흡연 감소는 어떻게 건강과 교육 및 소득에 영향을 미치는가

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How Smoking Reduction Affects Health, Education, and Income in South Korea

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초록

목적: 본 연구는 흡연감소가 건강과 교육 및 소득에 유효한 방안이 될 가능성을 탐구함에 있다.
방법: 내생변수들의 다중인과관계를 분석하기 위하여 한국의 18 년 (2005-2022) 간의 연간 시계열 자료를 사용하여 모형을 추정한다. 모형에서는 외생변수의 직간접효과와 총효과를 제시한다. 3 개의 모형들을 평가하기 위하여 진단검사를 시행한다. 또한 모형의 모수 안정성을 검증하고, 불안정이 존재한다면 모수 불안정성을 분석한다. 본 연구의 자료는 통계청 지표누리(index.go.kr)와 국제통계연감, OECD 보건의료통계, 질병관리청의 국민건강영양조사 자료를 활용한다.
결과: 다른 모든 조건이 일정할 때 흡연감소는 건강에 직접적으로 그리고 건강을 경유하여 교육과 소득에 간접적으로 영향을 미친다.
결론: 회귀분석 결과로부터 반과다흡연 캠페인은 건강상태를 증진시킬 뿐만 아니라 교육과 소득도 증가시킨다. 하루 6.32 개비 이하의 1 인당 평균담배소비량은 한국의 건강과 교육 및 소득 증진에 효과적인 방안이 될 수 있다.
주제어: 흡연감소, 건강, 교육 소득 인과관계

I. Introduction

Well-educated individuals tend to be future-oriented since the internal rate of return to education exceeds the alternative rate of return or the discount rate. This suggests that individuals with a high propensity to invest in education would engage in other forward-looking behaviors, such as health habits, income, smoking and drinking behaviors. Evidence suggests that addicts with higher discount rates respond more to changes in money prices of addictive goods, partly because they place a smaller monetary value on health. In contrast, addicts with lower rates of discount respond more to changes in harmful future consequences of addictive goods, such as a negative effect of smoking on health [1].

Smoking reduction can improve self-perceived health and quality of life by reducing stress, anxiety,

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and depression, and improving positive mood. For instance, evidence shows that smoking reduction decreased cardiovascular disease rates, reporting a hazard ratio (HR) of reducers over maintainers of 0.77 (95 % confidence interval (CI), 0.66–0.94). This implies that, in a telephone survey of 1,000 daily smokers in the US, a reduction in smoking decreased the harm from smoking [2].

A subsequent study using the Korean Longitudinal Study of Aging showed evidence that reducing smoking prevalence to zero led to disproportionately greater increases in remaining life expectancy for heavy smokers (those in the bottom 70th percentile of smoking intensity) than light smokers (those in the 30th percentile): Life expectancy at age 52 increased by 0.21 years (35.81 years before intervention and 36.02 years after intervention) among light smokers and by 2.36 years (32.65 years before the intervention and 35.01 years after intervention) among heavy smokers in South Korea [3].

Emerging evidence suggests that each one-pack reduction in the number of cigarettes smoked per day affects an improvement of 0.32 (95%CI = 0.12 to 0.54) on the health-related quality of life scale [4].

Given the importance of population health, smoking reduction may therefore be considered as a package in policy formulation and health outcomes. It follows that a higher future cost (perhaps because of greater information about health hazards) is likely to reduce the demand for cigarettes, particularly among wealthy people. Thus, the crux of the issue is whether a higher cigarette price is likely to have a substantial negative effect on the demand for cigarettes, which can subsequently have a substantial positive effect on health. As individuals with more education and higher income have lower rates of discount, a diminished demand for cigarettes, rather than higher prices, is likely to have a substantial positive effect on health. For example, assuming that the mortality risks of smoking are highly reversible, reducing smoking is one way to invest in health [5].

Smoking cessation and, to a lesser extent, smoking reduction decreases the risk of cancers. The substantial social and economic burden attributable to smoking is well-known, with heavy smokers at a higher risk of chronic diseases and premature mortality than smokers reducers and nonsmokers.

These beneficial health effects of smoking reduction transfer to the labor market, raising productivity and income; smoking reduction has a less negative effect on income than heavy smoking. Using data from four waves (1984, 1992, 1994, 1998) of the National Longitudinal Survey of Youth 1979 cohort conducted by the US Department of Labor, reductions in smoking will boosted wealth, especially among the poor [6].

Smoking reduction affects education and income, through improved health. For example, using a national sample of 4,960 youth (12-15 years old) from the Population Assessment of Tobacco and Health (PATH) study, the results indicate that initiating cigarettes was associated with lower academic performance (adjusted regression coefficient -0.51, 95% confidence interval -0.84, -0.18), reinforcing the importance of reducing tobacco use among youth, which may improve future educational attainment in addition to protecting their health [7].

Recent Australian research demonstrates that those who reduce their tobacco use will experience immediate and long-term economic benefit, such as incresed disposable income, fewer medical expenses, and greater earning opportunities [8].

Given the importance of the population health, many have argued that the community would be better off if the proportion of people who smoked regularly at harmful levels were reduced.

In contrast, other studies have shown that even smoking reduction negatively affects self-perceived health. For example, the risk of ischemic heart disease in light smoking men and women aged 35 - 39 years who smoke 1 to 4 cigarettes per day is nearly three times that of a nonsmokers [9]. More recently, data from the 2013 Brazilian National Health Survey with a total of sample 48,282 participants suggested that light smoking (<10 cigarettes per day) was associated with higher odds of poor self-perceived health [10].

A recent study of low-rate daily smokers (1–4 cigarettes per day) found a relative risk for all cause mortality of 1.6 (95%CI 1.3–1.9) in men and a relative risk of 1.5 (95% CI 1.2–1.8) in women [9]. Drawing data from the British Cohort Study (BCS70) with more than 17,000 individuals, estimates showed that the current-smoker group produced an increase in the probability of being in poor self rated health with respect to never-smokers of about 10 percentage points in the long term [11]. Tobacco control advocates should draw attention to these consequences in arguing for effective measures to reduce smoking initiation and increase cessation to achieve socially optimal outcomes [12].

Evidence finds a causal effect of smoking on lower educational attainment [13]. Australian research into smoking among young people aged 14 years has shown that, whether assessed by self-report or external standardized measures, smokers have lower levels of educational achievement than

non-smokers, with the association appearing stronger for boys than for girls [14].

In a previous study utilizing pooled data from three countries participating in the ITC Project: France (1070 smokers), Germany (547 smokers), and the Netherlands (1095 smokers), it showed that smokers became unemployed and face a decrease in income [15].

Using data from the Cardiovascular Risk in Young Finns Study survey (participants=1953), a 1-unit increase in pack-years of smoking was found to be associated with a 1.8 percent decrease in earnings [16].

The main objective of this paper is to analyze whether smoking reduction is one of, if not the most, effective ways to improve health, education, and income.

South Korea was selected for this study because of the availability of in-depth data from 2005 to 2022. Even though eighteen years do not provide sufficient observations to allow a full econometric evaluations of the causal relationships among the selected variables of endogeneity, South Korean data have the advantage of being an assessible health status indicator (i.e., self-perceived health) by year. Self-perceived health is likely to be an important determinant of the values of education and income [17].

To our knowledge, no empirical evidence exists regarding the total proportionate rate of changes in health, education, and income with respect to smoking reduction in South Korea.

The remainder of this paper is organized as follows. Section 2 describes the data sources and develops an analytical framework that highlights the effect of smoking reduction on health, education, and income. Section 3 presents our empirical results. The Strengths and weaknesses of this study are discussed in Section 4. Finally, Section 5 summarizes the principal findings and policy implications.

II. Methods

A. Data sources

The data for this investigation comes from index.go.kr by Statistics Korea, OECD Health Statistics, International Statistical Yearbook, and the Korea national health and nuitrition examination survey that have been conducted by the Korea Disease Control and Prevention Agency (KDCA). The following persons living in South Korea but not usually considered part of South Korean resident population were excluded from the scope of the Statistics Korea survey: Diplomatic personnel of overseas governments and non-South Korean members of their households, non-South Korean service personnel stationed in South Korea and their dependents, and overseas visitors whose usual place of residence is outside South Korea. Other than these persons, non-South Koreans working, studying, or having had settled in South Korea and their dependents were included in the survey.

B. Variables

H_t denotes for the proportion of persons reported being in good or excellent health by their perception to population aged 19 years or over (hereafter, health). Based on the graph shown at index.go.kr, the health data for 2021 can be obtained as [50.4(2020)+53.1(2022)]/2=51.8. This treatment reflects the data limitations. Health indicator implies a positive (+) health effect, such that a higher proportion is associated with better health. E_t denotes the proportion of persons who completed tertiary education among the population aged 25 to 64 (hereafter, education). Y_t denotes real Gross National Income per capita (hereafter, income).

$SMOKE_t$ represents annual consumption of tobacco per capita by those aged 15 years or older. The smoking indicator implies a positive (+) health effect, such that lower consumption will be associated with better health. ALC_t represents alcohol consumption per capita, aged 15 years or over. $DALC_t$ stands for D_t*ALC_t. D_t represents a dummy variable (outliers=1, 2013 and 2016~21 corresponding to years with less alcohol consumption per capita than the average; otherwise=0).

HV_t represents the number of hospital visits. $STDP_t$ represents the number of students per professor at the university. FAC_t represents the floor area of the facilities in the university building per student. YD_t represents the yellow dust. NRW_t represents the ratio of non-regular workers to regular workers. RSI_t represents the retail sales index.

The estimated correlation coefficients between health, education, and income are very high; the estimated correlation coefficients between H_t and E_t, H_t and Y_t, and E_t and Y_t were 0.79, 0.77, and 0.99, respectively. Therefore, these variables were included in separate regressions.

Least squares regression assumes that the dependent variable and, less critically, the independent variables are normally distributed, an assumption that is reasonably satisfied by our data. Standard tests for normality failed to reject the

hypothesis of a normal distribution for both the dependent and independent variables (Table 1).

→Table 1 here please

C. Analytical frameworks

If smoking reduction decreases the level of self-perceived good or excellent health, we reject the hypothesis that differences in health, education, and income are manifestations of smoking reduction. Therefore, this section specifies that differentials in smoking behavior are cause the differences in health, education, and income. The linear structural equations are defined as follows,

$$H_t = \alpha_0+\alpha_1E_t+\alpha_2Y_t+\alpha_3SMOKE_t+\alpha_4ALC_t+\alpha_5DALC_t + \alpha_6HV_t +Error \quad (1)$$

$$E_t = \beta_0 + \beta_1H_t + \beta_2Y_t+\beta_3STDP_t+\beta_4FAC_t+\beta_5YD_t+Error \quad (2)$$

$$Y_t = \gamma_0 + \gamma_1H_t + \gamma_2E_t+\gamma_3YD_t+\gamma_4NRW_t+\gamma_5RSI_t+Error \quad (3)$$

Structural equations (1) to (3) also comply with the hypothesis that causal relationships exist among health, education, and income. All equations appear to be identified. For this, it is necessary to obtain the predicted values of H, E, and Y from the estimates of the reduced-form equations for linear structural equations (1), (2), and (3), specified as [18]:

$$V_t=\pi_0+\pi_1SMOKE_t+\pi_2ALC_t+\pi_3D_tALC_t+\pi_4HV_t+\pi_5STDP_t+\pi_6FAC_t+\pi_7YD_t+\pi_8NRW_t+\pi_9RSI_t+Error \quad (4)$$

where $V_t=(H_t, E_t, Y_t)'$ refers to the row vector of the dependent variables, while the π's are the functions of the structural parameters indicated in the structural equations (1) to (3). The structural equations (1) to (3) stand for well-behaved production functions exhibiting everywhere diminishing returns to inputs, and show, for example, that there are two channels through which smoking reduction affects income. Smoking reduction affects income indirectly, through health and education,

$$dY/dSMOKE=Y_H*dH/dSMOKE+Y_E*dE/dH*dH/dSMOKE \quad (5)$$

III. Results

In this section, we examine the hypothesis that differences smoking behavior cause the differentials in health, education, and income.

A. Tests of non-nested models

The non-nested tests of the linear form of the model versus the double natural logarithmic model indicated that the linear model was preferred to the double natural logarithmic model in all equations for health, education, and income (Table 2).

→Table 2 here please

B. Estimates of structural equations

The results and analysis of all the estimated equations provide the following remarks (Table 3). For each statement, the qualifications 'when adjusting for' and 'on average' are to be understood. We conducted endogeneity tests. The regression results revealed strong statistical evidence of endogeneity among health, education, and income. Ramsey's RESET2 test was used as a general test for misspecification. The regression results suggest that the null hypothesis of functional form misspecification is rejected in the estimated regressions for health, education, and income with two exceptions; H-(2) and Y-(2). In the estimated OLS regression H-(2) and Y-(2), the observed R^2 is high (0.66 and 0.98, respectively), and the estimated F-statistic (5.12) is larger than the 95% critical value. Based on RESET2 test and the estimated values of $R^2$and F, correct specifications are implied in all six estimated OLS regressions, indicating that the assumption of zero expected values of the residuals is not violated.

The tests for heteroscedasticity were detected in all equations estimated by OLS. Therefore, the assumption that the variances of the disturbances were approximately constant for eighteen years could be rejected. However, the results of the RESET2 test, the estimated values of R^2 and F, indicate that correct specifications are implied in the six estimated OLS regressions. This indicates that the assumption of zero expected values of residuals is not violated.

The evidence along with the endogeneity tests indicates that health, education, and income are significant in explaining one another, suggesting a full simultaneous equations model. In short, an increase in each of these variables caused increases in the other two, *ceteris paribus*.

Table 3. OLS estimates of linear equations for health, education, and income*

	H_t		E_t[2)]		Y_t	
	(1)	(2)	(1)	(2)	(1)	(2)
H_t	-	-	0.11 (0.05)*	-	128.93 (39.49)***	-
E_t	0.98 (0.24)***	-	-	-	-	68.17 (3.26)***
Y_t	-	0.11 (0.10)**	-	0.01 (0.001)***	-	-
$SMOKE_t$	0.02 (0.006)***	0.02 (0.01)**	-	-	-	-
ALC_t	1.62 (1.80)	-0.52 (0.41)	-	-	-	-
$DALC_t$	0.54 (0.30)*	0.52 (0.41)	-	-	-	-
HV_t	-1.42 (0.53)**	-0.81 (0.65)	-	-	-	-
$STDP_t$	-		-0.96 (0.04)***	-	-	-
FAC_t	-		0.25 (0.09)**	0.50 (0.18)**	-	-
YD_t	-		-0.01 (0.01)	-0.01 (0.01)*	-3.25 (1.10)**	0.02 (0.27)
NRW_t	-		-	-	-13.04 (20.20)	-1.63 (4.16)
RSI_t	-		-	-	116.90 (59.53)*	19.36 (12.01)
Constant	-12.49 (17.97)	-8.20 (27.14)	74.48 (3.55)***	0.71 (1.97)	-2322.74 (1717.90)	150.91 (242.24)
Chow t[3)]	1.83*	1.27	-	-	-	-
Endogeneity tests[4)]	F(1,11)= 7.53**	F(1,11)= 8.17**	F(1,12)= 974.26***	F(1,13)= 333.07***	F(1,12)= 4.21*	F(1,12)= 119.20***
RESET2[5)]	t=1.42	t=3.43***	t=0.36	t=0.36	t=1.06	t=3.73***
Heteroscedasticity[6)]	F(8,10)= 12.98***	F(8,10)= 7.20***	F(7,11)= 762.30***	F(6,12)= 524.29***	F(7,11)= 3.22**	F(7,11)= 245.18***
R^2	0.80	0.66	1.00	0.98	0.6	0.98
F-Stat[7)]	9.33***	4.59**	1308.83***	301.94***	4.94**	152.48***

Notes:* . The values in parentheses are the estimated absolute standard errors of the regression coefficient. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively, on a two-tailed test.

2). The estimated correlation coefficient between STDP and Y is -0.992. Excluding STDP variable in education regressions, it should be excluded in the reduced-form equation.

3). For the Coefficient instability test procedure, see [19].

4). The joint F test is reported; The 95 percent critical value of F(1,11) is 4.84. For the test procedure, see [18].

5). Test for Functional form Misspecification. Individual t test is reported. For the test procedure, see [19].

6). The joint F test is reported; The 95 percent critical value of F(8,10) is 3.07. For the test procedure, see [18].

7). Test for Functional form Misspecification. The 95 percent critical value for F(5, 12) is 3.11.

These OLS estimates are consistent with previous evidence. For example, using simultaneous equation models on a sample comprising 108 developed and developing countries from 1990-2017, which are decomposed into three income classifications, previous empirical evidence finds a bidirectional causality

between health (life expectancy at birth) and education (secondary school enrolment), between health and economic growth (real Gross Domestic Product per capita), and between education and economic growth in middle-income countries [21]. Therefore, the instrument choice should not be based upon stability analysis of a single final target variable. Health can be improved directly by increased expenditure on medical care or indirectly through increased expenditue on education and through healthy environment, better diet and access to the better medical care as a result of higher income.

It can also be suggested that the cross effects among health, education, and income are positive, implying that they complement each other and that health and education are normal goods.

When adjusting for education (E), alcohol consumption (ALC), interaction variable drinking with dummy (DALC) and hospital visit (HV), the OLS estimates suggest that smoking reduction is positively and significantly related to self-perceived good or excellent health, as expected. This is due to a continued decline in the proportion of smokers aged 15 years and over in South Korea for the period of twelve years from 2011 to 2022 (Public Health Weekly Report, Korea Disease Control and Prevention Agency, 2023); A 10 percentage point increase in the proportion of persons aged 15 years or over who reduce tobacco use increases the proportion of persons aged 19 years or over with self-assessed good or excellent health by 0.2 percentage points. These results are consistent with those of previous evidence [2, 3,4, 5].

It also reviews the tests of coefficient instability for the estimated OLS regression on health possibly caused by the reduction in the demand for alcohol per capita dummy on health. The Chow t-test rejects the null hypothesis of no coefficient instability for the estimated health equations. The results indicate that DALC is statistically significant, suggesting that moderate drinking is positively and significantly associated with health. Analysis of the coefficient stability implies that the average annual alcohol consumption per capita of outliers of 8.31 liters (0.023 liters daily) or lower may be moderate. A 10 percentage point increase in moderate alcohol consumption per capita in people aged 15 years or over raises the proportion of persons reported being in good or excellent health by their perception to population aged 19 years or over by 5.4%. For instance, logistic regression model analyses have shown that moderate beer consumption leads to better self-perceived health outcomes [22].

When adjusting for E, SMOKE, ALC and DALC, hospital visit was negatively and significantly associated with self-perceived health. One implication is that participants with an ambulatory hospital visits are more likely to report poor health status [23].

We found that a decrease in number of students per professor in university raises the proportion of persons completed tertiary education to population aged 25 to 64. The research conducted by [24] also found that student faculty ratio is associated with undergraduate degree completion. The ordinary least squares (OLS) estimates suggest that academic buildings improve academic output and performance. For example, duration of access, availability of refreshment facilities, availability of discussion room and availability of personal workstation are considered as parameters that are important to students‘ academic output in relation to academic buildings. The study population consisted of students (higher education institutes) from several institutions across Malaysia [25].

Yellow dust is negatively and signifintly related to education. These results are consistent with those of a previous study, implying that the educulture (education and culture) sector was severely affected, with a loss of 1.0% of its total output of Beijing in 2000 by yellow dust [26].

The coefficient of the constant term appears to be positive and significant, suggesting that past family income positively impacts education. This implies that families have lived in South Korea for several generations. There is evidence that, employing data from the British Cohort Study (BCS) and the British Household Panel Study (BHPS), increasing inequality in family income will translate into inequalities in children’s educational outcomes and their life chances [27].

The estimated income equation suggests that yellow dust is negatively and significantly associated with income. There is a case stydy in Beijing for 2000 that the total economic impacts caused by supply effects are 5.7% of Beijing's GDP in 2000 [26].

The regression estimates imply that an increase in retail sales signals an expanding healthy economy, whereas a decrease in retail sales signals the opposite. For example, the recent empirical analysis reveals that higher retail sales are correlated with higher income [28].

IV. Discussion

The regression results suggest that smoking reduction affects health directly and indirectly through

education and income. Previous empirical evidences are consistent with our findings [2, 3, 4, 5, 6, 7, 8]. In particular, we add smoking behavior as a control in structural equation for health because there is evidence that alcohol and tobacco consumptions are jointly consumed [29].

With a few exceptions, the variables used in the model are expressed as proportions of an appropriate denominator. This is useful in health, education, and income research because it can help identify the factors that impact these areas. Our estimates were based on the number of cigarettes smoked. This measure may be exhaustive of the effect on self-perceived health [11].

On the contrary, there are studies that smoking reduction carries substantial health risks and therefore each of education and income [9, 10, 11, 14, 15, 16].

Despite the potential implications of our findings, the results should be taken with caution due to the several limitations of the study. First, even stable a reduction in cigarette consumption carries substantial health risks. Cessation is the only known primary therapy that can significantly reduce the risk of cancer and obstructive lung disease. More evidence is needed not only on self-perceived health but also on the mental, social, and emotional domains in relation to smoking reduction. Notably, there are numerous different smoking cultures and attitudes toward tobacco worldwide. Second, we need to include gender-related factors when developing tobacco reduction intervention. Smoking rates vary between men and women with men generally smoking more than women in South Korea. According to the 2023 Korea National Health and Nutrition Examination Survey that have been conducted by KDCA, around 32.4 percent of men smoked cigarettes, while only 6.3 percent of women did. Third, there are no standard definitions of light smoking, which has led to variability in the level of smoking considered “light” in different studies. Some studies have proposed the following definitions [9]: 1. Chippers: <5 cigarettes per day (CPD), 2. Very light smoking: <6 CPD and 3. light smoking: <10 CPD. The extent of tobacco toxicant exposure in former heavy smokers who significantly reduced their smoking was higher than those who were consistent light smokers [30]. Therefore, we used smoking reduction rather than light smoking. Finally, using annual time series data, variations in reporting practices and in the accuracy of information, which may be serious at the individual level, tend to be averaged out. Another advantage of using annual time series data as the unit of observation is that health is likely to vary less relative to variations in education and income. Nevertheless, this approach can be justified by the assumption that the relationships among aggregates depend on characteristics and resources among individuals [31].

In addition, medical research using big data has become very popular, and its value has become increasingly recognized. For example, hazard ratios from published aggregate data are most likely to agree with those from individual participant data when the information size was large [32]. Recently, the Korean National Health Information Database (NHID) has become representative of big data.

In this study, eighteen years (2005-2022) do not generate a sufficient number of observations. Therefore, further studies are required to explore the mechanisms underlying the relationship between smoking reduction and health outcomes. TSLS and reduced-form estimates are available from the authors upon request.

V. Conclusion

Employing the time series data from 2005 to 2022 for South Korea, the two-way causality between health, education, and income implies that smoking reduction affects health (as is generally known and appreciated) but also affects education and income indirectly. For example, a 10 per cent increase in the proportion of persons aged 15 years or over who reduce tobbaco use increases the proportion of persons aged 19 years or over with self-assessed good or excellent health, proportion of persons completed tertiary education to population aged 25 to 64, and real gross national income per capita by 7.98 per cent, 0.98 per cent, and 16.15 per cent, respectively (Table 4).

→Table 4 here please

Given that the positive total proportionate rate of changes in health, education, and income with respect to smoking reduction, *ceteris paribus*, campaigns implemented with the aim of influencing behavior, such as anti-heavy smoking campaigns, will not only improve health but also education and income.

A previous empirical study utilizing 14,692 students attending middle or high school in July 2005 suggested that an anti-smoking campaign and education must be effective enough to change students' attitudes toward smoking behavior rather simply deliver knowledge; moreover, the proportion of smokers who quit or reduce smoking in adults is very similar to that of adolescents [33].

Based on this study, the average tobacco consumption per capita for the period of 2005 to 2022 of 1,924.61 grams (5.273 grams daily which is equivalent to 6.32 cigarettes per day) or lower may be one of the most effective ways to improve health, education, and income in South Korea [34].

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Table 1. Statistical description of variables

Variable	Source	Mean (SD)	Normality Test Kurtosis (Skewness)¶
H	Korea national health and nuitrition examination survey (KDCA)	48.23 (2.48)	-0.40 (0.23) Accept H_0
E*	Statistics Korea	43.18 (6.59)	-1.09 (-0.24) Accept H_0
Y†	index.go.kr	3072.78 (439.24)	-1.55 (-0.10) Accept H_0
ALC	International Statistics, Statistics Korea	8.73 (0.49)	0.03 (-0.75) Accept H_0
SMOKE	OECD Health Statistics, Statistics Korea	1924.61 (304.50)	-1.87 (-0.05) Accept H_0
HA	Statistics Korea	18.79 (1.68)	-0.34 (-0.69) Accept H_0
STDP	Statistics Korea	42.75 (5.85)	-1.28 (0.29) Accept H_0
FAC‡	Statistics	18.47	-0.76

	Korea	(3.07)	(0.52) Accept H_0
YD§	index.go.kr	153.89 (97.77)	-0.22 (0.56) Accept H_0
NRW	Statistics Korea	52.39 (4.43)	-0.11 (0.94) Accept H_0
RSI ‖	index.go.kr	3.09 (1.97)	-0.72 (-0.14) Accept H_0

Notes:*. Include the total number of students completed lifelong learning education. An online bachelor's degree is valid for employ ment in South Korea if it is accredited by the National Institute for Lifelong Education.
†. Converted using Purchasing Power Parities (PPP's. Base year=2015). Unit: 10,000 Korean won.
‡. Unit: sqare meters.
§. The number of yellow dust days*monthly frequency. Unit: ㎍/㎥.
‖. Base=2010. RSI is modified as raw score times 10 for the period of 2005~2011. For more details see consumption survey, index.go.kr, Statistics Korea.
¶. H_0=the fits of normal distribution to the sample data is adequate, and H_1=the fits of a normal distribution to the sample data is not adequate. By “Accept H_0” strictly mean “cannot reject H_0.”

Table 2. Non-nested test of double logarithmic vs linear models of health, education, and income: OLS estimates*

Structural Equations	Regression Equations	Test I† Logarithmic model (H1)	Linear model (H0)	Test II‡ Logarithmic model (H1)	Linear model (H0)
H	(1)	T=2.26**	t=1.13 Accept H_0	0.69	0.71 Accept H_0
	(2)	t=2.86**	t=1.23 Accept H_0	0.55 Reject H_0	0.51
E	(1)	t=10.81***	t=-0.98 Accept H_0	0.98	1.00 Accept H_0
	(2)	t=2.40**	t=-0.98 Accept H_0	0.98 Reject H_0	0.98 Accept H_0
Y	(1)	t=1.14 Reject HH_0	t=-0.08 Accept H_0	0.43	0.48 Accept H_0
	(2)	t=4.64**	t=-0.05 Accept H_0	0.97 Reject H_0	0.97 Accept H_0

Notes:*. The estimated absolute t-value. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively, on a two-tailed test. By "Accept H_0" we stictly mean "cannot reject H_0". The value of *ln*RSI in 2020 is less than zero; -0.1. Therefore, the prediction of the double natural logarithmic model for the non-nested tests is obtained by relying upon the first-order Taylor series approximation $ln(1+x)\approx x$. For example, $lnRSI=ln(1+RSI-1)\approx RSI-1=-0.1-1=-1.1$.

†. If both the null and alternative hypotheses are not rejected, the tests are said to be inconclusive. For the test procedure, see [19].

‡. The Theil maximum adjusted multiple determination (Adj.R^2) criterion, as described by [20].

Table 4. Direct, indirect, and total proportionate rate of changes in health, education, and income with respect to smoking reduction (*Cet. Par.*)*

A 10 per cent increase in:	Smoking Reductionte H		E		Y	
	(1)	(2)	(1)	(2)	(1)	(2)
Direct	7.98	7.98	0.00	0.00	0.00	0.00
Indirect	0.00	0.00	0.98	0.00	16.15	0.00
Total	7.98	7.98	0.98	0.00	16.15	0.00

Notes:*. Obtained from Table 1 and OLS estimates in Table 3; For example, the positive direct effect of smoking reduction on income is Y_{SMOKE}=0. The means of H, E, Y, and SMOKE are 48.23, 43.18, 3072.78, and 1924.61, respectively. The indirect effect of smoking reduction on income through health and education can be obtained from Y_H*dH/dSMOKE+Y_E*dE/dH* dH/dSMOKE. Total= Direct + Indirect.