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A Monte Carlo Analysis on the Security and Health Benefits of Physical Exercise for Thai Baby Boomers

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Monte Carlo simulation is applied to measure exactly to what degree regular physical exercise helps Thai baby boomers to improve family security (the ability to support loved ones) and health (freedom from sickness), which are ranked highest in their generational value system. The analysis examines comprehensive retirement planning, which incorporates stochastic lifetime incomes, expenses, savings and investment returns together with mortality and morbidity data. Based on 5,000 simulated scenarios, the study finds that regular exercise improves health and family security significantly. Longevity increases by almost two years, while the probability of being non-communicable disease (NCD)-free goes up to more than 18%. Although on average Thai baby boomers are income-deficient and their bequests are negative, regular exercise can lessen negative bequests by more than 150,000 baht. Exercise offers much higher benefits if baby boomers start it early in their lives.

Keywords: *baby boomers, retirement planning, physical exercise*

Introduction

Baby boomers, as defined for the largest birth cohorts in the U.S., are those people born between the years 1946 and 1964. They are now in the middle age to older age groups as they turn 51 to 69 in 2015[2]. In Thailand, baby boomers rank family security (supporting loved ones) and health (freedom from sickness) highest in their generational value system (Murphy et al., 2010). Yet the lifestyle led by the average Thai baby boomer makes it very difficult for them to achieve these value goals.

Many older Thais see themselves as being burdensome to their children and have the impression that they should work to support themselves financially (Office of the National Economic and Social Development Board (NESDB), 2014). Hence for those baby boomers, supporting loved ones may as well mean being less of a burden to loved ones. According to the National Statistical Office (2012), 55.8% of Thai households were in debt in 2011, for an average of 241,760 baht (about $6,750). With large debt and no savings, it is safe to say that most Thais are not meeting the family security value goal.

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[2] In Thailand, some researchers define the "baby boom" using the same birth cohorts used in the U.S. while others use the years of the largest birth cohorts in Thailand, 1958-1972 (Holumyong & Punpuing, 2015; Murphy, Mujtaba, Manyak, Sungkhawan & Greenwood, 2010). See the discussion for an analysis of the 1958-1972 cohorts.

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As for the health of the Thai baby boom generation, the risk of illness, especially from non-communicable diseases (NCDs), rises with age, and the situation is worsening (Ministry of Public Health, 2013).

Baby boomers account for 22.7% of the Thai population, a massive proportion. Therefore, it is important to establish a means of assisting them to strive towards these value goals. Previous literature has not proposed any strategies to address health and security while measuring the baby boomers' combined success in an objective, quantitative way.

In this study, I analyze the benefits of regular physical exercise. It is universally accepted that physical exercise offers health benefits (Kravitz, 2007). At the same time, exercise yields wage increases due to greater productivity (Lechner, 2015), which may lead to family security by way of more income, lower debt and higher savings and bequests. I show by a Monte Carlo analysis exactly to what degree Thai baby boomers can lower their health risks and improve their family security if they change their lifestyles to exercise regularly.

This study has four primary contributions to the literature. First, the methodology is new. While previous research has examined retirement planning, this study is much more comprehensive than previous studies. It incorporates stochastic lifetime incomes, expenses, savings and investment returns together with mortality and morbidity data, and measures the extent to which health and financial risks are affected by physical exercise. Previous studies analyzed only some of these interesting factors. For example, from the security perspective, Budsaratrakul (2014) considered stochastic savings and investment returns, while Carreras, Ibern, Coderch, Sanchez and Inoriza (2013) considered stochastic healthcare costs with morbidity data. But they did not consider how or to what degree exercise affects those outcomes. From the opposite angle, Kosteas (2012) examined the effects of exercise on earnings, but the author did not analyze variation of the effects over the life path. From the health perspective, Kravitz (2007), for example, itemized health benefits from exercise but did not calculate health risk reductions or family security improvements.

Second, the study addresses the important question of whether promoting regular physical exercise can be an effective means of assisting Thai baby boomers to achieve their value goals. Third, the study supports the government's campaigns, for example the "smaller waist, less health risk" and physical-exercise-for-good-health campaigns, to promote exercise among Thai people. Kravitz (2007) warned that individuals viewed physical exercise as causing tiredness and immediate disutility. The fact that this study aims to measure how significantly regular exercise may contribute to daily life could motivate more Thai baby boomers to overcome the immediate disutility and incorporate physical exercise into their routines. Finally, assessing the financial health burden of baby boomers and the influence of preventive behaviors on reducing that burden can provide quantitative evidence for policy makers.

Methodology

Regular exercise requires at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity (U.S. Department of Health and Human Services, 2008). I analyze the benefits of regular physical exercise on health and family security with an understanding that exercise reduces NCD risks and raises work productivity so that baby boomers are more likely to live longer, healthier lives with higher net earnings, savings and bequests. In the analysis, each year baby boomers work and earn stochastic sums of money with respect to their ages and sexes. They also must spend at least enough of their earnings and savings to live at subsistence level. Healthy people may experience certain NCDs over the years, too. If they do develop diseases, this study assumes their work productivity will drop and they will earn less income. Moreover, they will likely incur inflated medical expenses. The steps repeat until death, which is a random event with respect to NCD-conditioned mortality rates. Upon death, family security, health and longevity are assessed.

I limit my interest to four NCDs—(1) diabetes, (2) heart disease, (3) stroke and (4) cancer—because the World Health Organization (2009) identifies physical inactivity as one of the leading causes of death due to these chronic diseases. The representative baby boomers are females and males who are categorized as 50-year-old accumulators, 55-year-old pre-retirees and 60-year-old retirees. The present time is year 2014.

Analysis of Family Security

Family security can be literal—being in the state of being free from danger or threat, or financial. Because it is difficult to quantify literal security, I consider only financial security.

Let $S^*_{t_0}$ be the starting savings level of the representative t_0-year-old baby boomer. The savings level $\tilde{S}_{t_0+1}$ in the following year when they turn t_0+1 must equal the starting level $S^*_{t_0}$ plus $\tilde{r}_{t_0+1}$-percent investment return plus income $\tilde{I}_{t_0+1}$ net of personal expenses $\widetilde{P}_{t_0+1}$ and medical expenses $\widetilde{M}_{t_0+1}$. That is,

$$\tilde{S}_{t_0+1} = S^*_{t_0} e^{\{\tilde{r}_{t_0+1}\}} + \tilde{I}_{t_0+1} - \widetilde{P}_{t_0+1} - \widetilde{M}_{t_0+1}, \quad (1.1)$$

so that

$$\tilde{S}_{t_0+j} = \tilde{S}_{t_0+j-1} e^{\{\tilde{r}_{t_0+j}\}} + \tilde{I}_{t_0+j} - \widetilde{P}_{t_0+j} - \widetilde{M}_{t_0+j}. \quad (1.2)$$

Eqs. (1.1) and (1.2) are adapted from the wealth constraint in a discrete-time intertemporal portfolio selection model (Ingersoll, 1987). Symbol " $\tilde{}$ " labels stochastic variables. I assume that the investment return $\tilde{r}_{t_0+j}$ is age-specific to reflect the fact that the baby boomer may adjust their investment strategies along their glide path[3] (Budsaratrakul, 2014). It is a normal variable with a μ_{t_0+j} mean and a σ_{t_0+j} standard deviation when $\tilde{S}_{t_0+j-1} \geq 0$. I assume a zero return if $\tilde{S}_{t_0+j-1} < 0$ (i.e., the baby boomer is in debt) because debt can be supported or given away by their children without costs.

In equation (2), because income $\tilde{I}_{t_0+j}$ is age-specific and rising with inflation for j years from its starting level $I^*_{t_0}$ in 2014, the income must be inflation-adjusted. In addition, it must be scaled to reflect the actual working days in the year. Finally, it must be adjusted downward or upward for falling or rising productivity from sickness or physical exercise (Mitchell & Bates, 2011).

[3] A formula that defines the asset allocation mix of a target-date, retirement fund.

$$\tilde{I}_{t_0+j} = I^*_{t_0} e^{\left\{\sum_{h=1}^{j} \tilde{\pi}^I_h\right\}} \times \left(1 - \sum_{d=1}^{4}\left(\frac{L^A_d}{252} + L^P_d\right)\tilde{\gamma}_{d,t_0+j}\right) \times \left(1 + \tilde{F}_{t_0+j}\right), \text{(2.1)}$$

where $\tilde{\pi}^I_h$ is the stochastic inflation rate for income in year h. It is assumed the income inflation is mean-reverting with respect to the Bank of Thailand's inflation targeting policy (Khanthavit, 2014).

$$\tilde{\pi}^I_h = \theta\left(\bar{\pi} - \pi^I_{h-1}\right) + \tilde{\varepsilon}^I_h. \text{(2.2)}$$

θ is the convergence rate, $\bar{\pi}$ is the long-run mean and $\tilde{\varepsilon}^I_h$ is the normally-distributed error of $\tilde{\pi}^I_h$.

NCDs can induce absenteeism and presenteeism losses. To account for these losses, let L^A_d be lost working days and L^P_d be the productivity loss from diseased. $\tilde{\gamma}_{d,t_0+j}$ is the disease-d indicator variable. $\tilde{\gamma}_{d,t_0+j}$ = 1 if the baby boomer experiences disease d at age $t_0 + j$. Otherwise, it is zero. Because NCDs are chronic, $\tilde{\gamma}_{d,t_0+j}$ = 1 if $\tilde{\gamma}_{d,t_0+j-1}$ = 1. But if $\tilde{\gamma}_{d,t_0+j-1}$ = 0, $\tilde{\gamma}_{d,t_0+j}$ is a (1, 0)-Bernoulli with probability of the disease-d incidence rate (Law & Kelton, 2000). The incidence rate corresponds with age, sex and physical exercise. The term $1 - \sum_{d=1}^{4}\left(\frac{L^A_d}{252} + L^P_d\right)\tilde{\gamma}_{d,t_0+j}$ scales the income proportionately with 252 working days in the year[4]. Finally, $\tilde{F}_{t_0+j}$ is the productivity adjustment variable. It equals the exercise-induced productivity increment rate if the baby boomer exercises regularly, i.e. at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity, and equals zero if they do not exercise. However, in any case, $\tilde{F}_{t_0+j}$ necessarily equals zero if $\tilde{\gamma}_{d,t_0+j}$ = 1.

As for personal expenses, an individual must spend at least enough to maintain subsistence level regardless of their income level. However, if a person earns more, they tend to spend more with their rising income. So, I assume that personal expenses $\tilde{P}_{t_0+j}$ depend on the subsistence level and income level as demonstrated in equation (3).

$$\tilde{P}_{t_0+j} = Max\left[P^*_{t_0} e^{\left\{\sum_{h=1}^{j} \tilde{\pi}^P_h\right\}}, 0.70\ \tilde{I}_{t_0+j}\right], \text{(3.1)}$$

$$\tilde{\pi}^P_h = \theta\left(\bar{\pi} - \pi^P_{h-1}\right) + \tilde{\varepsilon}^P_h. \text{(3.2)}$$

$P^*_{t_0}$ is the subsistence personal expenses for the t_0-year-old baby boomer in year 2014. It must rise with inflation, constituting a level of $P^*_{t_0} e^{\left\{\sum_{h=1}^{j} \tilde{\pi}^P_h\right\}}$ when they turn $t_0 + j$. If they earn more, they naturally spend more. Following Siritewankun (2013), I assume they spend 70% of their income. The actual spending is the maximum of the two amounts. $\tilde{\pi}^I_h$ and $\tilde{\pi}^P_h$ share the same θ and $\bar{\pi}$ parameters because they track the country's general inflation. But their errors $\tilde{\varepsilon}^I_h$ and $\tilde{\varepsilon}^P_h$ are uncorrelated because incomes and expenses of Thai households have been found to have a low correlation (Kinnan, 2014).

Medical expenses $\tilde{M}_{t_0+j}$ are the sums of disease-d expenses as represented in equation (4).

[4] The 252-working-days assumption is generally made in financial analyses.

$\widetilde{M}_{t_0+j} = \sum_{d=1}^{4} M_{d,t_0}^{*} e^{\{\sum_{h=1}^{j} \tilde{\pi}_h^d\}} \times \tilde{\gamma}_{d,t_0+j}$, (4)

where M_{d,t_0}^{*} is the medical expenses for disease d for the t_0-year-old baby boomer in year 2014.

M_{d,t_0}^{*} is adjusted randomly upward by the inflation $e^{\{\sum_{h=1}^{j} \tilde{\pi}_h^d\}}$ to reflect rising costs. $\tilde{\pi}_h^d = \mu_D + \sigma_D \tilde{z}_h^d$, where μ_D and σ_D are the expected general price increases and the standard deviation (De Nardi, French & Jones, 2009). $\tilde{z}_h^d$ is a standard normal variable. $\tilde{z}_h^d$'s for the diseases are independent from one another. The expense structure in equation (4) suggests that medical expenses share the same nature but do not necessarily rise or fall together systematically. The indicator variable $\tilde{\gamma}_{d,t_0+j}$ ensures that these medical expenses are incurred only by the person living with the chronic disease.

The term $\tilde{S}_{t_0+j} < 0$ can be interpreted as the baby boomer being in debt, or income deficient, when they are $t_0 + j$. Four questions—(i) how likely will they experience income deficiency in life, (ii) how many years ($\tilde{\tau}$) in their remaining life will they be income deficient, (iii) how much will they bequeath to their children and (iv) whether they will bequeath debt—should be particularly interesting to those who value family security highly.

To estimate the income-deficiency probability and duration, I define indicator variable $\tilde{\varphi}_{t_0+j} = \begin{cases} 1 & \text{if } \tilde{S}_{t_0+j} < 0 \\ 0 & \text{if } \tilde{S}_{t_0+j} \geq 0 \end{cases}$ so that deficiency duration $\tilde{\tau} = \sum_{t_0+j \leq 100} \tilde{\varphi}_{t_0+j}$. The condition $t_0 + j \leq 100$ is imposed with respect to the 100-year maximum age in the Office of Insurance Commission's 2008 mortality table. Next, I define indicator variable $\tilde{\alpha} = \begin{cases} 1 & \text{if } \tilde{\tau} > 0 \\ 0 & \text{if } \tilde{\tau} = 0 \end{cases}$. It follows that expected $\tilde{\alpha}$ is the income-deficiency probability.

A bequest is the savings $\tilde{S}_{\tilde{T}}$ at age $\tilde{T}$ at death. Let indicator variable $\tilde{\beta} = \begin{cases} 1 & \text{if } \tilde{S}_{\tilde{T}} < 0 \\ 0 & \text{if } \tilde{S}_{\tilde{T}} \geq 0 \end{cases}$. The probability of leaving a negative bequest then equals expected $\tilde{\beta}$. I define the age-at-death variable $\tilde{T}$ below.

Analysis of Health and Longevity

According to Murphy et al. (2012), good health ranks higher than family security among Thai baby boomers. At least two important questions arise related to health—(i) how likely will baby boomers be free of NCDs and (ii) how long will they live. To answer question (i), I consider joint NCD-incidence indicator variable $\tilde{D}$. $\tilde{D}$ = 1, if $\tilde{\gamma}_{d,t_0+j}$ =1 for all NCDs d=1,…,4 and all ages $t_0 + j \leq 100$. Otherwise, $\tilde{D}$ = 0. This variable is important. Its expected value is the probability of the baby boomer living with at least one NCD, so that 1.00 minus the expected value is the probability of being NCD-free. The answer to question (ii) is based on the fact that death is an absorbing state and a baby boomer may die at age $t_0 + j$ with probability of the age-, sex- and disease-specific mortality rate. Next, consider disease-specific death indicator variable $\tilde{x}_{t_0+j}^d$ for disease d. $\tilde{x}_{t_0+j}^d$ is a (1, 0) Bernoulli with probability of the disease-d specific mortality rate. And consider another (1, 0) Bernoulli $\tilde{x}_{t_0+j}$ with probability of the general, NCD-free mortality rate. If I set the variable $\tilde{X}_{t_0+j} = \tilde{x}_{t_0+j} \times \{1 - Max(\tilde{\gamma}_{1,t_0+j}, \ldots, \tilde{\gamma}_{4,t_0+j})\} + \sum_{d=1}^{4} \tilde{x}_{t_0+j}^d \tilde{\gamma}_{d,t_0+j}$, I can identify age $\tilde{T}$ at death by $Min\{t_0 + j \leq$

$100|\widetilde{X}_{t_0+j} > 0\}$. I assume Bernoulli distributions for $\tilde{x}^d_{t_0+j}$ and $\tilde{x}_{t_0+j}$ variables because they are discrete and can take on only 0 and 1 values (Law & Kelton, 2000).

The term $\widetilde{X}_{t_0+j} > 0$ means the person dies at age $t_0 + j$. Their health status can be NCD-free, which corresponds to the $\tilde{x}_{t_0+j} \times \{1 - Max(\tilde{\gamma}_{1,t_0+j}, .., \tilde{\gamma}_{4,t_0+j})\}$ term or living with one or more NCDs, which corresponds to the $\sum_{d=1}^{4} \tilde{x}^d_{t_0+j}\tilde{\gamma}_{d,t_0+j}$ term. These two statuses are mutually exclusive. It should be noted that when a baby boomer experiences more than one NCD, defining age $\widetilde{T}$ at death by $\widetilde{X}_{t_0+j}$ will be biased downward. The reason is that $\sum_{d=1}^{4} \tilde{x}^d_{t_0+j}\tilde{\gamma}_{d,t_0+j}$ implies a joint NCD mortality rate is the sum of disease-d specific rates. The resulting rate tends to be higher than the level it is supposed to be in reality. But the bias exists both for those who exercise regularly (exercise cases) and those who do not (general cases), so that it supports the performance of physical exercise only marginally.

Monte Carlo Simulations

A Monte Carlo simulation is a problem-solving technique that relies on repeated random sampling to obtain numerical results. It approximates the probability of random variables by running multiple trials. Statistics for the variables of interest can be estimated using the outcomes of the trials. For example, the expected value is estimated by taking the average.

I simulate health and financial variables based on the specifications described above for each representative baby boomer in 5,000 scenarios. The simulation is performed for those who do not exercise regularly (general cases) and those who exercise regularly at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity (exercise cases). The variables of interest for the health value are age $\widetilde{T}$ at death and NCD-free status $(1 - \widetilde{D})$, while those for the family-security value are debt level $\tilde{S}_{t_0+j} < 0$, income-deficiency status $\tilde{\alpha}$, income-deficiency duration $\tilde{\tau}$, bequest $\tilde{S}_{\widetilde{T}}$ and negative-bequest status $\tilde{\beta}$. Because the generated random numbers are kept fixed, the variables of interest in the general and exercise cases are matched. The improved performance resulting from physical exercise for health and security values can be tested by a paired-difference procedure. More details on the Monte Carlo simulations are in the Appendix.

Data

I collected the data used in the analysis from various sources.[5] Turning first to the age-and-sex specific data, annual income data for Thai baby boomers come from the National Statistical Office's labor force survey for quarter 1, 2013. I examined the data and realized that two points needed to be adjusted. First, annual incomes for 68-year-old female and male baby boomers were extremely high—931,358.64 and 1,115,739.72 baht, respectively—compared to the incomes of their slightly younger and older peers—121,509.12 and 41,348.82 baht for 67-year-olds and 86,352.13 and 79,685.65 baht for 69-year-olds. Meanwhile, the second highest incomes were 298,809.48 and 246,088.32 baht for 56-year-old female baby boomers and 57-year-old male baby boomers. These figures suggested that there are outliers.

[5] Details on data sources and data tables are available upon request to the author.

Secondly, the survey incomes for certain ages, for example people age 90, were lower than 12,000 baht. This is not possible because the government pays 1,000-baht, monthly senior allowances to those ages 90 years old and older. To adjust for the possible outliers, I substituted the annual income of 68 year olds by the average incomes of 67 and 69 year olds. For the understated incomes of those ages 60-69, 70-79, 80-89, and 90 years old and older, I adjusted their incomes to account for senior allowances, which meant 7,200, 8,400, 9,600, and 12,000 baht which were their lowest possible incomes from 2012 onward.

Five mortality rates were considered in the analysis. First were the general mortality rates from the most recent mortality table for the general population in 2008, complied by the Office of Insurance Commission. The four NCDs are leading causes of death among Thai baby boomers (Porapakkham et al., 2010). If the baby boomer has NCDs, their mortality risk rises and the general mortality rates cannot be applied. The remaining four mortality rates are NCD-specific. I computed the mortality rates for diabetes, heart disease and stroke directly from the 2013 case fatality data from the Bureau of Epidemiology, Ministry of Public Health. Because cancer fatality data are not available, I had to compute the cancer mortality rates indirectly based on the formula in Cho, Howlader, Mariotto and Cronin (2010), using the mortality rates for the general population from the Office of Insurance Commission together with the average cancer mortality rates from 2008 to 2012 reported by the Bureau of Epidemiology. Because NCDs raise mortality risks, the final NCD mortality rates are adjusted so that they at least equal the general mortality rates.

The analysis assumes that baby boomers are NCD-free at time t_0. Over the years, they risk developing NCDs at NCD-incidence rates. I computed the diabetes-, heart-disease- and stroke-incidence rates using the 2013 new patient data from the Bureau of Epidemiology, together with the 2011-2012 average population data from the National Statistical Office, while I adapted the cancer-incidence rates from Sriplung's (2010) report to the Thai Health Promotion Office.

Some baby boomers invest their savings for investment returns. Their investment strategies can be age-specific to reflect their risk tolerance, hence affecting the risk-return profiles of the investment portfolios. I computed the expected returns and standard deviations of investment portfolios based on the current glide path of the Government Pension Fund and the return statistics of the assets in the investment universe. I obtained the input data from Budsaratrakul's (2014) report sponsored by Thailand's Securities and Exchange Commission. I assumed the investment returns to be savings only when they were positive. When they were negative (i.e., the baby boomers are in debt), I assumed a zero return. In the 2014 National Statistical Office Survey, 35.7% of older Thais lived on remittances from their children. I am aware that debt with financial institutions can cost up to 20% per year, and that the costs are much higher if debt is from informal sources. The zero-cost assumption should have little effect on the analysis because it discounts the benefits of physical exercise.

Turning next to the disease-specific data, if the baby boomers have NCDs they likely have to pay for medical expenses. I adopted the amounts they pay each year from Thavorncharoensap et al. (2011). Since medical expenses increase every year, in the analysis I assumed the expenses rise randomly. I computed their common, expected annual growth rate and standard deviation from the 2002 to 2011 national account data from the Office of the National Economic and Social Development Board.

NCDs can lead to absenteeism and presenteeism, which in turn can affect the annual incomes of baby boomers. Absenteeism is a pattern of absence from work, often due to

NCDs. In this study, I set the absenteeism rate to reflect the average number of days lost for in- and out-patient hospital treatments as reported by Thavorncharoensap et al. (2011). Presenteeism is the act of attending work while sick—in this case while living with NCDs—which may result in decreased productivity. The loss rates are disease-specific because of the NCD-specific symptoms and how they may affect an individual's work. Using the Medistat MarketScan Health and Productivity Management database and survey-based estimates of presenteeism losses in a 2003 value, Goetzel et al. (2004) report the productivity loss rates of 11.4%, 6.8% and 8.5% for diabetes, heart disease and cancer, respectively, for the U.S. A presenteeism loss estimate of $9,004 for those experiencing strokes was reported by Carter, Goren, Naim and Martin (2012). This loss is based on 2010 figures. When I converted the stroke's presenteeism loss from the 2010 to 2003 value by the U.S. hourly earnings index from the OECD.Stat database and interpolated it to a percentage loss vis-à-vis the diabetes, heart disease and cancer losses, I found that a stroke's productivity loss is 16.4%.

Despite the fact that the estimates reported above are American ones, I applied them to this study for three reasons. First, presenteeism loss rates are not available for Thailand and, in order to proceed, the analysis needs the estimates. Next, the rates are NCD-specific so that income losses from NCD-related productivity impairment are more precise than studies that do not specify. For example, Mitchell and Bates (2011) estimate productivity loss associated with health conditions or lifestyle health risks in the U.S. from a survey of OptumHealth HRA participants. The diseases and conditions include diabetes, heart disease and cancer as well as other diseases, but not stroke. Presenteeism losses are reported in terms of unproductive days by number of joint diseases and conditions. It is not clear how these losses are related to the four NCDs. Finally, I applied the American estimates because it is assumed that the NCDs induce productivity and income losses. A person should, therefore, incur the same rates of productivity and income losses from the same NCD regardless of the country in which they work.

In considering the benefits of exercise, one channel through which exercise can improve the health and family security of baby boomers is its ability to reduce the risk of NCDs. In order to analyze the impacts, the simulations need estimates of NCD-risk reduction.

In their review, Sigal et al. (2006) conclude that physical activity and regular exercise can reduce the risk of type-II diabetes. Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure, while exercise is a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness (Caspersen, Powell & Christenson, 1985). In most studies on diabetes risk and prevention, because physical activity and exercise are not assessed separately, it is not clear how much risk is reduced by physical activity and exercise alone. In this study, I assume the diabetes risk-reduction rate of 46% reported by Pan et al. (1997) for two reasons. First, the Pan et al. study considered only exercise which is the focus of this study. Second, the participants in the study are Chinese whose lifestyles should be similar to people in Thailand.

For heart-disease risk, I adopted the percent-reduction estimate from Williams (2001), who conducted a meta-analysis of 19 studies from the U.S. and Europe. He found that the relative risk associated with the median level of physical activities is 54%, so that the resulting risk reduction is 46%. For stroke risk, I adopted the percent-reduction estimate by Lee, Folsom and Blair (2003). The authors' meta-analysis of 31 publications from the U.S., Europe and Japan discovered a 27% risk reduction for high-active individuals over low-active ones. Although these risk-reduction rates are not based on Thai samples, they are from metaanalyses of sample sets in various countries and should be general enough to be applied to Thai baby boomers.

Cancer refers not to one disease but to many distinct site- and therefore sex-specific diseases. In this study, I set the risk reduction rates to 22.48% for men and 16.67% for women. These rates are from a study by Steenland, Nowlin and Palu (1995). Although the study was based in the U.S., it is one of few studies that considered overall cancer risk based on incidence samples. Moreover, the Steenland et al. study considered more extensive cancer sites than do other similar studies such as Albanes, Blair and Taylor (1989).

In addition to NCD-risk reduction, exercise potentially benefits baby boomers' earnings because it enhances soft skills such as self-discipline, endurance, stress management and team work, as well as overall physical and mental health (Lechner, 2015). The Lechner survey of studies on earnings effects in European countries and Canada concludes that the effects of exercise range from 4% to 17%. Employing propensity score matching to the U.S. National Longitudinal Surveys of Youth 1979 dataset to estimate the effect of exercise on weekly earnings, Koesta (2012) finds that frequent exercise is associated with a 6.7% and 11.9% wage increase for men and women, respectively.

As for the relationship between exercise and earnings in Thailand, Saksiriruthai's (2013) regression analysis, which employs the Time Use Survey and Labor Force Survey 2009 datasets, finds that sports and exercise in leisure time contribute small and insignificant portions to hourly wages. Despite potential earnings effects found for high-income countries, I will set the percentage earnings gain to zero with respect to Saksiriruthai (2013).

Turning last to the financial estimates, in this analysis a baby boomer must spend at least enough money to live at a subsistence level, regardless of their annual income. I set the subsistence personal expenses to equal 110,439 baht. This level was computed from the average 2012 household expenses reported by the Office of the National Economic and Social Development Board divided by the 2012 average number of household members reported by the National Statistical Office. The expenses were converted to their 2014 value using headline inflation.[6] The average saving is -46,770 baht. This statistic is the 2013 average household debt over the 2012 average household members reported by the National Statistical Office. I used maximum likelihood estimation to estimate the convergence rate θ, the long-run mean $\bar{\pi}$ and the standard deviation of inflation errors from the annual headline-inflation data from 2001 to 2014. The inflation data are from the Bureau of Trade and Economic Indices, Ministry of Commerce. The resulting estimates are 76.5%, 2.6% and 1.3%, respectively.

Results

Table 1 reports the benefits of regular exercise on health and longevity. For 50-year-old (50Y) female accumulators in the general category, life expectancy is 74.0 years, while it is 75.8 years, or 1.8 years longer, for women in the exercise category. Life expectancy (general, exercise) for 55Y and 60Y women is (75.2, 76.7) and (76.9, 78.2) years. The differences are 1.5

[6] A measurement of total price inflation within the economy, including commodities such as food and energy prices.

and 1.3 years, respectively. Life expectancy increases for the older groups because it is based on the living people who have reached those ages.

The longevity results for male participants are similar, but it should be noted that men live shorter lives than women and they gain fewer years from exercise.

As mentioned earlier, Thai baby boomers value health. As illustrated in Table 1, the gains for being free of NCDs are 18%, bringing the probability of being NCD-free up to approximately 45% in the exercising groups. Exercise is effective. The health risk reduction is statistically significant.

Highlighting the potential benefits of exercise on family security, Table 2 reports the statistics for income deficiency (Panel 2.1) and bequests (Panel 2.2). As shown in Panel 2.1, in most cases, exercise lengthens the duration but lowers the probability of being in debt. The longer duration can be explained by the fact that exercise raises life expectancy. On average, baby boomers have an initial savings of -46,770 baht, and their annual income is relatively low. If they cannot pay off their debt before their retirement, the debt continues and accumulates over the course of their lives. The lower probability results from the reduced NCD risk and, hence, low medical expenses.

Table 1: Health and longevity

Statistics	Female						Male					
	50Y Accumulator		55Y Pre-Retiree		60Y Retiree		50Y Accumulator		55Y Pre-Retiree		60Y Retiree	
	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise
Average	74.0	75.8	75.2	76.7	76.9	78.2	71.3	72.6	73.1	74.3	74.8	75.7
95% CI	55.0	55.0	59.0	59.0	62.0	63.0	53.0	53.0	58.0	58.0	62.0	62.0
	93.0	95.0	93.0	95.0	94.0	95.0	91.0	93.0	91.0	93.0	92.0	93.0
PB(NCD free)	26.0%	44.3%	25.1%	43.1%	28.1%	45.8%	23.6%	41.4%	25.7%	43.2%	27.8%	45.3%
H_o: Longer life	1.8***		1.5***		1.3***		1.3***		1.2***		0.9***	
H_o: Higher *PB*(NCD free)	18.3%***		18.0%***		17.7%***		17.8%***		17.5%***		17.5%***	

Note: *** = Significant at a 99% confidence level. *PB*(NCD free) = Probability of not experiencing NCDs over the lifetime. H_o: Longer life = Difference of average life expectancies of exercise and general groups. H_o: Higher *PB*(NCD free) = Difference of *PB*(NCD free)'s of exercise and general groups.

Table 2: Family security

Panel 2.1: Income deficiency

Statistics	Female						Male					
	50Y Accumulator		55Y Pre-Retiree		60Y Retiree		50Y Accumulator		55Y Pre-Retiree		60Y Retiree	
	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise
Average	5.7	6.0	10.1	11.1	16.9	18.2	2.2	1.9	4.3	4.4	13.8	14.7
95% CI	0.0	0.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0	1.0	1.0
	21.0	21.0	27.0	28.0	34.0	35.0	15.0	14.0	18.0	19.0	31.0	32.0
PB(income deficiency)	65.6%	64.7%	86.3%	86.2%	100.0%	100.0%	35.6%	30.9%	59.7%	57.1%	98.7%	98.7%
Ho: Fewer years in deficiency	0.3***		1.0***		1.3***		-0.3***		0.1***		0.9***	
Ho: Lower *PB*(income deficiency)	-0.9%***		-0.1%		0.0%		-4.7%***		-2.6%***		0.0%	

Note: *** = Significant at a 99% confidence level. *PB*(income deficiency) = Probability of experiencing negative savings over the lifetime. Ho: Fewer years in deficiency = Difference of average numbers of years that exercise and general groups experience negative savings. Ho: Lower *PB*(income deficiency) = Difference of *PB*(income deficiency)'s of exercise and general groups.

Panel 2.2: Bequests

Bequests	Female						Male					
	50Y Accumulator		55Y Pre-Retiree		60Y Retiree		50Y Accumulator		55Y Pre-Retiree		60Y Retiree	
	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise	General	Exercise
Average	-1,567,664	-1,478,715	-1,944,887	-1,916,245	-2,118,865	-2,112,682	-155,392	2,917	-774,890	-724,162	-1,120,709	-1,101,027
95% CI	-9,394,396	-8,016,812	-7,650,933	-7,039,568	-6,680,651	-6,188,677	-5,231,588	-4,494,418	-4,929,411	-4,592,717	-4,533,591	-4,292,222
	946,712	965,973	279,742	280,426	-199,846	203,866	1,542,955	1,597,446	440,317	451,166	-27,353	-27,353
PB(negative bequests)	65.4%	64.6%	86.2%	86.1%	100.0%	100.0%	35.4%	30.8%	59.6%	56.9%	98.7%	98.7%
Ho: Higher bequests	88,949***		28,642**		6,183		158,309***		50,728***		19,682***	
Ho: Lower *PB*(negative bequests)	-0.8%***		-0.1%		0.0%		-4.6%***		-2.7%***		0.0%	

Note: ** and *** = Significance at 95% and 99% confidence levels. *PB*(negative bequests) = Probability of experiencing negative savings at the time of death. Ho: Higher bequests = Difference between the bequests of exercise and general groups. Ho: Lower *PB*(negative bequests) = Difference between *PB*(negative bequests)'s of exercise and general groups.

As illustrated in Panel 2.2, baby boomers leave negative bequests. For those women who do not exercise, the average negative bequests are very large—from -1,567,664 baht for a 50Y accumulator to -2,118,865 baht for a 60Y retiree. Although their average bequests do not suddenly flip to positive if they exercise, the sizes of their negative bequests are smaller. The improvement is 88,949 baht for a 50Y accumulator, 28,642 baht for a 55Y pre-retiree and 6,183 baht for a 60Y retiree. The improvement is significant only for the 50Y and 55Y female, however.

As for men, negative bequests are not quite as severe. The study reveals -155,392 baht for a 50Y accumulator, though they can increase to up to -1,120,709 baht for a 60Y retiree. The improvement made by physical exercise among male baby boomers is larger, amounting to 158,309 baht for a 50Y accumulator, 50,728 baht for a 55Y pre-retiree and 19,682 baht for a 60Y retiree.

I measure how likely it is that Thai baby boomers will leave negative bequests, meaning dying in debt. Analysis reveals that 60Y retirees—both men and women—certainly or almost certainly will, regardless of whether they exercise or not. A 50Y accumulator is less likely to leave negative bequests, but the probability is still high. This finding can be explained as following. Starting with negative savings and a low age-specific income, a 60Y retiree must live on more debt until their death. By contrast, a 50Y accumulator earns more in their early years. In some years and some scenarios, the 50Y accumulator has a higher income to pay off the debt and then save. Exercise helps to decrease the probability of negative bequests, but the benefits are limited to 50Y and 55Y men.

Discussion

Following previous studies (Murphy et al., 2010), this study defines Thai baby boomers as people born between 1946 and 1964. It should be noted that this definition is from a U.S. perspective. I use the definition because of its recognition among scholars, as well as the general public. The baby boom cohorts for Thailand, however, are those born between 1958 and 1972 so that the youngest are about 40 years old. For completeness, I chose to calculate the exercise benefits for these 40Y baby boomers in Thailand's context. As shown in Table 3, regular exercise leads to increases in life expectancy by 2.0 and 1.4 years for female and male participants, respectively. The probability of developing NCDs over their lives significantly decreases 18.0% and 15.8%. The number of years living in debt for the 40Y group can decrease significantly. Exercise also is shown to be associated with significantly larger bequests and lower probability of leaving negative bequests.

Table 3: Analyses for 40-year-old Thai baby boomers

Panel 3.1: Health and longevity

Statistics	Female		Male	
	General	**Exercise**	**General**	**Exercise**
Average	72.5	74.5	69.7	71.1
95% CI	48.0	50.0	45.0	46.0
	93.0	94.0	91.0	92.0
PB(NCD free)	20.9%	38.9%	23.3%	39.1%
Ho: Longer life	2.0***		1.4***	
Ho: Higher *PB*(NCD free)	18.0%***		15.8%***	

Note: *** = Significance at a 99% confidence level. *PB*(NCD free) = Probability of not experiencing NCDs over the lifetime. Ho: Longer life = Difference of average life expectancies of exercise and general groups. Ho: Higher *PB*(NCD free) = Difference of *PB*(NCD free)'s of exercise and general groups.

Panel 3.2: Family security (income deficiency)

Statistics	Female		Male	
	General	**Exercise**	**General**	**Exercise**
Average	2.9	2.2	1.2	0.8
95% CI	0.0	0.0	0.0	0.0
	20.0	17.0	13.0	10.0
PB(income deficiency)	37.3%	30.8%	18.8%	14.0%
Ho: Fewer years in deficiency	-0.7***		-0.4***	
Ho: Lower *PB*(income deficiency)	-6.5%***		-4.8%***	

Note: *** = Significance at a 99% confidence level. *PB*(income deficiency) = Probability of experiencing negative savings over the lifetime. Ho: Fewer years in deficiency = Difference of average numbers of years that exercise and general groups experience negative savings. Ho: Lower *PB*(income deficiency) = Difference of *PB*(Income deficiency)'s of exercise and general groups.

Panel 3.3: Family security (bequests)

Statistics	Female		Male	
	General	**Exercise**	**General**	**Exercise**
Average	-234,910	437,294	1,817,110	2,355,373
95% CI	-12,368,170	-9,664,951	-6,032,034	-4,456,760
	4,648,883	4,860,622	6,681,531	6,958,194
PB(negative bequests)	37.3%	30.8%	18.0%	13.1%
Ho: Higher bequests	672,204***		538,263***	
Ho: Lower *PB*(negative bequests)	-6.5%***		-4.9%***	

Note: *** = Significance at a 99% confidence level. *PB*(negative bequests) = Probability of experiencing negative savings at the time of death. Ho: Higher bequests = Difference between the bequests of exercise and general groups. Ho: Lower *PB*(negative bequests) = Difference between *PB*(negative bequests)'s of exercise and general groups.

Although exercise helps strengthen soft skills and improve overall mental and physical health (Lechner, 2015), in Thailand exercise and wage rates are not correlated (Saksiriruthai, 2013). As the economy grows and the country continues to globalize, the model for wage setting should converge to adopt practices established in high-income countries. In order to understand a scenario in which the country applied the wage setting model of high-income countries, I re-calculate the income deficiency and bequest benefits by assuming a 4% earnings effects from exercise. The 4% rate is the lower bound of the benefits from the model in high-income countries (Lechner, 2015). The results are shown in Table 4. As expected, the 4% earnings effects significantly improve all of the metrics of income deficiency and bequest benefits for men and women of all ages.

Table 4: Analysis of 4%-earnings effects from exercise

Panel 4.1: Income deficiency

Statistics	Female				Male			
	40Y	50Y	55Y	60Y	40Y	50Y	55Y	60Y
Average	1.9	5.5	10.3	18.2	0.7	1.6	3.8	14.6
95% CI	0.0 16.0	0.0 20.0	0.0 27.0	3.0 35.0	0.0 9.0	0.0 13.0	0.0 18.0	1.0 32.0
PB(income deficiency)	27.1%	61.3%	84.2%	100.0%	11.5%	27.7%	51.7%	98.7%
Ho: Fewer years in deficiency[a]	-1.0*** -0.3***	-0.2*** -0.5***	0.2*** -0.8***	1.3*** 0.0	-0.5*** -0.1***	-0.6*** -0.3***	-0.5*** -0.6***	0.8*** -0.1***
Ho: Lower *PB*(income deficiency) [a]	-10.2%*** -3.7%***	-4.3%*** -3.4%***	-2.1%*** -2.0%***	0.0% 0.0%	-7.3%*** -2.5%***	-7.9%*** -3.2%***	-8.0%*** -5.4%***	0.0% 0.0%

Note: *** = Significance at a 99% confidence level, [a] = the first line is against the general case and the second line is against the 0%-earnings-effects case. *PB*(income deficiency) = Probability of experiencing negative savings over the lifetime. Ho: Fewer years in deficiency = Difference of average numbers of years that exercise and general groups experience negative savings. Ho: Lower *PB*(income deficiency) = Difference of *PB*(Income deficiency)'s of exercise and general groups.

Panel 4.2: Bequests

Statistics	Female				Male			
	40Y	**50Y**	**55Y**	**60Y**	**40Y**	**50Y**	**55Y**	**60Y**
Average	866,019	-1,333,052	-1,836,759	-2,067,392	2,737,656	169,446	-614,935	-1,044,999
95% CI	-9,254,434 5,557,902	-7,844,668 1,060,110	-6,957,558 298,965	-6,151,644 -195,432	-4,120,330 7,777,884	-4,281,216 1,827,132	-4,453,544 539,383	-4,193,616 -20,276
PB(negative bequests)	27.1%	61.2%	84.1%	100.0%	11.5%	27.5%	51.6%	98.5%
Ho: Higher bequests[a]	1,100,929*** 428,725***	234,612*** 145,663***	108,128*** 79,486***	51,473*** 45,290***	920,546*** 382,283***	324,839*** 166,530***	159,955*** 109,227***	75,710*** 56,028***
Ho: Lower *PB*(negative bequests) [a]	-10.2%*** -3.7%***	-4.2%*** -3.4%***	-2.1%*** -2.0%***	0.0% 0.0%	-6.5%*** -1.6%***	-7.9%*** -3.3%***	-8.0%*** -5.3%***	-0.2%*** -0.2%***

Note: *** = Significance at a 99% confidence level, [a] = the first line is against the general case and the second line is against the 0%-earnings-effects case. *PB*(negative bequests) = Probability of experiencing negative savings at the time of death. Ho: Higher bequests = Difference between the bequests of exercise and general groups. Ho: Lower *PB*(negative bequests) = Difference between *PB*(negative bequests)'s of exercise and general groups.

In this study, I assume that mortality and morbidity rates are fixed. In reality, these rates change over time due to changes in economic patterns, the forces of modernization and globalization as well as shifts in food consumption patterns and nutritional preferences (Carmichael, 2011; Kosulwat, 2002). It is interesting to ask how exercise benefits will change with the transition of mortality and morbidity patterns. To address this important question, I re-examine exercise benefits using the Office of Insurance Commission's 1997 mortality table. The 1997 mortality rates are higher than the 2008 ones. The NCD-specific mortality data are adjusted from the ones in the previous analyses so that the rates are not lower than the 1997 mortality rates. The NCD-incidence rates remain unchanged. Under the specification of zero earnings effects, the exercise benefits based on the 1997 mortality data are in Table 5.

Table 5: Exercise benefits based on 1997 mortality rates

Statistics	Female				Male			
	40Y	50Y	55Y	60Y	40Y	50Y	55Y	60Y
Ho: Longer life	1.8***	1.6***	1.4***	1.1***	1.3***	1.2***	1.1***	0.8***
Ho: Higher *PB*(NCD free)	18.0%***	18.2%***	18.0%***	17.7%***	15.7%***	17.8%***	17.5%***	17.5%***
Ho: Fewer years in deficiency	-0.6***	0.2***	0.8***	1.1***	-0.3***	-0.3***	0.1***	0.8***
Ho: Lower *PB*(income deficiency)	-6.0%***	-1.4%***	-0.3%*	0.0%	-4.4%***	-4.7%***	-2.9%***	-0.0%
Ho: Higher bequests	620,649***	100,316***	37,470***	9,782	474,110***	152,945***	47,682***	22,810***
Ho: Lower *PB*(negative bequests)	-6.1%***	-1.3%***	-0.3%*	0.0%	-4.4%***	-4.7%***	-2.9%***	-0.0%

Note: *** and * = Significance at 99% and 90% confidence levels. Ho: Longer life = Difference of average life expectancies of exercise and general groups. Ho: Higher *PB*(NCD free) = Difference of the probabilities of not experiencing NCDs of exercise and general groups. Ho: Fewer years in deficiency = Difference of average numbers of years that exercise and general groups experience negative savings. Ho: Lower *PB*(income deficiency) = Difference of the probabilities of experiencing negative savings of exercise and general groups. Ho: Higher bequests = Difference between the bequests of exercise and general groups. Ho: Lower *PB*(negative bequests) = Difference between the probabilities of experiencing negative bequests of exercise and general groups.

In order to understand the impacts of the transition, Table 5 must be compared with Tables 1, 2 and 3. The transition leads to greater life-expectancy benefits from exercise, but the NCD-risk reduction remains unchanged. It decreases the benefits in terms of the number of years and the probability of being in debt. The transition impact on bequests is mixed. It tends to be positive for men and negative for women. Finally, the transition makes exercise less effective in lowering the probability of experiencing negative bequests.

Baby boomers may want to know how much longer they will live if they exercise regularly. From Table 1, the analysis suggested that life expectancy could be raised up to almost 2 years. Although the longer lives are significant statistically, conventionally, baby boomers may not consider it so (Shephard, 1993). Longer lives alone are unlikely to convince baby boomers to exercise regularly. It is important baby boomers realize security and health benefits from regular exercise.

Conclusions and Policy Implications

The study finds that physical exercise can increase longevity, reduce health risks and improve financial security for Thai baby boomers. This, in turn, may help baby boomers achieve their family-security and health value goals. Essentially, exercise is practical and economical. The national government has devised campaigns to promote exercise among

Thai people. Yet, most people, including baby boomers, do not exercise regularly because it causes tiredness and immediate disutility. This study shows exactly the degree to which baby boomers can benefit in terms of health and family security from exercise. Hopefully these benefits suffice to compensate the disutility so that baby boomers choose to exercise regularly. Responsible government agencies can make use of these findings to support their exercise campaigns. Based on these findings and analyses, I recommend all Thai baby boomers to incorporate exercise into their daily lives — and to start as soon as possible.

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Appendix Monte Carlo Simulations Explained

I wrote the computer program in Microsoft Excel 2010 for the Monte Carlo analyses. To generate investment returns in a scenario, I drew independent standard normal variables, multiplied them with the standard deviations and added the products to the expected returns. The inflated medical costs were simulated in a similar way.

Inflation rates for incomes and personal expenses follow mean-reversion processes. I set the rate for year 0 equal to the 2014 inflation rate. Then I drew independent standard normal variables to construct Year 1's rate from equations (2.2) and (3.2). The steps repeat until the baby boomer turns 100.

I generated Bernoulli variables for morbidity and mortality statuses by first drawing independent [0.00, 1.00] uniform variables and then comparing them with incidence and mortality rates. The Bernoulli variables are 1, if the drawn uniform variables are not larger than the referenced rates. Otherwise, they are 0. All the standard normal and uniform variables are drawn by Excel's random number generation function.

I identified age T at death by the age at which the first 1 for the mortality, Bernoulli variable is realized in the life path. Bequest is defined by the savings at age T. The negative-bequest status variable is 1 if the bequest is negative; otherwise, it is 0.

Whenever savings is negative before or at age T, I set the income deficiency variable to 1. Otherwise, it is 0. The duration of income deficiency is simply the sum of the deficiency variables. And, the income deficiency status is 1, if the duration is greater than 0.

I repeated these activities 5,000 times, hence constituting 5,000 joint scenarios for these interesting variables for the statistical analyses.