment effect for older workers.[9]

Assessing the direction of causality between technological change and labor has been a challenge in previous studies on the topic, as new technology adoption is potentially endogenous. Suppose our model includes unobserved confounders, U_j:

$$\lambda_i(t) = \lambda_0(t)exp(\beta_1 T_j A_i + \beta_2 T_j + \beta_3 A_i + \beta_4 U_j + \gamma X_i + \theta F_j) \quad (2)$$

If T_j is correlated with U_j, then the estimation from equation (1) would result in a biased inference.

---

[8] An amendment to the Act on Aged Workers' Employment was enacted in the National Assembly of Korea in 2013. According to the new bill, firms with over 300 employees were required to set their retirement age to at least 60 from the beginning of 2016. Firms with less than 300 employees were subject to the requirement of the bill from 2017.

[9] To analyze the effect of technological changes easily, we report all the estimation results in terms of hazard ratio.

To address this issue, we employed the two-stage residual inclusion (2SRI) approach, which was suggested first by Hausman (1978). The basic idea of the 2SRI approach is similar to that of the two-stage predictor substitution (2SPS), as an endogenous variable is regressed on exogenous variables and instruments in the first stage:

$$T_jA_j = \alpha_1^1 Z_jA_j + \alpha_2^1 Z_j + \alpha_3^1 A_j + \alpha_4^1 F_j + u_j^1 \quad (3)$$

$$T_j = \alpha_1^2 Z_jA_j + \alpha_2^2 Z_j + \alpha_3^1 A_j + \alpha_4^2 F_j + u_j^2 \quad (4)$$

where Z_j stands for a set of instrumental variables. Since technology adoption is determined by a firm, the first stage estimation is conducted at the firm level (A_j is the proportion of older workers in j). Unlike 2SPS, where the endogenous variable is replaced by predictors, the 2SRI approach includes residuals u_j^1, and u_j^2 as additional regressors in the second stage.

$$\lambda_i(t) = \lambda_0(t)exp(\alpha + \beta_1 T_jA_i + \beta_2 A_i + \beta_3 T_j + \beta_4 \hat{u}_j^1 + \beta_5 \hat{u}_j^2 + \gamma X_i + \theta F_j) \quad (5)$$

2SRI gives equivalent results to the two-stage 2SPS in a linear setting. In a non-linear setting, however, Terza et al. (2008) showed that only the parameters estimated from 2SRI are consistent and that those from 2SPS are not. Accordingly, non-linear estimation with the 2SRI approach has been widely employed (Cheng 2018; Guo, Konetzka, and Manning 2015; Lazuka 2018; Yeung 2017).

For each of the endogenous variables, we used a different instrument. First, we used the presence of small group activities for innovation to assess the adoption of new automation. In WPS 2015, about 43% of firms responded that the activities were put into practice, and 80% of them consisted of employees. It is likely that the proportion of employees participating in such activities is positively related to the probability of adopting new technology. However, such a bottom-up organization would be unlikely to have a direct effect on employment. Second, we use a code of conduct regarding internet use to measure investment in IT or IT equipment. The dependence on IT devices in a firm's working environment would raise security or communication issues and increase the need for making rules for preventing potential problems. Such rules, however, are not likely to be strongly correlated with unobservable firm characteristics influencing the employment of workers.[⑩]

2.4. Technological Change and Risk of Job Separation by Age: Results

2.4.1. Summary Statistics

Table 2.1. Sample Means of Variables

Variable	Full Sample (1)	Gender (2) Male	Gender (3) Female	Industry (4) Manufacturing	Industry (5) Service Sector
Demographic and labor outcomes of employees					
Male	0.6360	1	0	0.7962	0.6425
Age in 2015	41.2041	40.8494	41.8240	39.7332	41.7507
Aged 50 and older	0.2140	0.2014	0.2361	0.1736	0.2475
Job tenure in 2015	7.0739	8.1587	5.1786	8.0589	7.4246
Mandatory retirement policy applied	0.1490	0.1675	0.1166	0.1738	0.1816
Retired by the end of 2017	0.1848	0.1677	0.2148	0.1686	0.2174
Older workers retired by the end of 2017	0.0467	0.0434	0.0524	0.0321	0.0662
Technological Changes					
Newly adopted automation	0.213	0.220	0.200	0.310	0.134
Increased investments in IT	0.2734	0.2719	0.2761	0.2662	0.2790
Purchase of IT-related equipment increased	0.2347	0.2401	0.2254	0.2212	0.2676
Instrumental Variables					
Organize small group activities for product/service innovation	0.4327	0.4693	0.3688	0.5621	0.5333
Organize small group activities × Aged 50 and older	0.0816	0.0888	0.0689	0.0929	0.1149
Proportion of firms where a code of conduct regarding internet use exists	0.3318	0.3660	0.2720	0.4628	0.6747
Code of conduct regarding internet use × Aged 50 and older	0.0574	0.0663	0.0420	0.0741	0.1429
Workplace Characteristics					
Employees 99–299	0.5851	0.5341	0.6741	0.3573	0.5151
Employees 299–999	0.250	0.274	0.208	0.390	0.255
Employees 1000+	0.1649	0.1919	0.1177	0.2531	0.2298
The proportion of old workers in 2015	0.1170	0.1277	0.0984	0.1093	0.1506

⑩ A reviewer pointed out that the relationship between endogenous and instrumental variables is somewhat confusing: although there is not a perfect instrument, the proposed instruments are highly correlated with the characteristics of the endogenous variables. Considering this issue, we use a new instrument, robot density, which is widely used in literature. Details are reported in Appendix.

	(1)	(2)	(3)	(4)	(5)
Industrial Classification					
Manufacturing	0.3025	0.3787	0.1693	1	0
Electricity, gas, steam, and water supply	0.0041	0.0059	0.0011	0	0
Sewerage, waste management, materials recovery	0.0022	0.0030	0.0007	0	0
Construction	0.0192	0.0273	0.0051	0	0
Wholesale and retail trade	0.2828	0.1808	0.4611	0	0
Transportation	0.0695	0.0814	0.0487	0	0
Public administration and defense	0.0010	0.0009	0.0011	0	0
Accommodation and food service activities	0.0572	0.0610	0.0507	0	0.1796
Information and communication	0.0365	0.0421	0.0269	0	0.1147
Financial and insurance activities	0.0404	0.0363	0.0475	0	0.1268
Real estate activities	0.0037	0.0046	0.0021	0	0.0116
Professional, scientific, and technical activities	0.0312	0.0392	0.0174	0	0.0980
Business facilities management and business support services	0.0615	0.0514	0.0793	0	0.1931
Education	0.0005	0.0005	0.0006	0	0.0016
Human health and social work activities	0.0338	0.0151	0.0665	0	0.1061
Arts, sports, and recreation related services	0.0088	0.0082	0.0099	0	0.0277
Membership organizations, repair, and other personal services	0.0449	0.0637	0.0121	0	0.1409
Observation	962,404	612,070	350,334	291,087	306,716

Note: The Workplace Panel Survey 2015 and Employment Insurance Data are used. Service industry includes "accommodation and food services," "information and communication," "financial and insurance activities," "real estate activities," "professional, scientific, and technical activities," "business facilities management and business support services," "education," "human health and social work activities," "arts, sports, and recreation-related services," "membership organizations, repair, and other personal services."

Table 2.1 presents the sample means of the variables used in this study, including demographic characteristics and the labor market behaviors of workers, technological changes, and features of establishments. Column 1 provides the statistics for the full sample, and columns 2 and 3 compare those for males and females. The rest of the columns show how the sample means of the variables differ between the manufacturing and service sectors.

The first column shows that 63.6% of the entire sample consists of male workers, and aged workers (aged 50 and older) account for 21.4% of the full sample. The average length of tenure is 7.1 years, and 18.5% of workers employed in WPS firms at the beginning of 2015 (16.7% of males and 21.5% of females) retired from the job by the end of 2017. The proportion of workers who left the firms by the end of 2017 is slightly higher for aged workers (21.8%, 0.0467/0.2140) than for younger workers (17.6%, [0.1848-0.0467] / [1-0.2140]). 21.3% of individuals in the sample are in firms where any process or part of the main product/service was newly automated. The proportions of workers whose firms expanded investments in IT and IT-related equipment is 27.3% and 23.5%, respectively.

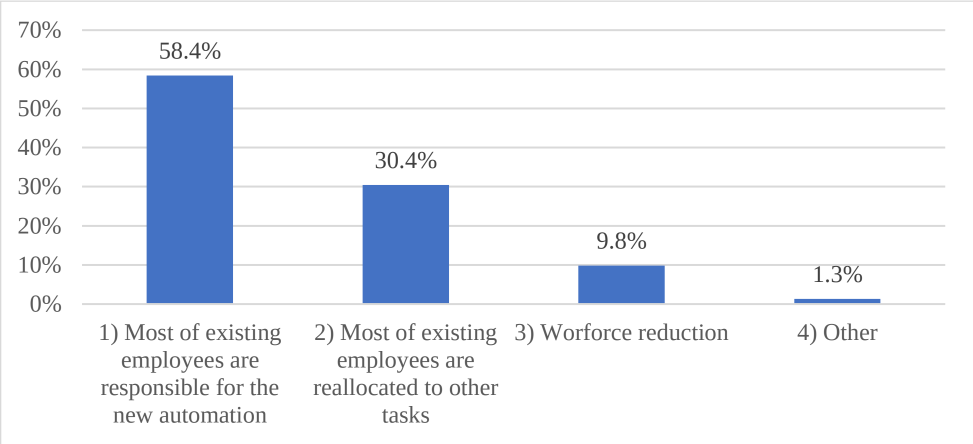
The linked data do not provide information on individual workers' job characteristics. However, firm-specific information on industry and firm size suggests that male workers are likely to have more decent jobs with higher salaries and safety compared to females. Given that multiple dimensions of job characteristics are closely associated with one another (for instance, a high-quality job commonly has various kinds of desirable features at the same time), we conjecture that the proportion of temporary, part-time, and low-skilled jobs should be higher for female workers than for males. Another basis for the conjecture is the high proportion of female workers who are engaged in the "wholesale and retail trade" and "accommodation and food services" industries, where temporary and low-skilled jobs are overrepresented in Korea.

The differences between the manufacturing and service sectors are apparent in many aspects. As expected, workers in the manufacturing industry are more likely to experience newly adopted automation. The production process would be closely related to robots and other automation systems. Moreover, in manufacturing industries, firm size is larger, employees are younger, and the retirement rate is lower compared to the service industries.

Service industries account for 31% of the full sample.[11] Although the use of IT is widespread across the industry, workers in the service sector are probably more accustomed to the use of the internet and IT devices. The mean value of "expanded investment in IT" is similar to the value of the full sample, but firms belonging to the "information and communication," "financial and insurance activities," and "professional, scientific, and technical activities" areas of the service sector show very high rates of IT investment. The service industry also shows a relatively high proportion of expanding IT investment and increasing expenditure on IT-related equipment.

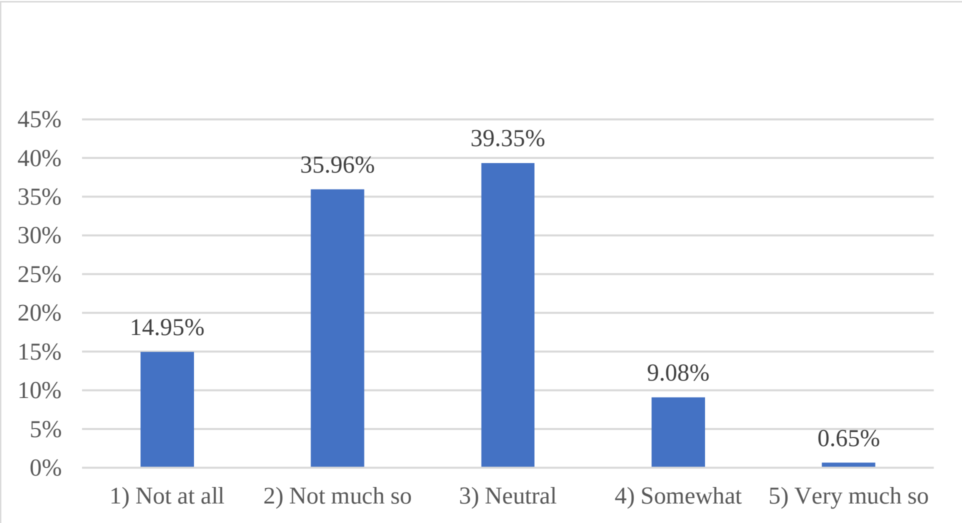
[11] Service industries consist of "accommodation and food services," "information and communication," "financial and insurance activities," "real estate activities," "professional, scientific, and technical activities," "business facilities management and business support services," "education," "human health and social work activities," "arts, sports, and recreation-related services," and "membership organizations, repair, and other personal services."

Figure 2.1. Major Changes in Workforce due to Newly Adopted Automation



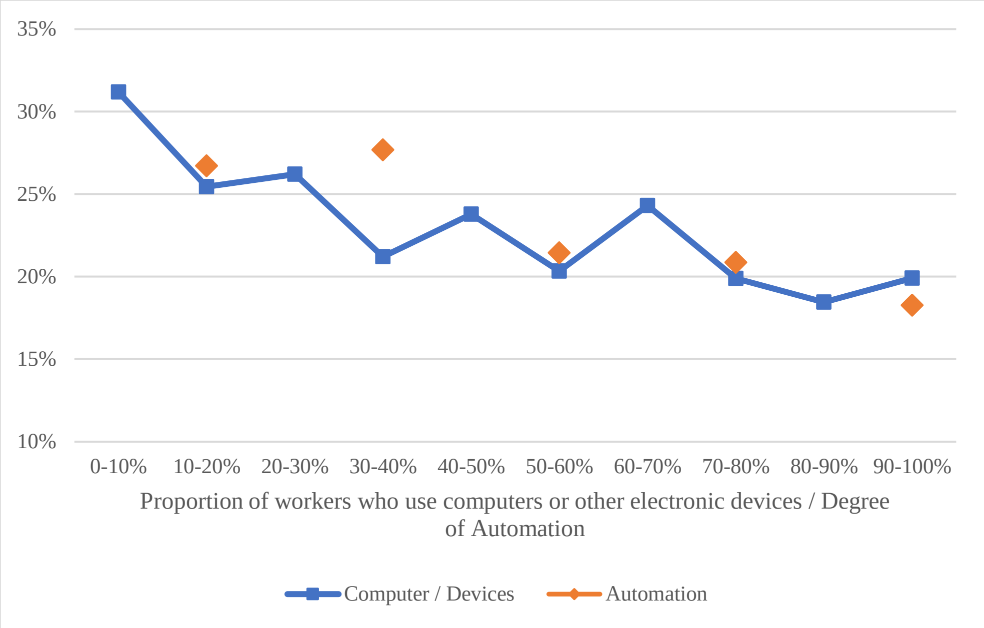
Notes: Workplace Panel Survey 2015 is used. Statistics are made based on the response of human resources officers and weighted for the size of the firm.

Figure 2.2. Whether Information Technology has Reduced Workforce over the Past Two Years



Notes: Workplace Panel Survey 2015 is used. Statistics are made based on the response of human resources officers and weighted for the size of the firm.

Figure 2.3. The Proportion of Old Workers by Degree of Technology Use



Notes: Workplace Panel Survey 2015 is used. The vertical axis is the proportion of workers aged 50 and older among employees. The degree of automation is surveyed in a five-point scale: 1) 0–20%; 2) 20–40%; 3) 40–60%; 4) 60–80%; and 5) 80–100%.

The WPS surveys human resources officers regarding how firms adjusted employment and tasks in response to technology adoption. Figure 2.1 shows how firms adopting new automation changed the number and allocation of their employees. The result shows that nearly 60% of the firms maintained the majority of existing workers in the same tasks. Only about 10% responded that they reduced the number of employees. Similarly, Figure 2.2 shows how increased investment in IT affected employment in the firms. Approximately 10% of firms responded that they reduced the number of employees as a result of making additional investment in IT over the past two years. These results suggest that the overall displacement effect of technological change, if any, was probably small in magnitude.

Newly introduced technology often requires the reallocation of workers across different tasks. Figure 2.1 shows that more than 30% of firms adopting automation reallocated their employees to new tasks. As noted in section 2.2, such changes in tasks could deteriorate the quality of matching between the job and the worker, especially for aged workers. Moreover, it would be more costly for workers with a low learning capability (such as older workers) to be reassigned to a new task. Consistent with these conjectures, Figure 2.3 shows a negative relationship between the proportion of older workers and the two indices of technology adoption, namely, automation and IT device use. The result may indicate the greater difficulty of innovation among firms with a higher proportion of older workers or/and higher rates of retirement of older workers in firms adopting new technology.

2.4.2. Baseline Results

We estimated a Cox proportional hazard model to determine the factors of retirement risk to examine how the adoption of new technology differently affected the employment of younger and older workers. Table 2.2 presents the baseline results based on using three different measures of technological change (newly adopted automation, increased investment in IT, and increased purchase of IT-related equipment). The main independent variables include the adoption of new technology, aged workers, and the interaction between the two. In addition, variables on the employee's personal characteristics (gender, age, and job tenure) and being subjected to the mandatory retirement reform are controlled. To take into account the unobservable heterogeneity across firms, we also included variables on the initial proportion of older workers in the firm (in 2015), firm size (categorical), and industry fixed effect.

The results reported in Table 2.2 suggest that technological change, measured by newly introduced automation and the increased purchase of IT-related equipment, has a favorable effect on the overall employment of incumbent workers. The estimated hazard ratios for the two technology variables are significantly less than one, indicating that technological adoption tends to lower the risk of retirement of workers who had been employed in the firm prior to the change. Unlike the two other measures of technological change, expanded IT investment turns out to be insignificant, although the tendency of the effect is negative.

Table 2.2. Cox Hazard Ratio of Employees

	(1)	(2)	(3)
Dependent Variable: Duration to Retirement from the Beginning of 2015			
New Automation × Old	1.272***		
	(0.021)		
New Automation	0.707***		
	(0.005)		
Investment in IT increased × Old		1.157***	
		(0.017)	
Investment in IT increased		0.991	
		(0.006)	
Increased purchase of IT equipment × Old			1.205***
			(0.018)
Increased purchase of IT equipment			0.897***
			(0.006)
Old	1.024**	1.036***	1.036***
	(0.011)	(0.011)	(0.011)
Male	0.950***	0.960***	0.961***
	(0.005)	(0.005)	(0.005)
Age	0.909***	0.911***	0.912***
	(0.002)	(0.002)	(0.002)
Age Squared	1.001***	1.001***	1.001***
	(0.000)	(0.000)	(0.000)
Job Tenure in 2015	0.916***	0.916***	0.916***
	(0.001)	(0.001)	(0.001)
Subjected to Extending Retirement Age	0.957***	0.916***	0.928***
	(0.007)	(0.007)	(0.007)
Initial Proportion of Older Workers in the Firm	0.973***	0.991	0.991
	(0.008)	(0.007)	(0.007)
Firm Size Fixed Effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Observations	962,404	962,404	962,404

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Coefficients denote the hazard ratio from the Cox proportional hazard model. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

More significantly, the estimated hazard ratios for the interaction term (of which magnitude is greater than one) suggest that the employment effect of technological change differs between aged and younger workers, with the former less favorably affected by newly adopted technologies than the latter. Conditional on adopting new production technology, aged workers were more likely to retire than younger workers by 15.7% (investment in IT) to 27.2% (new automation).

The direction of the overall effect of technological change on the employment of older workers differs by the choice of its index. In the case of new automation (column 1), the overall effect of technological change on aged workers' employment is actually positive (reducing the hazard of job separation absolutely), indicated by the multiplication result of the two hazard ratios (those for new automation and its interaction with the aged worker) being less than one. By contrast, expanded IT investment and the additional purchase of IT equipment actually increase the risk of job separation of aged workers absolutely, as well as relative to that of younger workers.

The results for the other independent variables are expected ones. Age is positively associated with the hazard of leaving the firm within each age group. The length of job tenure, being subject to extending mandatory retirement, and the proportion of older workers in the firm in 2015 are negatively related to the risk of retirement.

In addition to the Cox proportional hazard model, we estimated 2SRI models with instrumental variables. Since there are two endogenous variables of interest (each index of technological change and its interaction with a variable for the aged worker), two OLS regressions were conducted separately in the first stage. All the firm-specific variables considered in the baseline analysis, as well as the instrumental variables, were included in the model. The results of the first stage regressions, reported in Table 2.3, reveal a positive relationship between the two endogenous variables and corresponding instruments across columns. The presence of small-group activities for innovation increases the probability that the firm adopts a new automation system by 16.6 percentage points (column 1). Similarly, having a code of conduct for internet use increases the probabilities of increasing IT investment and the purchase of IT-related equipment by 11.3 and 14.6 percentage points, respectively (columns 3 and 5). The F statistics for weak instrument tests are all greater than 90, confirming that instrumental variables are not weak by the standard of the Stock-Yogo criteria (2002).

Table 2.3. The First Stage of Two-stage Residual Inclusion (2SRI)

Dependent Variable	(1) New Automation	(2) New Automation × Old	(3) Investment in IT increased	(4) Investment in IT increased × Old	(5) Increased purchase of IT equipment	(6) Increased purchase of IT equipment × Old
Activity for innovation (= 1) × Old	-0.067	0.092***				
	(0.056)	(0.027)				
Activity for innovation (= 1)	0.166***	0.010**				
	(0.022)	(0.005)				
Code of conduct × Old			-0.080*	0.061***	-0.145***	0.056**
			(0.047)	(0.021)	(0.048)	(0.023)
Code of conduct			0.113***	0.004	0.146***	0.006
			(0.022)	(0.004)	(0.022)	(0.004)
Old	-0.014	0.049***	-0.133***	0.025**	-0.102***	0.039***
	(0.024)	(0.011)	(0.029)	(0.011)	(0.030)	(0.011)
Initial Proportion of Old Workers	-0.002	-0.003**	0.000	-0.002*	-0.004	-0.003**
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Firm Size Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Weak IV F Statistics	119.16	91.24	172.85	220.49	164.28	75.99
R-Squared	0.229	0.179	0.226	0.113	0.205	0.143
Observations	3,033	3,033	3,033	3,033	3,033	3,033

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Linear Probability Models (LPMs) are conducted. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific, and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2.4 reports the estimation results of 2SRI, where predicted residuals are included in the proportional hazard model. The results are similar to those obtained from the baseline model (Table 2.3), although the differences in the retirement risk between aged and young workers are slightly diminished. In column 1, the hazard ratio for newly adopted automation increases from 0.707 to 0.711, and that for the interaction term decreases from 1.272 to 1.197. The overall effect of automation on older workers' risk of retirement decreases only by 5% (from 0.90 reported in column 1 in Table 2.2 to 0.85 in column 1 in Table 2.4), which indicates that the proportional hazard model slightly underestimates the negative effect on the employment of older workers. The estimated results from using the other indices of technological change are also similar to the baseline results, with a slight decrease in the disadvantage of aged workers compared to the young. Given that the predicted residuals are significant in all specifications, it is likely that endogeneity biases exist. However, the magnitudes of such biases appear to be small.

Table 2.4. Cox Hazard Ratio of Employees (2SRI Model)

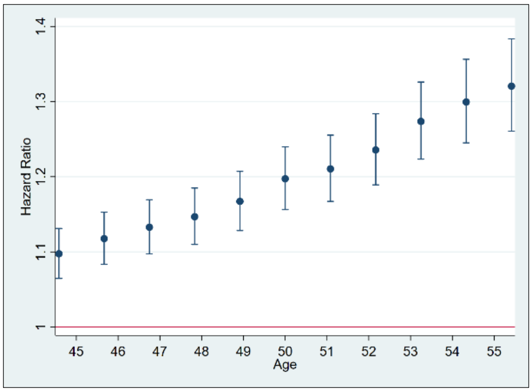
	(1)	(2)	(3)
Dependent Variable: Duration to Retirement from the Beginning of 2015			
New Automation × Old	1.197***		
	(0.021)		
New Automation	0.711***		
	(0.025)		
Investment in IT increased × Old		1.159***	
		(0.017)	
Investment in IT increased		1.034***	
		(0.007)	
Increased purchase of IT equipment × Old			1.208***
			(0.018)
Increased purchase of IT equipment			0.938***
			(0.006)
Old	1.034***	1.028**	1.029***
	(0.011)	(0.011)	(0.011)
Male	0.949***	0.948***	0.949***
	(0.005)	(0.005)	(0.005)
Age	0.909***	0.908***	0.909***
	(0.002)	(0.002)	(0.002)
Age Squared	1.001***	1.001***	1.001***
	(0.000)	(0.000)	(0.000)
Job Tenure in 2015	0.916***	0.916***	0.916***
	(0.001)	(0.001)	(0.001)
Subjected to Extending Retirement Age	0.959***	0.955***	0.960***
	(0.007)	(0.007)	(0.007)
Initial Proportion of Older Workers in the Firm	0.974***	0.981**	0.984**
	(0.008)	(0.008)	(0.008)
Residual from Technological Change × Old Estimate	1.076**	1.467***	1.446***
	(0.039)	(0.016)	(0.016)
Residual from Technological Change Estimate	0.648***	0.674***	0.664***
	(0.031)	(0.031)	(0.030)
Firm Size Fixed Effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Observations	962,404	962,404	962,404

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Coefficients denote the hazard ratio from the Cox proportional hazard model with two-stage residual inclusion. We used the existence of small group activities for innovation as an instrument to assess the adoption of new automation. Also, we use a code of conduct regarding internet use as an instrument to determine the investment in IT or purchase of IT-related equipment. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. "Other Controls" include gender, age, age squared, job tenure, being subjected to the extending retirement age policy, and initial proportion of older workers in the Firm. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

2.4.3. Sensitivity to Choice of Age Cutoff

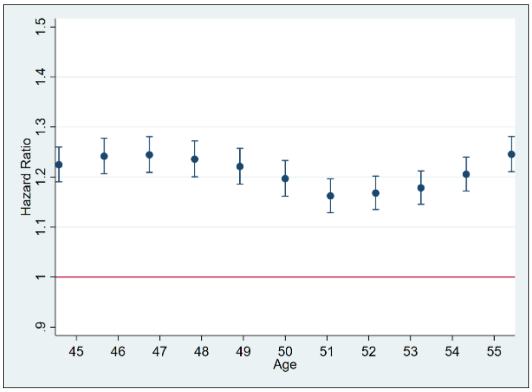
A possible concern arises whether the results are sensitive to the cutoff age for defining "aged worker," which was set to 50 years old in the baseline specification. We conducted a sensitivity test that examines how the regression results change with alternative cutoff ages for aged workers ranging from 45 to 55. Figures 2.4, 2.5, and 2.6 plot the estimated hazard ratios for the interaction between older workers and each of the technological change indices. In general, the results suggest that the interaction between aging and the influences of technological change could differ by the type (or feature) of the technology that is put into practice.

Figure 2.4. Estimated Hazard Ratios for the Interaction between Older Workers and New Automation



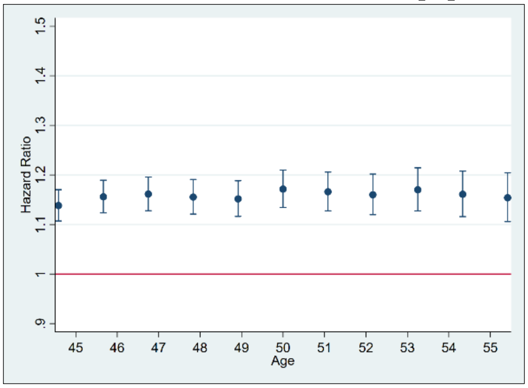
Source: The Workplace Panel Survey 2015 and Employment Insurance Data are used.

Figure 2.5. Estimated Hazard Ratios for the Interaction between Older Workers and Investment in IT increased



Source: The Workplace Panel Survey 2015 and Employment Insurance Data are used.

Figure 2.6. Estimated Hazard Ratios for the Interaction between Older Workers and Increased Purchase of IT-related Equipment



Source: The Workplace Panel Survey 2015 and Employment Insurance Data are used.

Regarding adopted automation (Figure 2.4), the estimated hazard ratio for the interaction continues to increase with age from the mid-forties. This result suggests that the adverse employment effect of adopting a new automation process becomes increasingly strong with the aging of workers. The result could be explained by a particularly strong displacement effect among older workers, which is slightly different from Acemoglu and Restrepo (2018b), who found that automation technologies tended to substitute for tasks performed largely by middle-aged workers. A possible explanation for this finding is that automation could create a need for task reallocation (see Figure 2.1). As noted in section 2.2, transferring to a new task would be more costly for aged workers.

In the case of expanding investment in IT (Figure 2.5) and investment in IT equipment (Figure 2.6), the estimated hazard ratio for the interaction term does not change much with the choice of cutoff age. It remains around 1.2 for IT investment and between 1.1 and 1.2 for IT equipment across the different cutoff ages. The outcome confirms the baseline result that the employment effect of technological change is less favorable for aged workers compared to the young. The result also suggests that the disadvantages associated with aging in terms of coping with IT perhaps start from middle age. Typical employees in the IT industry are relatively young, and the speed of IT development is faster than in any other industry. For this reason, employees in their mid- to late-40s in the industry could face difficulties in catching up on the latest state-of-the-art technology, such as a transition to a new programming language.

2.4.4. Heterogeneity

Table 2.5. Cox Hazard Ratio of Employees by Gender (2SRI Model)

Dependent Variable: Duration to Retirement from the Beginning of 2015	(1)	(2)	(3)	(4)	(5)	(6)
	Samples					
	Male			Female		
New Automation × Old	1.543***			0.925***		
	(0.036)			(0.027)		
New Automation	0.697***			1.257***		
	(0.032)			(0.068)		
Investment in IT increased × Old		1.299***			1.032	
		(0.025)			(0.023)	
Investment in IT increased		0.980**			1.045***	
		(0.008)			(0.010)	
Inc. purchase of IT equipment × Old			1.244***			1.091***
			(0.025)			(0.026)
Increased purchase of IT equipment			0.854***			1.010
			(0.008)			(0.011)
Old	1.192***	1.206***	1.228***	0.920***	0.902***	0.895***
	(0.018)	(0.019)	(0.019)	(0.015)	(0.015)	(0.014)
Firm Size Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Residuals from the 1st Stage of 2SRI	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	612,070	612,070	612,070	350,334	350,334	350,334

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Coefficients denote the hazard ratio from the Cox proportional hazard model with two-stage residual inclusion. We used the existence of small group activities for innovation as an instrument to assess the adoption of new automation. Also, we use a code of conduct regarding internet use as an instrument to determine the investment in IT or purchase of IT-related equipment. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. "Other Controls" include gender, age, age squared, job tenure, being subjected to the extending retirement age policy, and initial proportion of older workers in the Firm. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We conducted similar hazard analyses separately for males and females. The results presented in Table 2.5 reveal stark gender differences. Only aged males have strong relative disadvantages in terms of the employment effect of technological change. The estimated hazard ratios for the interaction terms are substantially larger for males compared to those estimated from the full sample. Conversely, females do not reveal clear disadvantages associated with aging. Aged female workers were more favorably affected by adopting automation than were young workers (column 4). For the other indices of technological change, the relative handicap of older females is either insignificant (column 5: investment in IT) or smaller in magnitude than that for the full sample (column 6: IT equipment). Another gender difference is observed in the overall employment effect of technological change. Whereas technology adoption positively affects males' employment, it increases females' risk of leaving the firm.

Table 2.6. Cox Hazard Ratio of Employees by Type of Industry (2SRI Model)

Dependent Variable: Duration to Retirement from the Beginning of 2015	(1)	(2)	(3)	(4)	(5)	(6)
	Type of Industry					
	Manufacturing			Service		
New Automation × Old	1.257***			1.040		
	(0.038)			(0.037)		
New Automation	1.045			0.460***		
	(0.062)			(0.024)		
Investment in IT increased × Old		1.332***			1.247***	
		(0.036)			(0.028)	
Investment in IT increased		1.079***			0.854***	
		(0.012)			(0.009)	
Inc. purchase of IT equipment × Old			1.260***			1.234***
			(0.040)			(0.028)
Increased purchase of IT equipment			0.807***			0.921***
			(0.011)			(0.010)
Old	0.948**	0.929***	0.959*	0.998	0.942***	0.945***
	(0.022)	(0.021)	(0.021)	(0.019)	(0.018)	(0.018)
Firm Size Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	-	-	-	Yes	Yes	Yes
Residuals from the 1st Stage of 2SRI	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	291,087	291,087	291,087	306,716	306,716	306,716

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Coefficients denote the hazard ratio from the Cox proportional hazard model with two-stage residual inclusion. We used the existence of small group activities for innovation as an instrument to assess the adoption of new automation. Also, we use a code of conduct regarding internet use as an instrument to determine the investment in IT or purchase of IT-related equipment. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Service industries are classified as follows: (1) Accommodation and food service activities, (2) Information and communication, (3) Financial and insurance activities, (4) Real estate activities, (5) Professional, scientific, and technical activities, (6) Business facilities management and business support services, (7) Education, (8) Human health and social work activities, (9) Arts, sports, and recreation-related services, (10) Membership organizations, repair, and other personal services. "Other Controls" include gender, age, age squared, job tenure, being subjected to the extending retirement age policy, and initial proportion of older workers in the Firm. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We also examined whether the effect of technological change differs across industries by comparing the results of similar regressions conducted separately for workers engaged in the manufacturing and service sectors. Table 2.6 reports the comparison results. In manufacturing, similar to the results for the entire sample, older workers were at a higher risk of leaving the firm than younger workers when a new technology was adopted. Newly adopted automation and investment in IT raise the overall retirement hazard by 1.2 and 1.3 times, respectively. However, the overall employment effects of technological change among older manufacturing workers is less favorable than those observed for the entire sample: each of the three indices of the technological change absolutely increases the probability of retirement for older manufacturing workers.

In service industries, too, the employment effect of technological change is less favorable for older workers than for the young. The relative disadvantage associated with old age is significant if investment in IT or purchase of IT equipment is concerned. Newly adopted technologies significantly reduce the overall probability of job separation. Automation, in particular, has a strong positive effect on employment in the service sector. Meanwhile, in the wholesale and retail industry (the results are not reported here), the employment effects of technological changes are insignificantly estimated. The result may account for the relatively small impact of technological changes on the employment of female workers in Table 2.5, as nearly half of them in our sample (46.1%) are engaged in the wholesale and retail industry.

Lastly, we investigated how the effect of technological change differed by the reason for retirement, motivated by the fact that certain types of retirement, such as disciplinary dismissal, could be irrelevant for this study. Korean Employment Insurance provides reasons for job separation as follows: 1) voluntary retirement due to a personal reason; 2) voluntary retirement due to a relocation of the workplace, a change in working condition, or wage arrears; 3) going out of business; 4) inevitable managerial issues; 5) disciplinary dismissal; 6) mandatory retirement; and 7) termination of a contract. We assumed that technological change might induce workers to retire through the following two channels. First, firms would lay off workers as a result of adopting new technologies. Second, workers would quit their jobs because of a deteriorated quality of matching with the newly assigned task. Accordingly, we chose to consider two types of retirement in the analysis, namely, inevitable managerial issues (i.e., a forced layoff) and voluntary retirement due to a personal reason or a change in working conditions.[12] We conducted 2SRI regressions, using each of these two types of retirement as the dependent variable.

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[12] Korean Employment Insurance does not provide more details on voluntary retirement. To screen the cases for the relocation of a workplace or wage arrears, we excluded the case if a retiree's workplace had moved in the last two years, or the firm had a deficit. In case of inevitable managerial issues, we also excluded the cases in which firms had difficulties with finance management.

Table 2.7. Cox Hazard Ratio of Employees by Reason of Retirement

Dependent Variable: Duration to Retirement from the Beginning of 2015	(1)	(2)	(3)	(7)	(8)	(9)
	Reason of Retirement					
	Inevitable Managerial Issues (Forced layoff)			Voluntary Retirement for Personal Reason / Change in Working Condition		
New Automation × Old	1.650***			1.041		
	(0.064)			(0.031)		
New Automation	0.974			0.684***		
	(0.077)			(0.033)		
Investment in IT increased × Old		1.058*			1.209***	
		(0.034)			(0.027)	
Investment in IT increased		0.907***			1.064***	
		(0.014)			(0.009)	
Inc. purchase of IT equipment × Old			1.570***			1.264***
			(0.057)			(0.030)
Increased purchase of IT equipment			0.509***			1.008
			(0.010)			(0.009)
Old	1.034	1.109***	1.052**	1.017	0.975	0.977
	(0.023)	(0.025)	(0.023)	(0.017)	(0.017)	(0.017)
Firm Size Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Residuals from the 1st Stage of 2SRI	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	962,404	962,404	962,404	962,404	962,404	962,404

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Coefficients denote the hazard ratio from the Cox proportional hazard model with two-stage residual inclusion. We used the existence of small group activities for innovation as an instrument to assess the adoption of new automation. Also, we use a code of conduct regarding internet use as an instrument to determine the investment in IT or purchase of IT-related equipment. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. "Other Controls" include gender, age, age squared, job tenure, being subjected to the extending retirement age policy, and initial proportion of older workers in the Firm. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2.7 reports the estimation results. If the alternative definitions of retirement are applied, the more unfavorable effect of new technology on aged workers' employment still stands out. The estimated hazard ratios for the interaction terms are all greater than one and statistically significant, except for the effect of new automation on retirement for a personal reason. All types of technological change reduce the overall risk of forced layoff, although the effect is statistically insignificant for automation. The effect of technological change on the overall probability of voluntary retirement for personal reasons differs across indices of technology. Newly adopted automation strongly reduces the risk of retirement, whereas investment in IT has a modest positive effect on the probability of retirement. The increased purchase of IT equipment has no significant effect.

The results suggest that technological changes may affect aged workers' employment through various pathways. The results regarding increased forced layoffs indicate that the adoption of new technology actually played a role in replacing the tasks previously conducted by older workers. It appears that automation brings a particularly strong replacement effect for older workers, given that it raises their risk of forced layoff by more than 1.6 times. It is notable that investment in IT and purchase of IT equipment absolutely increase the possibility of voluntary retirement for personal reasons among older workers as well as their risk of forced layoff. A possible explanation is that the quality of matching between the workers and their jobs deteriorates because of the workplace changes accompanied by the introduction of new devices.

Further questions may arise based on the results. First, what if more than two technologies are adopted simultaneously? The correlations between 1) automation and IT investment and 2) automation and the purchase of IT equipment are 0.23 and 0.27, respectively, indicating firms tend to adopt these technologies in the same period. We conducted the baseline regressions by replacing the explanatory variable with ① both adopting automation and IT investment, ② both adopting automation and the purchase of IT equipment, and ③ either ① or ② is satisfied. The estimation results are reported in Table 2.A.3, which suggests that the positive employment effect of technological changes is stronger for employees: their retirement hazards are much less than those from the baseline results. In addition, for older workers, we found that the negative impact of technological changes on employment alleviates, but the relatively unfavorable effects on younger workers are still present.

In addition, the results in Table 2.7 also give rise to the question of the purpose of technological progress: are these for labor-saving or employing new workers who are more familiar with the new technologies? Firms may consider both of the two, but we could check the hiring effect separately. We examined whether the changes in technology affected the new employment in general. The estimation results suggest that the effect is insignificant, indicating the retirement of older workers is not to replace them with new skilled workers. Details on the analyses are reported in Appendix 2.A.3.

2.5. Conclusion

This study has investigated how the adoption of new production technology affects the employment of older workers in Korea by using establishment-level panel data (WPS) that were newly linked with administrative records (Korean Employment Insurance data).

More specifically, we estimated proportional hazard models to examine how indices of new technology adoption affect the probability that employees leave their jobs and how the effects differ between old and young workers. For constructing variables on technological change, we utilized responses to the following three questions: 1) whether new automation was adopted, 2) how much investment in IT sectors increased, and 3) how much the purchase of IT equipment increased. To address potential bias arising from endogenous technology adoption, we used the two-stage residual inclusion (2SRI) method.

The baseline results suggest that the employment effect of technological change differs between aged and younger workers, with the former less favorably affected by newly adopted technologies than the latter. Technological changes, measured by newly introduced automation and investment in IT equipment, tend to lower the overall risk of retirement for workers who had been employed in the firm prior to the technological change. However, the retirement risk of older workers compared to that of younger workers is increased by the adoption of new technology.

In some conditions, technological changes increase the retirement risk of older workers absolutely as well as relative to that of younger workers. Specifically, the negative employment effect of newly adopted automation is stronger for aged males who are employed in the manufacturing industry. If the reason for retirement is considered, it is the probability of forced layoff among older workers that was strongly increased by newly adopted automation. These results indicate that automation could play a role in replacing the tasks previously conducted by older workers.

We also found that investment in IT and the purchase of IT equipment absolutely increase the retirement hazard of older workers employed in service industries. These types of technological change significantly increase both the possibilities of voluntary retirement for personal reasons and of forced layoff of older workers. Possible explanations for this are: 1) a deterioration in the quality of matching between the workers and their jobs caused by the introduction of new devices and 2) firms' managerial decisions are unfavorable for the employment of older workers.

Our study has various limitations. First, we used three specific indices of production technology available from our data, which provide only a partial picture of the effect of technological change. Second, our data do not provide detailed information on the personal characteristics of individual workers. A more sophisticated examination would be possible given information on wages, education level, and the specific skills of workers. Third, we only provided some speculative explanations and highly circumstantial evidence regarding the result that technological changes are less favorable for older workers. Further studies are required to fully understand the mechanisms behind the relationships between technological advances in production and the employment of workers with heterogeneous characteristics. Lastly, since our study covers only three years of employment status, we were only able to examine the short-run effect of technological change. Given that the productivity or reinstatement effects of technological changes may not emerge instantly, an extended period needs to be analyzed to capture possible long-term effects fully.

In spite of these limitations, the evidence provided in the paper raises the possibility that technological changes could negatively affect the employment of older workers. Of course, the results based on several specific types of technology adoption in a single country can hardly be generalized. The features of ongoing technological progress may differ from one another, and certain types of new technologies may help people become active and productive until a very old age by alleviating the disadvantages associated with aging. However, given that automation and IT are the two major types of the current wave of technology innovations, our study strongly suggests that radical changes in technology may bring unfavorable labor market consequences for older people, at least compared with the young. In this sense, technological changes would likely produce an additional challenge for a rapidly aging society.

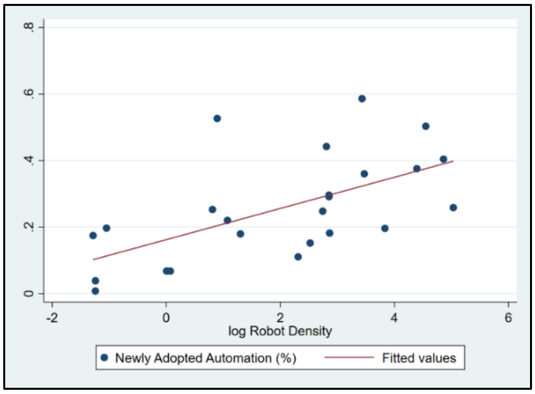
2.A. Appendix

2.A.1. Analyses Using New Instruments: Robot Density

Robot density is broadly used in literature to examine the relationship between robot adoption and employment (Acemoglu and Resrepo 2020; Graetz and Michaels 2018).[13] As an alternative to the original instruments, we used robot density as an instrumental variable. We used a dataset (IFR, 2018) on the number of robots by country and industry released by the International Federation of Robotics (IFR, hereafter). The advantage of IFR data is that we can collect the data for major countries around the world. The weakness is; however, the IFR surveyed only manufacturing industries.

Since a robot is a kind of automation system, using the robot density of Korea is not desirable. Instead, we employed the robot density of China and Japan, where every manufacturing industry is closely connected to the Korean industry. We collected the number of employees by country and industry from OECD statistical data and national yearbooks and computed the 24 densities by industry level.[14] The export volume of each country is used for weights. Figure 2.A.1 shows the positive relationship between automation adoption rate and robot density.

Figure 2.A.1. Newly-adopted Automation and Robot Density



Source: Datasets from IFR (2018) are used

[13] IFR adopted the definition of robot described in ISO 8372:2012: “An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications” (IFR, 2018) According to IFR (2018), the definition of robot density is the number of robots over 10,000 employees per industry.

[14] 7 classes out of 24 are duplicated. Refer to the 9th industrial classification code in Table 2.A.1

Differing from the baseline analysis where the regressions are conducted at the individual level, we are able to examine the analysis using robot density by industry level. Since we were able to examine only workers engaged in the manufacturing industry where the IFR industrial classification is matched to the 9th Korean industrial classification code, the sample size is 291,087. We selected variables available to the new analysis among the originals and used them as controls. The estimation results are reported in Table 2.A.2, examining the impact of the proportion of newly-adopted automation on maintaining employment from 2015 to 2017. The estimation results support the original results where the new automation absolutely increases the retirement hazard of older workers aged 50 or older in the manufacturing industry but lowers that of younger workers.

Table 2.A.1. Robot Density

9th Korean Industrial Classification Code	Industry	Robot Density		Weight (by exports volume)		Weighted Density
		CHN	JPN	CHN	JPN	
10-12	Food products and beverages; Tobacco products	18.482	3.298	0.924	0.076	17.336
13-15	Textiles, leather, wearing apparel	0.290	0.104	0.932	0.068	0.277
16	Wood and wood products (incl. furniture)	0.344	1.034	0.989	0.011	0.351
17-18	Paper and paper products, publishing & printing	0.874	2.119	0.840	0.160	1.074
19	Unspecified chemical, petroleum products	5.145	72.182	0.815	0.185	17.531
20-21	Chemical products, pharmaceuticals, cosmetics	5.684	0.088	0.640	0.360	3.671
22	Rubber and plastic products without automotive parts	104.75	208.033	0.764	0.236	129.170
23	Glass, ceramics, stone, mineral products n.e.c. (without automotive parts)	2.760	3.948	0.861	0.139	2.925
24	Basic metals (iron, steel, aluminum, copper, chrome)	2.903	1.203	0.730	0.270	2.444
25	Metal products (without automotive parts), except machinery and equipment	15.573	15.380	0.730	0.270	15.520
26	Industrial machinery	7.596	20.180	0.614	0.386	12.459
28	Electrical/electronics	90.195	130.767	0.893	0.107	94.529
27	Medical, precision and optical instruments	1.318	3.595	0.591	0.409	2.248
29	Electrical machinery unspecified	60.672	-	0.762	0.238	46.257
30	Automotive	260.83	106.198	0.305	0.695	153.353
31-32	Other transport equipment	9.122	12.000	0.663	0.337	10.092
33	All other manufacturing branches	80.305	89.436	0.937	0.063	80.882

Note: Every statistic is computed based on statistics in 2014. The number of robot data is from IFR(2018). The number of employees engaged in each industry is collected from OECD statistical data (STAN) and China Statistical Yearbook (2014). The export dataset is collected from UN Comtrade database.

Table 2.A.2. The Relationship between Newly-adopted Automation and Employment: Instrumental Variable Estimation Results at the Industry Level

	(1)	(2)	(3)
Dependent Variable	Proportion of employees working until 2017		
Sample	Total	Old (age>=50)	Young (age<50)
Proportion of newly adopted automation	0.2226***	-0.3084***	0.3734***
	(0.0013)	(0.0069)	(0.0021)
Proportion of male workers	0.3081***	0.2095***	0.2008***
	(0.0007)	(0.0029)	(0.0009)
Proportion of workers subjected to the MRA	-0.1010***	0.0594***	-0.0845***
	(0.0012)	(0.0029)	(0.0012)
Proportion of old workers	0.5753***		
	(0.0021)		
Constant	0.4718***	0.0669***	0.4300***
	(0.0007)	(0.0011)	(0.0009)
Observations	291,087	50,542	240,545

*** p<0.01, ** p<0.05, * p<0.1

2.A.2. Additional Analysis: Multiple Technologies Adopted

Table 2.A.3. Additional Analysis: Simultaneously Adopted Technologies and Retirement

	(1)	(2)	(3)
Dependent Variable		Retired by 2017	
Automation × IT Investment × Old	1.071***		
	(0.026)		
Automation × IT Investment	0.798***		
	(0.008)		
Automation × IT equipment × Old		0.997	
		(0.024)	
Automation × IT equipment		0.823***	
		(0.008)	
Automation × IT tech. × Old			1.066***
			(0.025)
Automation × IT tech.			0.800***
			(0.008)
Old	0.985	0.990	0.985
	(0.010)	(0.010)	(0.010)
Male	0.925***	0.926***	0.926***
	(0.005)	(0.005)	(0.005)
Age	0.883***	0.884***	0.883***
	(0.002)	(0.002)	(0.002)
Age Squared	1.002***	1.002***	1.002***
	(0.000)	(0.000)	(0.000)
Job tenure in 2015	0.909***	0.909***	0.909***
	(0.001)	(0.001)	(0.001)
Subjected to extending retirement age	0.946***	0.947***	0.947***
	(0.007)	(0.007)	(0.007)
Initial Ratio of Older Workers in the Firm	1.068***	1.068***	1.068***
	(0.004)	(0.004)	(0.004)
Firm Size Fixed Effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
Occupation Controlled	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Observations	962,404	962,404	962,404

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used. Firm sizes (the number of employees) are classified as follows: (1) 10 to 299, (2) 300 to 999, (3) more than 1000. Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Public administration and defense, (14) Education, (15) Human health and social work activities, (16) Arts, sports, and recreation-related services, (17) Membership organizations, repair, and other personal services. "Other Controls" include gender, age, age squared, job tenure, being subjected to the extending retirement age policy, and initial proportion of older workers in the Firm. Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

2.A.3. Technological Change and New Employment

We employed the first-difference estimator to examine the impact of technological changes on new employment at the firm level. Specifically, we estimate:

$$\Delta Y_{jt} = T'_{jt}\beta_1 + \Delta F'_{j}\beta_3 + \mu_t + \varepsilon_{jt}.$$

ΔY_{jt} is the outcome variable, representing the time-to-time changes in new employment of firm j. Since the WPS biennially survey firms, time t is either 2013 or 2015. T_{jt} is an indicator variable for newly adopted technology. F_j is the annual sales revenue of firm j.

Estimation results are reported in Table 2.A.4. For columns 1-3, young workers are defined as workers aged less than 50, as we define in the paper. For columns 4-6, we also restricted the dataset to workers aged under 30 and conduct the same regressions. Regardless of the definition, the estimation results suggest that technology adoption does not have an impact on new employment. We found that the retirement of older workers is not for replacing them with newly-skilled labor.

Table 2.A.4. Technological Change and New Employment

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Newly employed workers under 50 (log)			Newly employed workers under 30 (log)		
New Automation	-0.0272			-0.0995		
	(0.0687)			(0.0666)		
Investments in IT		0.0232			-0.0319	
		(0.0628)			(0.0608)	
Investments in IT equipment			0.0102			-0.0175
			(0.0637)			(0.0617)
Δ Log Sales	0.0335	0.0336	0.0335	0.0281	0.0285	0.0287
	(0.0249)	(0.0249)	(0.0249)	(0.0242)	(0.0242)	(0.0242)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	2,440	2,440	2,440	2,440	2,440	2,440
R-squared	0.0589	0.0589	0.0588	0.0286	0.0270	0.0268
Number of Firms	1,220	1,220	1,220	1,220	1,220	1,220

Note: The Workplace Panel Survey 2015 and Korean Employment Insurance are used.

Chapter 3. The Impact of the Minimum Retirement Age and Labor Substitutability

3.1. Introduction

As major countries have experienced rapid aging, aged people constitute a significant fraction of the labor force. The importance of labor policies regarding older workers has also been increasing. These policies aim to follow: 1) to maintain labor supply and total productivity, 2) to maintain the income and consumption level of the elderly, and 3) to alleviate financial pressure on pension funds. Meanwhile, discussions are underway on how government policies promote aged workers' employment at the cost of young workers' employment opportunities. Youth unemployment is also a crucial issue for many countries. Since long-term unemployment of the young would reduce their permanent wealth on the life cycle, which could become a heavy burden on the economy in the future.

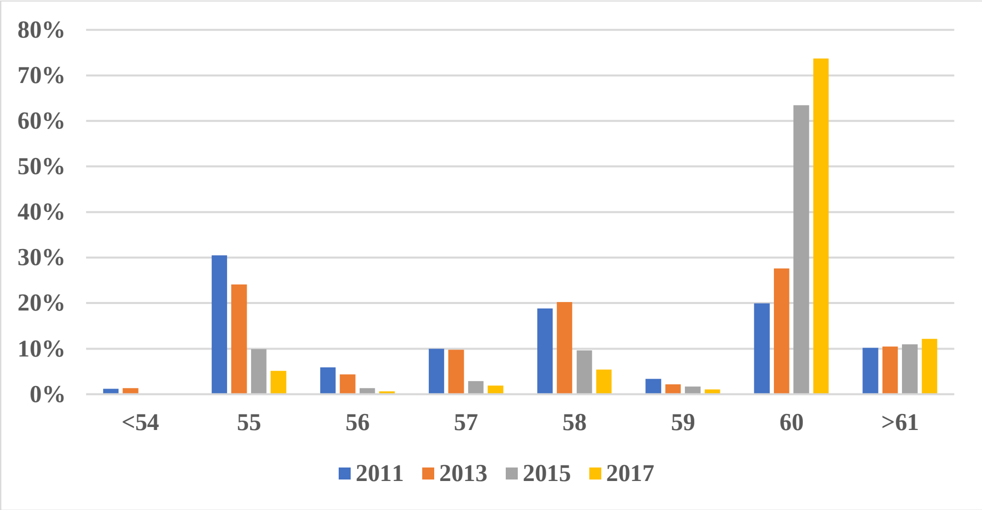
This study aims to investigate how a newly implemented minimum retirement age affects the employment of aged people and younger generations, based on Korean society. In 2013, an amendment to the Act on old workers' employment passed the National Assembly of Korea. The new bill's main point is that firms with more than 300 employees were required to set the retirement age at least 60 at the beginning of 2016. The implementation of the policy for firms with less than 300 employees was postponed for one year.

Before 2016, firms located in Korea operate the retirement system at their discretion. In general, when an employee reaches a certain age, firms can terminate the employment contract irrespective of its intention. The firms' retirement ages are mostly ranged from 50 to 60, which is problematic because the retirement is too early to meet pension eligibility.[15] Through this policy, the Korean government expected that older workers' employment would increase, and the financial burden

[15] Specifically, the pension eligibility age is as follows: 60 for people born before 1952; 61 for 1953-1956 birth cohorts; 62 for 1957-1960 birth cohorts; 63 for 1961-1964 birth cohorts; 64 for 1965-1968 birth cohorts; and 65 for people born after 1969.

will be eased as Korea is the fastest aging society in the world.

Figure 3.1. Retirement Age Across Firms in Korea



Source: The WPS 2011-2017

Figure 3.1 shows the retirement age distribution of firms across 2011 to 2017, surveyed by the Korea Labor Institute. Prior to 2013, 90% of firms set their retirement age below 60. During the 2013-2015 period, 50% of workplaces responded by changing the retirement age to 60 or older, but many still set below 60. Since the policy implementation, it is notable that the proportion of retirement age under 60 significantly decreased and is nearing zero.

On the other hand, to cope with the minimum retirement age, firms have several countermeasures divided into two main categories. First, adjusting working conditions are suggested. Representatively, both employer and employee agree to a ‘wage-peak system,’ which is to fix or cut wages during the extended working period. The government also encouraged the policy by imposing negotiating obligations or providing financial support to implement the wage-scheme policy. Second, an incentive system is considered to induce early retirement before workers can benefit from the minimum retirement age. If appropriate compensation for early retirement is offered, marginal workers will respond better to the plan. In that case, however, the employment of older workers might reduce, opposite to the government’s intention.

Based on the background, we aim to investigate the impact of minimum retirement age on the Korean labor market. First, we assessed how much the policy increases older workers' employment: that is a task of clarifying whether the policy meets the government's goals. A simple analysis shows that birth cohorts affected by the policy are 25.1 percentage points less likely to retire from their original retirement age than the other cohorts. Second, we examined whether the changes in employment of older workers between the ages of 55 to 60 affected the employment of younger generations. Using a unique set of microdata from the Workplace Panel Survey linked to Korean Employment Insurance records, we checked the impact of the policy change at both firm and individual levels. The estimation results suggest that the policy also reduces the employment of mid-aged (aged 30-54) workers. Much of the reduction in employment can be accounted for by the changes in male workers working more than two years. We also found that some characteristics (e.g. union, the proportion of older workers) or systems (e.g. wage-peak system) of each firm influence the magnitude of the MRA effect.

Our study is organized as follows: Section 3.2 reviews previous studies; Section 3.3 shows a theoretical framework for the study; Section 3.4 presents data used for this study; Section 3.5 measure the impact of the policy on retirement hazard of old workers; Section 3.6 reports estimation results examining the labor substitutability between the old and young workers and additional analyses for heterogeneity; and Section 3.7 concludes the study.

3.2. Literature Survey

It is undoubtedly accepted that Social Security provisions account for the employment of older workers (Gruber and Wise 2002). In the U.S. and European countries where the pension system is mature, governments tend to adjust pension eligibility or the retirement age for the sake of the soundness of pension finances[16]. Those policies are different from those of Korea based on the minimum retirement age, but they are the same in changing retirement timing.

Empirical studies have shown strong evidence that such adjustments

[16] Once the US set mandatory retirement policy, but it was abolished in 1986 due to The Age Discrimination in Employment Act (Von Wachter 2002).

influence the aggregate labor supply of older workers. Using a Social Security reform in 1983 that full retirement age increased from 65 to 66, Behaghel and Blau (2012) confirmed that the timing of Old Age and Survivors Insurance (OASI) benefit claiming was also delayed along with the change of full retirement age. Mastrobuni (2009) also found that workers tend to delay retirement as the normal retirement age increases through the U.S. social security reform. Von Wachter (2002) investigated the impact of mandatory retirement abolition in the U.S. and showed that the mandatory retirement age serves as a benchmark for aged workers to continue working as they reach the retirement age. Staubli and Zweimuller (2013) examined pension reforms in Austria and showed that the increase in early retirement age significantly increases older workers' employment, especially those with higher wages. Kondo and Shegeoka (2017), who exploited a dataset on pension reform in Japan in 2001, found that the expansion of pension eligibility age increased male workers' employment around the age of 60.

On the other hand, is there a crowding-out effect of the increase in older workers reducing young workers' employment? Questioning the problem is based on *lump of labor* hypothesis: the labor market is characterized as a boxed economy that creates a generational competition to increase their own share. However, empirical studies have shown that there is no evidence to support the hypothesis. Gruber and Wise (2010), who compiled research on European countries' early retirement policy, showed that policies that encourage older workers do not reduce youth employment. They denied the boxed economy and showed that economic condition is a major factor affecting both young and old workers' employment. Using the historical data of employment among OECD countries, Kalwij et al. (2010) and Boheim and Nice (2019) also found no evidence of the trade-off between the employment of old and young workers. Examining the German labor market, Borsh-Span and Schnabel (2010) supported the argument that the labor demand across the economy is more important than the substitution effect between the two generations. Munnell and Wu (2012) examined the late retirement of baby boomers and its impact on youth employment in the U.S. Using the CPS data from the 1970s to the 2010s, they found no evidence of young people being pushed out of the labor market. Another point of explaining the fallacy of the hypothesis is that factors such as technological progress may improve total productivity as well as the employment of old workers. For example, adopting an automation system can have a negative impact on employment in the short-run (Acemoglu and Restrepo 2018), but the technology may promote total employment through cost reduction and create new jobs that people have comparative advantages (Acemoglu and Restrepo 2019).

While researchers agreed on the 'lump of labor fallacy,' a possibility of substitution between old and young workers remains in microeconomic contexts. The pension reform in Italy is a case in point. Since 1992, the Italian government has strengthened pension eligibility and delayed the benefit claiming for fiscal sustainability. Reforms have been revised several times as the government changed, but the age of pension eligibility has gradually increased (Bertoni and Brunello 2017). Using province-level data covering the years from 2004 to 2015, Bertoni and Brunello (2017) found that five additional workers over the age of 50 reduced about one worker aged 16-34. Boeri et al. (2016) focused on the Italian government's drastic increase in the minimum retirement age in 2011. Using an establishment-level dataset, they found 36,000 young workers lost their job due to the 2011 reform. A more recent study by Bovini and Paradisi (2019) examined the degree of substitutability between age cohorts after the pension reform. They found that the delayed retirement resulted in spillover effects: co-workers who were highly replaceable to older workers were more likely to exit the labor force after the reform. Bovini and Paradisi (2019) suggested a channel that reductions in labor income due to an increase in older workers close to retirement might reduce other workers' motivation to work. Meanwhile, Carta et al. (2020) showed the complementarity between older and young workers even though they studied the same 2011 reform. They explained that studies on the substitutability between the two only examined the employment of workers at the establishment level, but their study is closer to showing the impact of the reform on the overall economy. Thus, they suggest that the Italian case can also be evidence of 'lump of labor fallacy.'

Studies in other countries also report similar results supporting the substitutability. Vestad (2013), using a Norwegian case, also showed an increase in employment of young people as the participation of older workers in the labor force decreased due to the easing of early retirement policies. Exploiting a case of pension reform in Japan, Kondo (2016) suggested that the increase in older workers' employment due to the pension reform positively affects the number of young workers but negatively for the middle-aged female workers.

3.3. Theoretical Framework

Boeri et al. (2016) contributed pioneeringly to the theoretical model in which changes in retirement due to an exogenous shock affect labor demand for youth. This section provides a brief description of the model.

A production function with two inputs, $F(L,K)$ is quasi-concave and shows constant returns to scale. As our interest is to focus on labor supply (L), we assume that capital (K) is fixed to $\overline{K}$. Thus, we have a simplified function which is $y = F(L,\overline{K}) = f(L)$. The function is also assumed to be $f'(\mathrm{L}) > 0$ and $f''(\mathrm{L}) < 0$. The model also defines labor market consists of old workers (L_o) and young workers (L_y). Wage functions can be obtained using the first-order condition of labor for profit-maximizing,

$$w_o = f'(L)L_1(L_o, L_y)$$

$$w_y = f'(L)L_2(L_o, L_y)$$

Consider the situation where the employment of older workers marginally increases due to an exogenous policy change. Given the wage equilibrium w_o and w_y, the impact of the policy change on young workers' labor can be described as the following equation:

$$\frac{dL_y}{dL_o} = -\frac{f'(L)L_{12} + f''(L)L_1L_2}{f''(L)L_1^2 + f'(L)L_{11}}.$$

The denominator of the equation is negative because $f'(L)$>0, $f''(\mathrm{L}) < 0$ and L_{11} < 0. The effect of the policy change, $\frac{dL_y}{dL_o}$ depends on the numerator, $f'(L)L_{12} + f''(L)L_1L_2$. Thus, the sign and the relative magnitude of L_{12} is the key determinant. The condition of L_{12} > 0 means that additional older workers promote the marginal productivity of young workers, resulting in more hiring of young workers. However, if either $f'(L)$, the marginal productivity of total labor or L_{12} is not sufficiently large, the policy would have a negative effect on young workers' employment.

To separate the classification of factors affecting the sign of numerator, we also summarize Han's (2019) idea assuming that $F(L,K)$ is Cobb-Douglas production function, and labor production exhibits constant elasticity to substitution. Specifically,

$$\mathrm{F(L,K)} = \mathrm{z}L^{\alpha}K^{1-\alpha},$$

$$L(L_o, L_y) = \left(\theta L_o^{\rho} + (1-\theta)L_y^{\rho}\right)^{\frac{1}{\rho}} \quad where\ \rho \leq 1, 0 < \theta < 1.$$

Based on these assumptions, total differentiation of the production function is

$$\frac{dL_y}{dL_o} = -\frac{L_{12} - \alpha L_1 L_2 / L}{L_{11} - \alpha L_1^2 / L}.$$

The sign of the numerator would be determined by the size of L_{12} and $\alpha L_1 L_2 / L$. L_{12} depends on ρ, the cross-elasticity of old and young workers. In the second term of the numerator, α, the output elasticity of labor is also a crucial factor[17]. Overall, young workers' employment depends on both changes in labor demand on the young due to the increasing the old (i.e., labor substitutability) and the marginal productivity in total labor (Han, 2019).

If we calculated the equation using the assumptions, the substitutability condition between the old and the young is $1-\rho < \theta$. If ρ is 1, old and young workers are the perfect substitute, the situation always meets the condition. If ρ is ranged from 0 to 1, the magnitude of α determines.

In the study, we attempt to examine how the minimum retirement age affects the employment substitution between the old and the young. More specifically, we analyze changes in employment of older workers and their correlation with employment for other generations. If the theoretical framework discussed above is applied, the empirical analysis will help to estimate ρ, the

[17] Considering the wage function solved, α is also involved in the cost of labor.

substitutability between generations.

3.4. Data

We use a unique dataset that combines establishment-level panel data with individual-level employment records. In particular, two data sets are merged: The Workplace Panel Survey (WPS, hereafter) and the records of Korea Employment Insurance (KEI, hereafter). Thanks to the Korea Labor Institute's cooperation, each KEI record is given a clear firm identification code that can be combined with the WPS.

The WPS, which Korea Labor Institute surveyed, is a representative dataset for workplaces established in South Korea. The survey's main objectives are to identify labor industry-wide labor demand and employment structures, evaluate human resources management, and support the government to develop policies for systematic workforce supply. The firm answers detailed questions about people, financial performance, workplace characteristics, and other topics in each survey year. Baseline surveys with 1,905 firms were conducted in 2005, and the WPS tries to re-interview the firms every two years[18].

Korea Employment Insurance is the administrative employment record of the employed. In Korea, firms hiring at least one worker are required to purchase employment insurance to protect their employees from involuntary unemployment, which allows us to track down all workers employed ever. The data provides information on the demographic characteristics of workers and when they enter and exit the firm. However, the downside of the data is that the record does not track post-retirement careers. If a significant number of workers are re-employed after retirement, the impact of the minimum retirement age we estimate will be underestimated[19].

Our sample includes the 2013-2017 period, which covers all the entry and exit of employment across the WPS firms. We restricted samples by firms with

[18] The new sample of 2,136 firms are added in 2015.

[19] On the other hand, since we only use the records consistent with the firms surveyed by the WPS, the proportion of samples moving from the original workplace to another one will be rare.

larger than ten employees because firms with fewer than ten employees are too small to investigate the change in older workers' employment status. Overall, the sample contains 956,414 individuals employed by 2,340 firms. Based on each research question, we use the data for either firm-level or individual-level analysis

3.5. The Impact of the MRA on Retirement

3.5.1. The Discontinuity of Retirement Age

Our empirical analysis is conducted in two steps. The first step is to measure the impact of the minimum retirement age (the MRA, hereafter) on retirement hazards. It is expected to positively affect the employment of the elderly due to the policy. However, it is still uncertain whether the employment of the elderly will actually increase. In a situation where the retirement timing is forced to be postponed by the MRA policy, employers may encourage early retirement or recommended resignation to reduce labor costs. In addition, the voluntary retirement of marginal workers would increase if workers are set to implement a wage-peak system, which sets a ceiling of older employees' salary levels. Lastly, there may not be a significant number of workers who work until they reach the retirement age, which makes the policy non-binding.

To empirically examine the impact of extended retirement age on older workers' employment, we compared the differences in employment before and after the policy implementation. Specifically, we use the discontinuity of retirement age between two birth cohorts. The discontinuity occurs because firms can set the retirement age (the original retirement age, or the ORA hereafter) at their discretion before the extension, but the extension was implemented at a particular point in time. For example, if a firm with more than 300 employees sets its retirement age at 58, the retirement age should be extended to 60 in 2016. In 2015, the birth cohort born in 1957 (1957 cohort, hereafter) became 58 years old and were to retire. For the 1958 birth cohort, however, they will have the right to work for another two years at the age of 58. Although the two cohorts' birth years continue, the policy change made two years of gap in their retirement age.

The idea of the first step in our empirical strategy is to compare the retirement rate of two birth cohorts for whom the discontinuity of retirement age is observed. If a firm with more than 300 employees had set their retirement age at α before 2016, we could use the '2016- α' birth cohort for the treatment group and '2015- α' birth cohort for the control group. Since the dataset has employment records by the end of 2017, we are only able to examine the impact of MRA for just one or two years.

Firms setting the ORA before 2016 constitute 74.6% of our sample. In 2015, the number of firms where the ORA was below 60 was 457, which is 19.5% of all firms. Among them, 366 firms hired at least one employee who was treated or controlled.

Table 3.1. Descriptive Statistics: Treatment and Control Group

	Full Sample (Obs. 4,684)	Group	
		Treated (2,585)	Control (2,099)
Individual-level Information			
Male	0.708	0.703	0.713
Birth Year	1959.0	1959.4	1958.5
Year Hired	1999.1	1999.0	1999.2
Retired by 2017 (=1)	0.444	0.313	0.606
Firm-level information			
Employees more than 300 (=1)	0.684	0.689	0.678
Original Retirement Age	56.861	56.891	56.823
Sales Revenue (log)	12.027	12.030	12.025
Unionized firm (=1)	0.592	0.604	0.576
Industry			
Manufacturing	0.555	0.547	0.565
Electricity, gas, steam and water supply	0.007	0.005	0.009
Sewerage, waste management, materials recovery	0.005	0.004	0.007
Construction	0.013	0.010	0.016
Wholesale and retail trade	0.055	0.076	0.030
Transportation	0.062	0.056	0.070
Accommodation and food service activities	0.058	0.056	0.060
Information and communication	0.060	0.066	0.053
Financial and insurance activities	0.046	0.048	0.044
Real estate activities	0.000	0.000	0.000
Professional, scientific, and technical activities	0.019	0.019	0.018
Business facilities management and business support services	0.048	0.041	0.056
Human health and social work activities	0.023	0.021	0.025
Arts, sports and recreation related services	0.001	0.002	0.000
Membership organizations, repair and other personal services	0.048	0.048	0.048

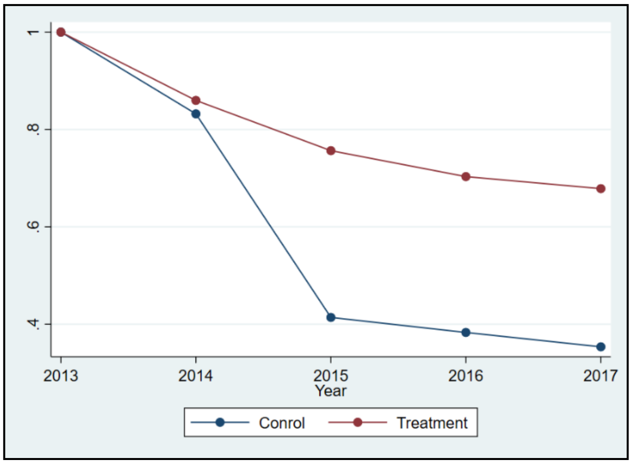
Notes: WPS 2015 and KEI 2013-2017 records are used. Samples are restricted to 1) workers born from 1955 to 1965 and hired before May 2013 2) firms with more than ten employees.

Table 3.1 shows the summary statistics for both treatment and control cohorts. The analysis is based on a sample of 4,684 employees born between 1956 and 1962. The treatment and control cohorts constitute 2% and 1.5% of all 366 firms, respectively. They were hired before the amendment of the Act on aged workers' employment passed in May 2013. They have worked for an average of 16 years as of 2015. The samples turned out to be male-dominated, and they were born between 1956 and 1962.

The ORA distributed from 54 to 59. From 2014 through 2017, 60.6 % of control cohorts retired, but only 31.3% of treated cohorts retired. Figure 3.2 and 3.3 shows how the MRA protects the treatment cohorts' retirement by the discontinuity of the retirement age. Figure 3.2 is for the case of firms with more than 300 employees where the MRA was implemented in 2016. In 2014, the retirement rates of the two groups were similar. In 2015 when the control cohorts reach the original retirement age, the employment of them highly decreased. In 2016, however, the employment of the treatment cohorts did not sharply decrease. The gap between the two cohorts continues until 2017.

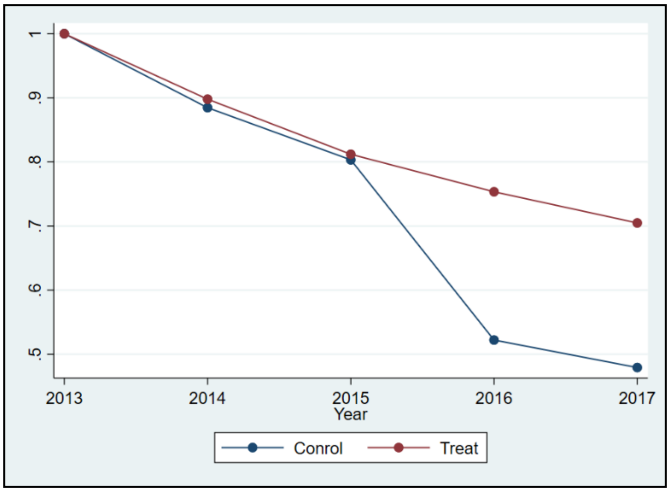
Figure 3.3 also shows the retirement rate gap of firms with less than 300 employees. Although the data just represents the timeframe when the policy was implemented, the gap of employment occurs in 2017, and the magnitude of the gap is remarkably similar to Figure 3.2.

Figure 3.2. Employment Rate of Birth Cohorts: Firms with more than 300 Employees



Source: WPS 2015 and KEI 2013-2017 records are used.

Figure 3.3. Employment Rate of Birth Cohorts: Firms with less than 300 Employees



Source: WPS 2015 and KEI 2013-2017 records are used.

3.5.2. Regression Results

We conduct a simple regression to measure the impact of MRA on treated cohorts by controlling other factors. Specifically, the following equation is made:

$$Ret_{ijt} = \sum_{a=0}^{1} \alpha_a Treat_i * 1(t = \tau_j - a) + \beta Treat_i + \gamma_a \sum_{a=0}^{1} 1(t = \tau_j - a) + X'_i\delta + F'_j\lambda + \mu_t + \varepsilon_{it}. \quad (1)$$

The outcome of the model, Ret_{ijt} is a dummy variable indicating the employment status of the worker i employed in firm j. The variable equals one if i retires at t. $Treat_{it}$ stands for the dummy variable for birth cohorts who are subjected to the retirement age extension (i.e. treatment cohorts). Thus, α_a is the parameter expected to capture how much the employment probability of treatment cohorts has increased or decreased compared to the controlled cohorts at the time '$\tau_j - a$.' τ_j is the time the MRA is implemented. Based on the size of firms, τ_j is either 2016 or 2017. If there exists a positive effect of the MRA on the employment of the treated cohorts, the estimation results would show negative α_0. X is a set of individual characteristics: age dummy and gender. F is a set of firm characteristics: annual sales revenue, information on the union, and industry dummies. μ_t is a year fixed effect. The standard error is clustered in birth cohort and year in every specification.

Table 3.2 reports the regression results for equation (1). Columns 1-2 shows the results for the full samples, and columns 3-6 show the estimation results of subsamples separated by the firm size. The odd-numbered columns summarize the regression results without controls, and the even-numbered columns show the results with controls. Columns 3 and 5 are the results basically observed in Figures 3.2 and 3.3.

In column 1, the magnitude of the variable MRA-1 represents 37.4% of the samples retired a year before the policy was implemented. The coefficient of the interaction term with the treatment cohorts (MRA-1 X Treat), however, shows -0.285, which indicates the retirement rate of treated cohorts did not sharply decrease. The trend continues to the year the MRA was implemented; the overall retirement rate is 40.9%, but the treated cohorts are 27 percentage points less likely to retire compared to the control cohorts. We additionally controlled sales revenue, the existence of union (dummy), and industry (categorical variable) in column 2. The trend of discontinuity continues, and the retirement rate of the treated cohorts decreases by 25.1 percentage points. If we analyze the results like the increase in employment, the impact of the MRA policy is 0.5% (2%×25.1%). Similar trends are observed in columns 3-6, where samples are estimated by the firm size. Between the two, firms with more than 300 employees show a higher retirement rate than the control cohorts, and the gap between the treated and controlled is also more significant than firms with less than 300 employees. The difference might indicate that bigger firms were more likely to comply with regulations for retirement.

As Figure 3.1 has shown, the retirement age tends to increase during the grace period (2013-2015). 28.8% of the firms extended the retirement age to 60 during the period. As a result, 48.3% of firms had experienced extended retirement for the period 2013-2017. Assuming that the rise of retirement age during the grace period is also the impact of the MRA, the overall employment effect of the MRA would be 0.24% (0.5% × 48.3%).

Table 3.2. The Effect of the MRA on Older Workers

	(1)	(2)	(3)	(4)	(5)	(6)
	All		Size of Firms			
			>300		<300	
MRA-1 X Treat	-0.285***	-0.297***	-0.315**	-0.324***	-0.223***	-0.219***
	(0.102)	(0.083)	(0.144)	(0.111)	(0.063)	(0.040)
MRA X Treat	-0.268***	-0.251***	-0.292**	-0.278**	-0.217***	-0.178***
	(0.094)	(0.082)	(0.137)	(0.115)	(0.061)	(0.046)
Treat	-0.022	-0.022	-0.028	0.012	-0.009	-0.042*
	(0.060)	(0.041)	(0.089)	(0.045)	(0.042)	(0.022)
MRA-1	0.374***	0.332***	0.418***	0.347***	0.281***	0.309***
	(0.060)	(0.078)	(0.080)	(0.095)	(0.030)	(0.040)
MRA	0.409***	0.332***	0.449***	0.281**	0.324***	0.346***
	(0.058)	(0.096)	(0.080)	(0.105)	(0.039)	(0.034)
Other controls	N	Y	N	Y	N	Y
Constant	0.177***	0.283**	0.168**	-0.203	0.197***	0.707***
	(0.043)	(0.122)	(0.063)	(0.164)	(0.024)	(0.120)
Observations	14,052	14,052	9,615	9,615	4,437	4,437
R-squared	0.127	0.245	0.154	0.348	0.076	0.126

Notes: WPS 2013-2017 and KEI 2013-2017 records are used. The dependent variable is a dummy equal to one if a worker retires. Other controls include age, gender dummy, sales revenue (annual), the existence of union (dummy), industry (categorical). Industries are classified as follows: (1) Manufacturing, (2) Electricity, gas, steam, and water supply, (3) Sewerage, waste management, materials recovery, (4) Construction, (5) Wholesale and retail trade, (6) Transportation, (7) Accommodation and food service activities, (8) Information and communication, (9) Financial and insurance activities, (10) Real estate activities, (11) Professional, scientific and technical activities, (12) Business facilities management and business support services, (13) Human health and social work activities, (14) Arts, sports, and recreation-related services, (15) Membership organizations, repair, and other personal services. Standard errors are clustered in year and birth cohort. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

3.6. Labor Substitutability Between Old and Young Workers

3.6.1. Empirical Strategy

In the second step, we aim to investigate the possibility of labor substitutability between old workers being subjected to the MRA and young workers at the firm level. Using the advantage of the panel data set, which has repeatedly surveyed firms, we employed the first-difference estimator, which corresponds to estimating the following model:

$$Y_{jt} = T'_{jt}\beta_1 \; + \mathrm{O}'_{jt}\beta_2 \; + F'_{j}\beta_3 \; + \lambda_j + \mu_t + \varepsilon_{jt}. \qquad (2)$$

Y_{jt} is the outcome of our interest: the employment level of workers in firm j at t. We defined employment as the number of employees in j at the end of the year t. Time t covers three years: 2015-2017. Also, the outcomes are targeted at old (aged 55-60), mid-aged (aged 30 to 54), and young (aged under 30) workers, respectively. T_{jt} is the number of employees being subject to the MRA. Thus, β_1

is expected to capture the impact of T_{jt} on the outcome Y_{jt}. O_{jt} is expected number of employees who were supposed to delay their retirement within 3 years. Controlling O_{jt} allows us to consider relatively long-term effect of the MRA. F is a set of time-varying covariates: annual sales revenue is controlled. λ_j is a firm fixed effect for the time-invariant.

Table 3.3 reports descriptive statistics of variables used in the study. For estimating equation (2), 2,340 firms with 956,414 employees are used. The first column shows sample means of variables in the baseline year, 2015, and the second column reports those in the year when the MRA was implemented: 2016 for 530 firms with over 300 or 2017 for 1,810 firms with less than 300 employees. In 2015, 408 employees worked for a firm on average, with old, mid-aged, and young workers accounting for 7.7%, 72.5%, and 19.8% of the samples, respectively. The overall employment slightly decreased when the MRA was implemented, but stark differences are observed when we divide the employment by generation. The only number of older workers increased, but the other generations experienced a decrease in employment. The number of older workers increased by 13.8 percentage points, but mid-aged and young workers decreased by 1 and 4 percentage points, respectively. The changes in employment of mid-aged and young female workers are relatively small, which indicates that male workers experience a higher decrease in their employment.

To check where the changes in employment came from, we observed the changes in the population size of employees who worked more or less than two years: people who worked less than two years were more likely to be temporary workers. The statistics show that the increase in the number of old workers mainly depends on the number of workers working more than two years, which suggest the impact of the MRA focus on permanent (or non-fixed term) workers.

The sample means of T_{jt} reveal that a firm experiences 1.2 additional employment on average due to the MRA implementation. The magnitude T_{jt} of depends on firm size: the average value is 3.82 for firms with more than 300 employees and 0.42 for firms with less than 300 employees. Meanwhile, the predicted number of older workers supposed to delay retirement within 3 years (O_{jt}) slightly increases during the period 2015-2017.

Table 3.3. Descriptive Statistics: Firm Level

Variable	Baseline Year (2015)	Year the MRA Implemented (2017)
Sample means for equation (2) (Firm Level, Obs.: 2,340)		
Number of employees	408.724	407.234
Employment		
Number of old workers employed (55-60)	31.378	40.060
Number of middle-aged workers employed (30-54)	296.181	291.804
Number of young workers employed (20-29)	81.165	75.371
Job Tenure > 2 years		
Number of old workers employed (55-60)	22.207	31.689
Number of middle-aged workers employed (30-54)	238.274	240.657
Number of young workers employed (20-29)	31.800	29.954
Female Workers		
Number of old female workers employed (55-60)	11.256	15.877
Number of middle-aged female workers employed (30-54)	109.494	107.319
Number of young female workers employed (20-29)	35.866	33.284
Explanatory variable		
Changes in older workers' employment by the MRA(T)	0.000	1.197
Predicted older workers subjected to the MRA within 3 years (O)	3.614	3.934
Firm Information		
Annual Revenue ($ 1M)	251.149	320.845
Adopts a wage-peak system (=1)	0.127	0.190
Unionized firm (=1)	0.273	0.273

Notes: WPS 2015 and KEI records 2013-2017 are used. Samples for estimating equation (2) are restricted to firms with more than ten employees. The number of firms with more than 300 employees is 530, that with less than 300 employees is 1,810.

3.6.2. Baseline Results

We estimate the impact of the MRA on the employment of age groups, respectively. Table 3.4 reports the estimation results of equation (2) using the firm-level data. Columns 1-3 in Table 3.4 show the estimation results using the full sample, and columns 4-6 show the results using the firms where the original retirement age (in 2015) was below 60.

Estimation results in Table 3.4 suggest that the impact of the MRA varies across generations. In column 1, the increase in the employment of older workers, T_{jt} raises the actual employment of themselves: one employee being subject to the MRA increases the employment of older workers by 0.84 people. However, it also appears to have a negative effect on mid-age employment: one worker being subject to the extension of his/her retirement timing reduces mid-age workers' employment by 0.45 (in column 2). The estimated coefficient of T_{jt} in column 3 is negative but insignificantly different from zero, which shows that the impact of the

MRA did not reach to young workers.

Table 3.4. The Effect of the MRA on Employment

Generation	(1) Old (55-60)	(2) Mid (35-54)	(3) Young (20-29)	(4) Old (55-60)	(5) Mid (35-54)	(6) Young (20-29)
		Full Sample			**Firms the ORA was below 60**	
Emp. by MRA	0.8412***	-0.4524**	0.0319	0.9207***	-0.4963***	-0.0205
	(0.0770)	(0.2268)	(0.1191)	(0.0251)	(0.0813)	(0.0721)
Emp. by MRA within 3 yrs.	0.7923***	-0.1787	-0.0935	0.8342***	-0.2221	-0.1227
	(0.1338)	(0.3942)	(0.2070)	(0.0427)	(0.1381)	(0.1225)
Log Sales	7.7728***	13.9535***	-2.4887**	-0.1907	2.0521	0.9737
	(0.7172)	(2.1136)	(1.1101)	(0.4334)	(1.4014)	(1.2435)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	7,020	7,020	7,020	1,356	1,356	1,356
R-Squared	0.0807	0.0110	0.0059	0.6934	0.0499	0.0027
Number of Firms	2,340	2,340	2,340	452	452	452

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. The dependent variable is a change in the number of employees. Columns 1-3 report estimation results of the individual fixed-effect model for all firms. Columns 4-6 report estimation results for individual fixed effects models for firms where the original retirement age was below 60. *** p<0.01, ** p<0.05, * p<0.1

Table 3.4 also suggests that the increase in the expected number of workers supposed to postpone retirement in the short run at least does not have at least a positive impact on the employment of younger generations. O_{jt} affect the employment in the same direction: the employment of older workers increases, but those for the other generation decrease due to the change in O_{jt}. However, the impact of O_{jt} on younger generation is not statistically significant. Meanwhile, Sales revenue significantly affects employment. The estimated coefficient for the sales revenue suggests that a doubling of sales revenue increases employment of old and mid-aged workers by 7.7 and 13.9, respectively. The sales revenue in our model may represent the scale of each firm because the model does not control the number of employees.

Estimation results from columns 4-6 are similar to those of the fixed effects estimations in columns 1-3. The magnitude of the coefficient is larger by 0.04 to 0.08 in the estimation for firms where the original retirement age is below 60, which suggests that the impact of the MRA on employment is mainly concentrated on those firms. Overall, total employment increases due to the MRA, but the results consistently show that the policy negatively affects the employment of younger generations.

3.6.3. Heterogeneity: Job Tenure and Gender

There are two ways to reduce the size of incumbent workers: to lay off employees or to terminate a contract with temporary workers. Although our dataset does not provide information on the job status of each employee, we can conjecture most temporary workers are employed for less than two years. According to the Act on the protection, etc. of fixed-term and part-time employees, employers in Korea can hire temporary workers if the fixed-term in the contract is less than two years[20]. If a temporary worker is hired for more than two years, he or she is subjected to non-fixed term (permanent) employment.

Table 3.5. The Effect of MRA by Job Tenure

	(1)	(2)	(3)	(4)	(5)	(6)
Employment Period		>= 2 years			< 2 years	
Generation	Old (55-60)	Mid (35-54)	Young (20-29)	Old (55-60)	Mid (35-54)	Young (20-29)
			Employment			
Emp. by MRA	0.8394***	-0.5547***	0.0887	0.0018	0.1023	-0.0568
	(0.0805)	(0.1817)	(0.0716)	(0.0218)	(0.1202)	(0.0884)
Emp. by MRA within 3 yrs	0.6070***	-0.2003	-0.0884	0.1853***	0.0216	-0.0051
	(0.1399)	(0.3157)	(0.1243)	(0.0380)	(0.2089)	(0.1537)
Log Sales	7.1879***	17.0039***	-1.8298***	0.5849***	-3.0504***	-0.6589
	(0.7500)	(1.6928)	(0.6667)	(0.2036)	(1.1201)	(0.8240)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	7,020	7,020	7,020	7,020	7,020	7,020
R-Squared	0.0723	0.0239	0.0034	0.0096	0.0084	0.0043
Number of Firms	2,340	2,340	2,340	2,340	2,340	2,340

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. In columns 1-3, The dependent variable is a change in the number of employees who worked for more than two years. In columns 4-6, The dependent variable is a change in the number of employees who worked less than two years. *** p<0.01, ** p<0.05, * p<0.1

We split the workers into two groups depending on their working years and examined how the MRA affects each of them. Table 3.5 reports the estimation results. As expected, the positive impact of the MRA concentrated on older workers working for more than two years (column 1). Comparing columns 2 and 5, mid-aged workers working more than two years account for the negative impact of MRA on themselves. The impact of O_{jt} on both mid-aged and non-fixed term workers is also negative but insignificant. The employment of young workers is not affected by the MRA regardless of their working years.

Considering the theoretical framework that the labor substitution occurs

[20] There are several exceptions. Some cases in point are as follows: 1) where the period required to complete a particular task or project; 2) where a temporary worker is needed to fill a vacancy arising from an employee's temporary suspension from duty or dispatch; 3) where an employer enters into an employment contract with a senior citizen.

between groups performing a similar task, the results suggest that the task of old and non-fixed term workers is similar to that of mid-aged and non-fixed term workers. In addition, the estimation results suggest that the negative impact on the younger generation's employment may represent the labor-saving purpose of firms. Since non-fixed term employees can work until they reach the retirement age, their retirement behavior might be voluntary (i.e., transferring to another firm). If the firm tries to fill the vacancy through recruitment, the MRA effect on workers working less than two years will be positive. However, estimation results from columns 5 and 6 do not show any statistical significance of the MRA effect.

Table 3.6. Estimation Results by Gender

	(1)	(2)	(3)	(4)	(5)	(6)
		Male			Female	
Generation	Old (55-60)	Mid (35-54)	Young (20-29)	Old (55-60)	Mid (35-54)	Young (20-29)
			Employment			
Emp. by MRA	0.5860***	-0.5700***	-0.0265	0.2552***	0.1176	0.0583
	(0.0392)	(0.1587)	(0.0674)	(0.0656)	(0.1013)	(0.0664)
Emp. by MRA within 3 yrs	0.6816***	0.0652	0.1211	0.1107	-0.2439	-0.2146*
	(0.0681)	(0.2758)	(0.1171)	(0.1140)	(0.1760)	(0.1154)
Log Sales	0.1281	13.3741***	-1.3199**	7.6448***	0.5795	-1.1688*
	(0.3650)	(1.4787)	(0.6279)	(0.6114)	(0.9438)	(0.6187)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	7,020	7,020	7,020	7,020	7,020	7,020
R-Squared	0.0911	0.0203	0.0058	0.0451	0.0017	0.0047
Number of Firms	2,340	2,340	2,340	2,340	2,340	2,340

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. In columns 1-3, The dependent variable is a change in the number of male employees. In columns 4-6, The dependent variable is a change in the number of female employees. *** p<0.01, ** p<0.05, * p<0.1

Since the gender difference for the proportion of temporary jobs generally appears, it is beneficial to examine which gender is highly influenced by the MRA. We next examined how the impact of delayed retirement on employment varies by gender. Table 3.6 provides the results of estimation analyses separately for male and female workers. The results remarkably reveal gender differences. In column 1, the impact of the MRA on old workers concentrates on male workers. T_{jt} significantly affects both the employment of male and female workers, but the magnitude for males is more than twice as large as females. Also, O_{jt} significantly affects only old and male workers.

Much of the gender difference can be explained by labor substitutability. The negative impact of the MRA on younger generations is concentrated on male workers. Result in column 2 suggest that one worker being subject to the extension of his retirement timing reduces mid-age and male workers' employment by 0.57.

3.6.4. Heterogeneity: Labor Cost and Wage-peak System

The previous analyses suggest that the increase in labor costs may be the major burden for firms if the MRA is implemented. After the announcement of the MRA policy, the Korean government promoted an agreement for a wage-peak system which has become the most preferred countermeasure. If the system is determined through an agreement between the management and the labor, employees can postpone their retirement timing at the cost of lowered wages. According to the WPS 2015 survey, 50% of firms responded they considered a wage-peak system before the MRA implementation. 76% of firms implementing the wage-peak system started the system after 2013.

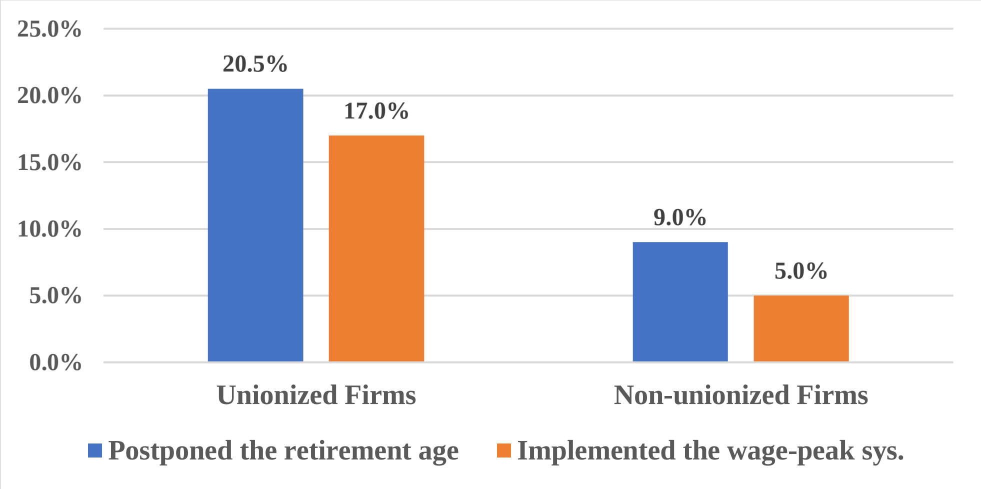
Since the wage-peak system alleviates the labor cost, it can also decrease labor substitutability between generations. We conduct baseline regressions for firms adopting the system and the others separately. Estimation results are reported in Table 3.7. As expected, the labor substitution is statistically significant only for firms that do not adopt the system. Columns 5-6 show that an increase in employees being subjected to the MRA significantly decreases both mid-aged and young workers. The sum of two estimated coefficients of T_{jt} is bigger than that for old workers, suggesting that total employment of firms adopting wage-peak system decreases. For firms implementing the system, conversely, we do not find evidence of labor substitution.

It is worth noting that the results do not suggest wage-peak system can be an efficient policy since the decision-making regarding the system is also an endogenous process. Instead, we examined which characteristics of firms are correlated with the wage-peaks system and also be more exogenous. We found that firms adopting the system tend to show a low proportion of older workers and have at least one labor union. It is predictable that an increase in the number of older workers nearing retirement age would be a bigger financial burden to firms when implementing the MRA. The labor union may claim the preemptive postponement of retirement age, and the management could suggest they accept a wage-peak system as a countermeasure. Figure 3.4 shows supports this claim as the evidence. In the case of unionized firms, the proportion of firms that preemptively postpone the retirement age during the grace period 2014-2015 was 20.5%, which is more than twice as high as that of non-unionized firms (9%). In addition, during the same period, 17% of them implemented the wage-peak system, but only 5% of the non-unionized did.

Adding one of two conditions to the subsample already divided by the wage-peak system, we can derive the new 2×2 samples. We tried to conduct analyses using the four kinds of samples to examine whether the wage-peak system alleviates the labor substitution among generations. First, Table 3.8 reports the estimation results using the samples categorized by wage peak-system (Panel A and B) and the proportion of older workers (Top 50% for the columns 1-3 and bottom 50% for the columns 4-6). Comparing the first three columns with the others, we found that firms with a higher proportion of the elderly show higher labor substitutability between generations. Both Panel A and B report the same tendency, indicating that the demographics within the firm are important to affect the heterogeneity of the MRA effect. Both Panel A and B report the same tendency, indicating that the demographics within the firm are important to affect the heterogeneity of the MRA effect, apart from the wage-peak system.

Second, we found the same tendency for the labor union. Table 3.9 presents the estimation results using the samples categorized by wage peak-system (Panel A and B) and the existence of at least one labor union (unionized firms for columns 1-3 and the non-unionized for the columns 4-6). Non-unionized firms are more likely to show higher labor substitutability. Overall, both the characteristics and systems influence the magnitude of the MRA effect. Panel A shows that unionized firms show no labor substitution from the MRA, but non-unionized firms do. For Panel B, both two groups show the labor substitution between the old and the mid-aged workers, the magnitude of substitution is bigger for the non-unionized firms. Overall, through the analyses of 2×2 samples, we found both the characteristics and systems of each firm influence the magnitude of the MRA effect.

Figure 3.4. Labor Union, Preempted Retirement Policy Revision, and Wage-peak System



Source: The WPS 2013-2015

Table 3.7. Heterogeneity: Wage-peak System and the MRA Effect

	(1)	(2)	(3)	(4)	(5)	(6)
	Wage-peak System Implemented			Not Implemented		
Generation	Old (55-60)	Mid (35-54)	Young (20-29)	Old (55-60)	Mid (35-54)	Young (20-29)
			Employment			
Emp. by MRA	0.8179***	-0.3135	0.3548	0.7487***	-0.9285***	-0.2714*
	(0.1039)	(0.5935)	(0.2247)	(0.1202)	(0.1644)	(0.1591)
Emp. by MRA within 3 yrs	0.4413**	-0.8646	0.2535	1.1862***	0.2255	-0.2950
	(0.1977)	(1.1291)	(0.4274)	(0.1915)	(0.2619)	(0.2534)
Log Sales	5.1267***	41.8089***	5.7395**	9.5183***	-3.5249***	-7.7055***
	(1.1366)	(6.4907)	(2.4568)	(0.9245)	(1.2647)	(1.2234)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	1,584	1,584	1,584	5,436	5,436	5,436
R-Squared	0.1315	0.0382	0.0162	0.0713	0.0174	0.0160
Number of Firms	528	528	528	1,812	1,812	1,812

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. The dependent variable is a change in the number of employees. *** p<0.01, ** p<0.05, * p<0.1

Table 3.8. The Proportion of Older Workers, Wage-peak System, and the MRA Effect

Generation	(1) Old (55-60)	(2) Mid (30-54)	(3) Young (20-29)	(4) Old (55-60)	(5) Mid (30-54)	(6) Young (20-29)
	Panel A. Firms Wage-peak system Implemented					
Proportion of old workers	1) Top 50%			2) Bottom 50%		
Emp. by MRA	0.8022***	-0.5533**	-0.0257	0.6156	4.2530	2.4238
	(0.1356)	(0.2465)	(0.1863)	(0.4678)	(5.1547)	(1.7739)
Emp. by MRA within 3 yrs	0.3466	-1.4298***	0.0659	0.4226	-0.3405	-0.2122
	(0.2413)	(0.4387)	(0.3316)	(0.4644)	(5.1178)	(1.7612)
Observations	417	417	417	768	768	768
R-squared	0.2211	0.0711	0.0184	0.1141	0.0900	0.0495
Number of Firms	165	165	165	298	298	298
	Panel B. Not Implemented					
Proportion of old workers	3) Top 50%			4) Bottom 50%		
Emp. by MRA	0.7083***	-0.7029***	-0.2592***	1.1668***	-1.2901***	-0.2375
	(0.0790)	(0.1154)	(0.0326)	(0.3480)	(0.4710)	(0.5077)
Emp. by MRA within 3 yrs	1.1139***	-1.3634***	-0.2199**	0.9992***	0.5220	-0.4030
	(0.2416)	(0.3529)	(0.0997)	(0.3349)	(0.4533)	(0.4886)
Observations	3,105	3,105	3,105	2,730	2,730	2,730
R-squared	0.0577	0.0687	0.0463	0.1229	0.0188	0.0397
Number of Firms	1,078	1,078	1,078	984	984	984

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. The dependent variable is a change in the number of employees.
*** p<0.01, ** p<0.05, * p<0.1

Table 3.9. Labor Union, Wage-peak System, and the MRA Effect

Generation	(1) Old (55-60)	(2) Mid (30-54)	(3) Young (20-29)	(4) Old (55-60)	(5) Mid (30-54)	(6) Young (20-29)
	Panel A. Firms Wage-peak system Implemented					
Labor Union	1) Unionized Firms			2) Non-unionized Firms		
Emp. by MRA	0.7636***	-0.1256	0.1746	1.8211***	-1.8563*	0.7178
	(0.1431)	(1.2323)	(0.3970)	(0.3135)	(1.0372)	(1.0317)
Emp. by MRA within 3 yrs	0.4703*	-1.3936	0.0228	-0.4953*	-1.5633	-0.4229
	(0.2580)	(2.2225)	(0.7161)	(0.2945)	(0.9742)	(0.9690)
Observations	569	569	569	616	616	616
R-squared	0.1935	0.0920	0.0422	0.1704	0.0364	0.0183
Number of Firms	213	213	213	250	250	250
	Panel B. Not Implemented					
Labor Union	3) Unionized Firms			4) Non-unionized Firms		
Emp. by MRA	0.7707***	-0.5391**	-0.0329	0.4707**	-0.9009***	-0.4955
	(0.1812)	(0.2544)	(0.1939)	(0.2071)	(0.2789)	(0.3054)
Emp. by MRA within 3 yrs	0.6060	-0.7629	-0.4289	1.3456***	0.5707**	-0.1112
	(0.4411)	(0.6194)	(0.4720)	(0.2022)	(0.2722)	(0.2981)
Observations	1,348	1,348	1,348	4,487	4,487	4,487
R-squared	0.1837	0.0656	0.0966	0.0416	0.0048	0.0073
Number of Firms	484	484	484	1,578	1,578	1,578

Notes: WPS 2015-2017 and KEI records 2015-2017 are used. The dependent variable is a change in the number of employees.
*** p<0.01, ** p<0.05, * p<0.1

3.7. Conclusion

The aging countries have been trying to reform their retirement policies to cope with pressure on pension funds and reduced gross productivity in the perspective of the older workers. But the policy often lacks consideration of its impact on employment opportunities on younger generations.

Using the Korean data, we examined 1) if the newly implemented minimum retirement age increased the employment of aged workers and 2) whether it has an impact on that of younger workers. In the theoretical framework, we showed that the substitutability of old and young workers' employment depends on the labor productivity and cross-elasticity of the two groups. A set of data connecting establishment-level panel data with individual-level employment records is used. We found that birth cohorts affected by the MRA are less likely to retire than other cohorts for whom the discontinuity of retirement age is observed. In addition, if the policy delays older workers' retirement, the employment of mid-aged workers decreases. Also, the policy helps older people currently working maintain their employment but has a negative effect on non-fixed term and male workers. The magnitude of the impact is heterogeneous by demographics, the existence of labor union, and the countermeasure of firms.

It is worth noting that our findings do not support the 'lump of labor' hypothesis since the study is conducted from a micro-level perspective. However, our findings suggest policymakers are required to take a cautious approach in reforming the retirement system. The minimum retirement age policy may secure the current elderly labor. However, our estimation results consistently show that encouraging old employment requires the loss of youth employment in the short run. This will be indebted to the future generation who would lose their opportunities to build a career and increase productivity. To ease the employment shock on young workers, the government should have additional measures such as job support schemes promoting youth employment following a retirement policy reform.

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Abstract in Korean

한국의 고령자 노동 연구

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본 학위논문은 한국의 고령자 노동에 영향을 미치는 세 가지 요인들에 대한 연구를 담고 있다. 구체적으로 1) 주택자산 시장, 2) 기술 변화, 3) 정년 제도가 고령자의 노동공급 및 은퇴에 미치는 영향을 살펴보았다.

한국 가계의 자산 구성이 부동산 자산에 집중되어 있는 현 상황에서, 주택 가격의 변화는 곧 가구 자산의 변화를 의미하며, 특히 고령 가구의 경우 노후자산 및 가용소득에 지대한 영향을 미치게 된다. 1장은 고령화패널자료 2006-2016 자료와 인구주택총조사(Census) 자료를 이용하여 주택가격의 변화로 인한 자산 효과(wealth effect)가 고령 근로자의 노동공급에 어떠한 영향을 미치는지, 그리고 고령자들이 은퇴 후 노후 생활에서 주택자산을 어떻게 활용하는지 연구하였다. 분석 결과, 주택 자산의 가치 상승은 고령 근로자의 노동공급을 줄이며, 이 효과는 고령자 내에서도 연령이 높은 층에게서 더욱 높아, 은퇴가 가까운 근로자에게서 더욱 큰 것으로 확인되었다. 한편 은퇴자들은 주택자산의 노후 활용에 있어 주택연금 등 금융상품을 통한 현금화 보다는 상대적으로 저렴한 주택으로 이동한 뒤 발생한 차액으로 생활비를 마련하는 경향을 보였다. 이는 한국 고령자들의 주택 소유에 대한 선호, 그리고 향후 주택 가격 상승에 대한 기대심리 등이 반영되었을 것으로 추측된다.

최근 자동화 시스템, 로봇, IT, AI 기술 등 다양한 기술이 산업현장에 도입됨에 따라 이들이 고용에 미칠 충격이 매우 클 것으로 예상된다. 기술과 고용 간의 관계에 관해서는 많은 선행연구가 진행됐으나 기술이 고령자 노동, 특별히 한국 고령자 고용에 미칠 영향에 대한 연구는

비교적 심도 있게 다루어지지 못했다. 2장(이철희 공저)은 사업체패널조사 (Workplace Panel Survey)와 연계된 고용보험 자료를 이용하여, 기업의 새로운 기술도입 (자동화 기술 도입, IT 투자확대)이 고용에 어떠한 영향을 미치는지, 특별히 기술로 인한 고령근로자의 퇴직위험이 젊은 근로자들과 비교해 어떠한 차이가 있는지 확인하였다. 분석 결과, 기업의 기술 도입은 소속 근로자의 퇴직위험을 낮추지만, 고령근로자의 위험 감소폭은 젊은 근로자에 비해 낮아 기술도입이 고령자 고용에 상대적으로 비우호적으로 작용하는 것으로 나타났다. 한편 특정 조건 하에서는 기술도입이 고령근로자의 퇴직위험을 절대적으로 낮추는데, 제조업 기업의 자동화 기술 도입은 남성 고령근로자의 퇴직위험을 크게 높이며, 서비스 기업의 IT 기술 도입은 근로자들의 자발적인 퇴직위험을 높이는 것으로 확인되었다. 이러한 기술도입의 부정적 고용효과가 발생한 이유로는 첫째로 기업의 비용 절감 목적, 둘째로 기술 도입으로 인해 변동된 직무와 근로자의 직무 선호 간 부조화가 복합적으로 작용한 것으로 추측된다.

한국은 2013년 고령자고용법 개정에 따라 2016년부터 최소정년을 60세로 정하여 운영 중이다. 정년연장의 효과에 관해 다양한 연구가 진행되는 가운데, 정년연장이 실제로 고령자 고용에 어떠한 영향을 미치는지, 또한 그로 인해 전체 고용시장은 어떠한 변화를 겪게 될지에 대한 논의가 진행 중이다. 3장은 사업체패널조사 (Workplace Panel Survey)와 연계된 고용보험 자료를 이용하여, 정년연장 시행이 고령자 고용에 어떠한 영향을 미쳤는지, 또한 고령자 고용 증가가 중년 및 청년 세대의 고용에 미치는 영향을 집중적으로 살펴보았다. 분석은 크게 두 단계로 진행되었는데, 첫 단계에서는 정년연장이 시행된 직후 고령자 고용의 변화를 살펴보았다. 정년연장의 적용을 받는 출생 코호트와 직전 연도에 태어나 적용을 받지 못한 코호트를 비교분석한 결과 정년연장 적용 코호트의 퇴직율이 정년연장 시점에서 큰 폭으로 감소하는 것을 확인하였다. 다음단계로, 정년연장으로 인해 고용이 유지된 고령 인력이 다른 세대의 고용에 미치는 영향을 살펴보았다. 분석 결과 정년연장 시행

은 55세 이상 고령자 고용에 긍정적인 영향을 미쳤으나 이로 인해 30-54세 중년층 고용을 낮추는 것으로 확인되었다. 이러한 부정적 고용효과는 남성 및 2년 이상 종사한 근로자에게서 명확하게 나타났다. 정년연장에 대한 기업의 대표적인 대응책으로 임금피크제가 제시되는데, 임금피크제를 시행한 기업의 경우 정년연장으로 인한 세대간 노동대체가 발생하지 않았다. 반면 임금피크제를 시행하지 않은 기업의 경우 정년연장은 중년층을 비롯해 청년층 고용에도 부정적인 영향을 미치는 것으로 나타났다. 이외에도 기업 내 노동조합의 유무, 사내 고령근로자 비율에 따라 고령인력 증가가 다른 세대 고용에 미치는 영향은 큰 차이를 보여, 정년연장으로 인한 세대 간 노동 대체는 기업 특성과도 관련이 높은 것을 확인하였다.

주요어 : 고령자 노동, 주택 자산, 기술 변화, 정년연장, 노동 대체성
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