The Earned Income Tax Credit and the Tax-benefit Link of Public Pensions

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October 2022

PRELIMINARY AND INCOMPLETE

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Abstract

The labor supply response to the Earned Income Tax Credit (EITC) during the working age of the life cycle increases pension income in retirement through the tax-benefit link of public pensions. This mechanism can amplify the income-increasing effects of the EITC by (1) raising pension income and (2) intensifying the labor supply and earnings responses via the dynamic incentive for work. This paper quantitatively analyzes the income-increasing and welfare effects of the EITC and highlights the role of the pension tax-benefit link. To this end, we develop a heterogeneous-agent life-cycle model with the extensive margin labor supply choice and a public pension system. We find that, for newborns with low lifetime income, the pension tax-benefit link explains more than half (a quarter) of the increase in lifetime income (welfare) due to the EITC.

JEL Classification: *E62, H31, H53, H55*
Keywords: *EITC, Labor Supply, Public Pensions, Life-cycle model*

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1 Introduction

The Earned Income Tax Credit (EITC), or in-work benefits, has been widely adopted and expanded across OECD countries over the past few decades (Immervoll and Pearson, 2009; Laun, 2019). As an income support program for low-income families, the distinct feature of the EITC from other welfare programs is that it requires earned income. Therefore, it provides labor supply incentives as well as cash assistance to low-income households. Most empirical studies found that tax credit programs increased low-income individuals' labor market participation.[1] Recent work by Hoynes and Patel (2018) examines the EITC's impact on labor earnings and income. The key contribution of their study is that they explore how much we miss its impact on income by not accounting for the increase in earnings due to the labor supply response. They find that the income-increasing effect of the EITC is substantially larger if we consider the earnings response.[2]

While this empirical literature provides short-run evidence of the labor supply and income-increasing effects of the tax credit, several studies examine its *long-term* impact from a life-cycle perspective. Using a structural life-cycle model, Athreya et al. (2014) and Blundell et al. (2016) show that the tax credit programs increase labor market participation for those with low lifetime income. Moreover, a notable contribution of their works is the finding that the tax credit does more than increase the level of income (and thus consumption) in the dynamic context. That is, it provides partial insurance against income risk (reduces the volatility of income), which enables the target population to reduce precautionary savings and enjoy more consumption. They find that the tax credit enhances welfare for the low lifetime income with this consumption insurance effect over the working periods of the life cycle.[3]

This paper develops a life-cycle framework to argue that the effects of the tax credit on lifetime income and welfare could be larger if we take into account the tax-benefit link of public pensions. In the public pension systems of many countries, benefits and contributions have a linkage. Therefore, an increase in lifetime pension contributions through more labor supply increases pension

[1] See, for example, Eissa and Liebman (1996), Meyer and Rosenbaum (2001), Francesconi and Van der Klaauw (2007), Laun (2017).

[2] Neumark and Wascher (2001) and Grogger (2003) also made a similar point by exploring the EITC's effects on cash income.

[3] Froemel and Gottlieb (2021) also capture the consumption insurance effect of the EITC using a DSGE model with idiosyncratic labor productivity risks. However, their focus is on how the EITC affects the distribution of earnings and wealth through the behavioral response of labor supply and savings and the resulting change in the skill premium in general equilibrium.

income after retirement. Incorporating such a pension tax-benefit link into the model amplifies the EITC's impact on lifetime income for two reasons. First, the labor supply response to the tax credit not only raises current income but also increases pension income in the future. Second, the future payoff for work intensifies the labor supply and earnings responses to the EITC. This *public pension channel* amplifies the welfare effect of the tax credit by allowing the target individual to consume more—through the greater increase in income and by reducing savings for retirement. In this context, this paper examines the *long-term* impacts of the EITC on lifetime income and welfare and highlights the role of the pension tax-benefit link.

To this end, this study constructs a heterogeneous-agent life-cycle model in the tradition of Huggett (1993) and Aiyagari (1994). Individuals face idiosyncratic labor productivity risk, which is uninsurable and persistent. Persistent labor market risk is an essential element that generates the distribution of lifetime income (and wealth) and thus affects eligibility for the EITC. It also allows us to capture the consumption insurance effect of the tax credit emphasized in the previous studies. Individuals make consumption-savings decisions over their lives while facing borrowing constraints. Labor supply is endogenous at the participation margin in each period, as in Chang and Kim (2006), until the mandatory retirement age.[4] The key innovation of the model is that it embeds a public pension system with an explicit link between labor market histories and pension benefits. In this setting, pension benefits are endogenously determined through endogenous labor supply decisions over the working periods of life. The model also incorporates mortality risk so that lifespan is uncertain. This feature allows us to avoid overstating (the value of) the increase in lifetime pension income due to the labor supply response to the EITC.

The selected laboratory environment for the analysis is South Korea (Korea, hereafter), which runs a sizable EITC program yet its impacts have been understudied so far in the literature.[5] The calibrated baseline model economy successfully replicates some salient features in the data, such as the age-employment rate profile, the EITC recipiency rate, and the distribution of income and wealth. Also, the labor supply elasticities implied by the model are within the range of the literature on the extensive margin of labor supply. Then the long-run effects of the EITC are analyzed

[4] Most of the labor supply effects of the tax credit have been found at the participation margin in the literature. See, e.g., a review by Hotz and Scholz (2003) and Eissa and Hoynes (2006).

[5] According to the National Tax Service of Korea, about 10% of the working-age population received the tax credit in 2019, and the overall expenditure amounted to 0.2% of GDP.

by removing it from the baseline economy and comparing the two steady-states. The main focus of the analysis is the impact on the life cycle of newborns with unfavorable productivity histories. This group is supposed to be the most affected by the tax credit because their income (and wealth) would be persistently low over their lives. Then, we repeat the same experiment, but this time the pension tax-benefit link is shut down to isolate the role of the *public pension channel*. Throughout the analysis, we proceed in partial equilibrium framework where equilibrium prices (wages and interest rates) and tax rates are held fixed. This setting is consistent with the previous structural studies on the tax credit, thus allowing us to shed light on how much we miss the *benefit side* (or direct effect) of the tax credit by not accounting for the pension tax-benefit link.

The results show that the pension tax-benefit link plays a quantitatively important role in accounting for the EITC's effects on lifetime income and welfare. First, the low lifetime income group works for about one more year over their lives in response to the introduction of the tax credit. As a result, their lifetime earnings and pension contributions increase by about 1.4%. The consequent increase in annual pension income is 34% larger than the per-period receipts of tax credits during working life. This result shows that the spillover effect on pension income is substantial. Even after controlling for mortality risk, which is pervasive in retirement periods, the rise in lifetime pension income amounts to more than half of the lifetime receipts of tax credits. In addition, the labor supply response to the tax credit and the consequent increase in pre-retirement income is larger with the pension tax-benefit link. It explains about one-third of the rise in career length and lifetime earnings due to the EITC. The stronger labor supply response mainly occurs near retirement. This is because the additional work incentive through the pension tax-benefit link becomes larger nearing retirement. Taking all this together, we find that the *public pension channel* explains more than half of the increase in lifetime income for newborns with unfavorable productivity histories (42% for the present discounted value). In terms of welfare, measured by consumption equivalence, which also considers the value of leisure, the *public pension channel* accounts for more than a quarter of the welfare gain.

This paper contributes to two strands of the literature. First, we extend the literature on the benefits of the tax credit program. We find that the pension tax-benefit link can be an amplifying mechanism to the benefit of the EITC, and we also provide a quantitative analysis of its importance. The findings imply that it is crucial to consider the *public pension channel* when assessing

EITC reforms, analyzing its optimal scale, or studying the optimal shape of the income transfer program (Saez, 2002). Second, to the literature on retirement financing, we find that the EITC can serve as an alternative policy tool to raise old-age income for those with low lifetime income.

The rest of the paper is organized as follows. Section 2 describes the EITC and the public pension system in Korea along with the model economy. Section 3 explains the calibration of the model economy. An exploration of the results is presented in Section 4. Conclusions are provided in Section 5.

2 Model

In modeling choice, we consider the following empirical facts: (i) 70% of the EITC recipients pay pension contribution.[6] (ii) 75% of those who receive the tax credit and contribute to the public pension pay for 12 months per year.[7] (iii) The labor supply effect of the EITC is concentrated to participation margin in the literature (see literature review by Eissa and Hoynes, 2006). (iv) Most of the tax credits rewarded to eligible households are calculated based on *individual*—not family—earnings in Korea.[8]

Taking into account these facts and Korea's individually assessed tax and old age pension system, we build a life-cycle model in which *individuals* are units of decision-making. Time is discrete and one period in the model corresponds to one year. Labor supply is endogenous at the participation margin until the exogenously set retirement age (Chang and Kim, 2006). Labor market participation is tied to the public pension system. Individuals choose how much to save and consume in each period. They also face uninsurable idiosyncratic labor productivity risk, as in Aiyagari (1994) and Huggett (1993), which is the driving force that generates the distribution of lifetime income and wealth in our environment. Individuals also face borrowing constraints and uninsurable mortality risk. The model can also be viewed as an extension of the standard incomplete markets overlapping-generations model of Huggett (1996).

[6] Author's calculation using the Survey of Household Finances and Living Conditions (SHFLC) data for 2017–2020.

[7] Author's calculation using the National Survey of Tax and Benefit data for 2009–2019.

[8] In Korea, the tax credits are calculated on family earnings, but 94% of households that received the tax credit were singles or single-earner couples in the 2019 tax year, according to administrative data from the National Tax Service of Korea.

2.1 EITC

The basic structure of the Korean EITC is similar to its US counterpart. To qualify for the tax credit, one needs strictly positive and sufficiently low earnings, and the amount of tax credits is calculated based on annual earnings.[9] The tax credit amounts increase up to a certain amount of earnings (the phase-in region), then do not change (the plateau), and then gradually phase out. There is also asset-based means-testing so that households with sufficiently low asset holdings (instead of asset income in the US EITC) can receive the tax credit.

A notable difference from the US EITC is that the tax credit schedule—the trapezoid—does not vary by the number of dependent children. Instead, it differs by the type of household: whether they are singles, families with a single earner, or families with dual-earners. Since we do not distinguish household composition in the model, it is necessary to choose a specific tax credit schedule to be analyzed. In this paper, we consider the schedule for single-income families. Because the earnings limit and the maximum tax credit are generous in that order of the stated household type, it can be thought of as an intermediate one.

The schedule for the EITC can be summarized by eq. (1) and eq. (2), consisting of six parameters $\{\beta_{in}, \beta_{out}, \alpha_{out}, \bar{\psi}, \bar{a_1}, \bar{a_2}\}$:[10]

$$\psi(a,y) = \begin{cases} \psi(y) & \text{if} \quad a < \bar{a_1} \\ 0.5 \cdot \psi(y) & \text{if} \quad \bar{a_1} \leq a < \bar{a_2} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where

$$\psi(y) = \begin{cases} \beta_{in} \cdot y & \text{if} \quad 0 < y < \underline{T} \\ \bar{\psi} & \text{if} \quad \underline{T} \leq y < \bar{T} \\ \alpha_{out} - \beta_{out} \cdot y & \text{if} \quad \bar{T} \leq y < \hat{T} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

[9] In contrast, in the US system, the tax credit amounts are calculated on adjusted gross income (earned income plus asset income). Although the income limit for the tax credit is applied to adjusted gross income as well in Korea, we ignore this aspect for simplicity.

[10] We closely follow the notation used in Froemel and Gottlieb (2021) for comparability to the US program.

and $\underline{T} = \frac{\bar{\psi}}{\beta_{in}}$, $\bar{T} = \frac{\alpha_{out} - \bar{\psi}}{\beta_{out}}$, $\hat{T} = \frac{\alpha_{out}}{\beta_{out}}$. β_{in} and β_{out} in eq. (2) are the phase-in and phase-out rates, respectively, of the tax credit schedule applied to earned income y. $\bar{\psi}$ is the maximum amount of the tax credit, and α_{out} is the intercept of the phase-out region. $\bar{a_1}$ and $\bar{a_2}$ in eq. (1) represent the asset test: those with asset holdings a greater than $\bar{a_2}$ are ineligible for the tax credit even if their earned income y is below the earnings limit $\hat{T}$. The tax credit is reduced by half for those with asset holdings greater than $\bar{a_1}$ but less than $\bar{a_2}$.

Figure 1 graphically illustrates the tax credit schedule we will analyze in this study, where the solid line represents the schedule for the full tax credit $\psi(y)$ and the dashed line is the schedule cut by half due to the asset test.

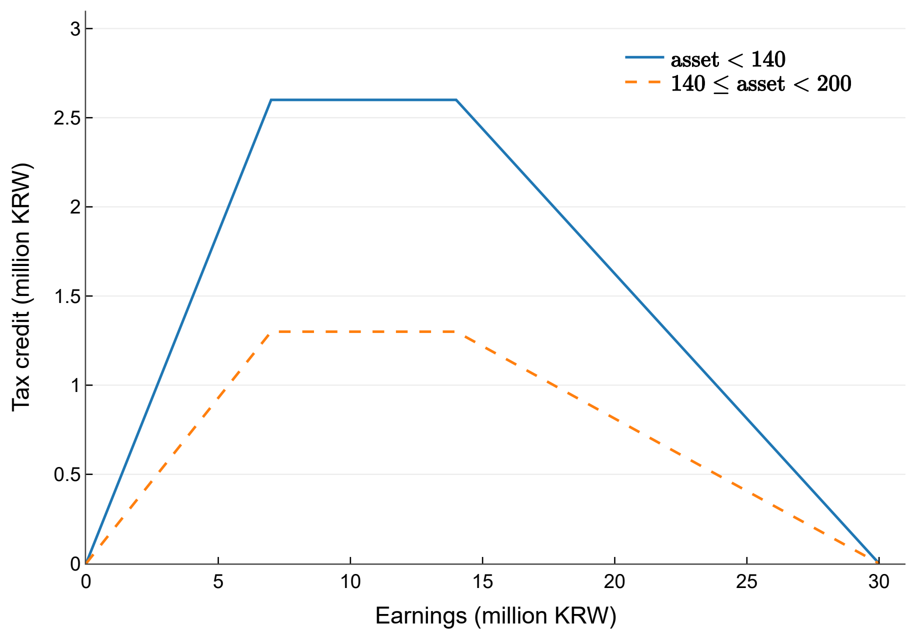


Figure 1: EITC schedule for married single-earner, 2019, Korea

2.2 Public pension

From the mandatory retirement age, an individual receives pension benefits $\xi(e, n)$, the amount of which depends on the individual's contribution period, n, and the individual's average taxable earnings over the contribution period, e, as follows:[11,12]

$$\xi(e,n) = \kappa(E+e)n \tag{3}$$

where E denotes the economy-wide average taxable earnings, and κ is the scale parameter that controls the replacement rate of the pension benefit.

Notice that the pension benefit ξ increases with the contribution period n, which indicates that the employment response to the EITC during working age could increase pension income in retirement.

The expenditure for the pension benefit is financed by the pension contribution in a pay-as-you-go fashion. The contribution rate is τ_p, and it is applied to labor earnings y up to the taxable maximum of $\bar{y}$.

[The figure for the pension benefits to be inserted]

2.3 Income

Until the mandatory retirement age, individuals earn before-tax labor earnings $y = w\epsilon_j z$ if they work at each age j. w is the market wage rate, ϵ_j is the age-specific component of labor productivity, and z is a persistent idiosyncratic shock to labor productivity. Individuals also receive returns on their asset holdings a at a risk-free interest rate r for each period.

Labor earnings is subject to a progressive income tax $T(y)$ as well as public pension contributions, as explained in the preceding subsection. Returns on asset holdings, ra, are subject to proportional capital income tax at a rate of τ_k.

Working-age individuals can receive three kinds of welfare transfers: the EITC $\psi(a,y)$; lump-sum transfer tr; and welfare benefits to those not working Ω. We separate Ω and tr to reflect the regressive nature of public transfer programs in a simple way. Retired individuals receive pension benefits $\xi(e,n)$, the amount of which is determined by their own labor market histories, as well as a lump-sum transfer to the retiree bp (basic pension).[13]

[11] The pension benefit formula is constructed based on the National Pension Service of Korea. Details of the manipulation are left in the appendix.

[12] Pension benefits are provided for those with a contribution period of at least 10 years as of retirement age. The author confirmed that all individuals in the simulated economies work for more than 10 years throughout their lives.

[13] The basic pension in Korea is a means-tested old-age income support program that plays a similar role to the

Thus, disposable income before retirement is market income minus income taxes and pension contributions, plus the tax credit $\psi(a, y)$, welfare benefits tr and $\Omega(h)$. The retiree's disposable income is after-tax asset income plus pension income $\xi(e, n)$ and basic pension bp.

2.4 Individual's problem

Individuals enter the economy at age 25 (which corresponds to age 1 in the model economy) with the same initial asset holdings of $a_{j=1}$. Until the retirement age of J_R, they choose whether or not to work at each age j if they are alive with the probability $\prod_{k=1}^{j} \phi_k$. They also make consumption-savings decisions every period. An individual's problems consist of working-age periods and retirement periods.

Recursive form of the working-age individual's $(j < J_R)$ problem is,

$$V_j(a, z, e, n) = \max_{c, a', h} \log c - \nu_j h + \beta \phi_{j+1} E_{z'|z} V_{j+1}(a', z', e', n') \tag{4}$$

subject to

$$\begin{aligned}
(1 + \tau_c)c + a' &= y + (1 - \tau_k)ra + a - T(y) - \tau_p \cdot \min\{y, \bar{y}\} + \psi(a, y) + \Omega \cdot (1 - h) + tr \\
y &= w\epsilon_j z h \\
e' &= \frac{e \cdot n + \min\{y, \bar{y}\}}{n'} \\
n' &= n + h \\
a' &\geq 0, \quad c \geq 0, \quad h \in \{0, 1\},
\end{aligned}$$

where $V_j(a, z, e, n)$ denotes the discounted expected lifetime utility of an individual at age j with asset holdings a, idiosyncratic labor productivity z, career average earnings e, and contribution period n. The next-period utility is discounted by the time discount rate β and the (conditional) survival probability ϕ_{j+1}, and also the expectation is taken over the realization of the next-period labor productivity z'. (The logarithm of) z is assumed to exogenously evolve over the life cycle

Supplemental Security Income in the US. We do not incorporate its means-tested feature into the model because the means-test is quite generous. In 2019, almost 70% of those aged 65 or above received the benefits, and more than 80% of the beneficiaries received the maximum benefits (according to the Ministry of Health and Welfare).

according to an AR(1) process as in eq. (5).[14] The four individual state variables, (a, z, e, n), imply that individuals at the same age j could be different in those dimensions. The exogenous evolution of idiosyncratic labor productivity over the life cycle is the driving force behind this within-cohort heterogeneity.

$$\log z' = \rho_z \log z + \epsilon'_z, \quad \epsilon'_z \sim i.i.d\ N(0, \sigma_z^2) \tag{5}$$

Consumption and savings decisions are represented by c and a', respectively. Borrowing is not allowed, and consumption is subject to tax at a rate of τ_c. It is worth noting that the labor supply h is modeled as a binary variable with a value of 0 or 1, indicating that individuals are allowed to choose the labor supply at the participation margin. Participation in the labor market entails a fixed utility cost ν_j that varies with age j. Also, if an individual works ($h = 1$), his contribution period n increases by one (year), and his career average earnings e is updated, affecting his future pension benefits as described in Section 2.2. The other terms in the set of constraints are as explained in the preceding subsection.

Recursive form of the retiree's ($j \geq J_R$) problem is,

$$V_j(a, e, n) = \max_{c, a'} \log c + \beta \phi_{j+1} V_{j+1}(a', e, n) \tag{6}$$

subject to

$$\begin{aligned}
&(1 + \tau_c)c + a' = \xi(e, n) + bp + (1 - \tau_k)ra + a \\
&a' \geq 0, \quad c \geq 0,
\end{aligned}$$

where pension benefits ξ and basic pension bp are as described in Sections 2.2 and 2.3. Retirees only decide how much to consume and save in each period while facing only mortality risks. Notice that z has been removed from the individual state variables, and the state variables related to pension income, e and n, no longer change over time.

The important departure of our model from the previous structural analysis of the tax credit is that it embeds the linkage between one's labor market history, e and n, and pension income

[14] This is similar to the settings in Athreya et al. (2014) and Blundell et al. (2016).

ξ in retirement. With this pension tax-benefit link, the EITC potentially has a spillover effect on pension income through its impact on labor supply. Moreover, the magnitude of the labor supply response to the tax credit would also change due to the dynamic return on labor supply.

In this environment, individuals make savings decisions to smooth consumption over the state of labor productivity and over the life cycle.

3 Calibration

This section describes the calibration of the baseline model economy. The baseline economy features general equilibrium so that factor prices and tax rates are determined in equilibrium by market clearing conditions and balanced budget conditions. We calibrate this general equilibrium economy to the data, but the equilibrium variables are held fixed when conducting counterfactual analyses. Therefore, further details of the model regarding general equilibrium are left in Appendix A.2.

3.1 Demographics and preferences

The mandatory retirement age and the maximum age are set to 66 and 100, respectively. Conditional survival probability by age $\{\phi_j\}_{j=2}^{J}$ (upon survival at age $j-1$) is constructed from the Life Table (2015) by Statistics Korea. Figure 2 depicts the survival probabilities, which shows that the mortality risk is pronounced in retirement periods. Age-dependent fixed utility cost of work $\{\nu_j\}_{j=1}^{J_R-1}$ is calibrated to match the employment rate by age in the data, using the power function: $\nu_1 + \nu_2 \cdot j^{\nu_3}$.[15] Discount rate β is set to match the annual real interest rate of 4%.

3.2 Endowments

The initial wealth $a_{j=1}$ is calibrated to match, together with the age-dependent utility cost of work, the employment rate at age 25. The calibrated initial wealth is 6 million KRW which is about one-third of the mean earnings at age 25 (cf. Huggett and Kaplan, 2016). The age-specific component of labor productivity $\{\epsilon_j\}_{j=1}^{J_R-1}$ is estimated using the Survey of Household Finances

[15] Employment rates are computed using the Economically Active Population Survey data from Statistics Korea for 2015–2019.

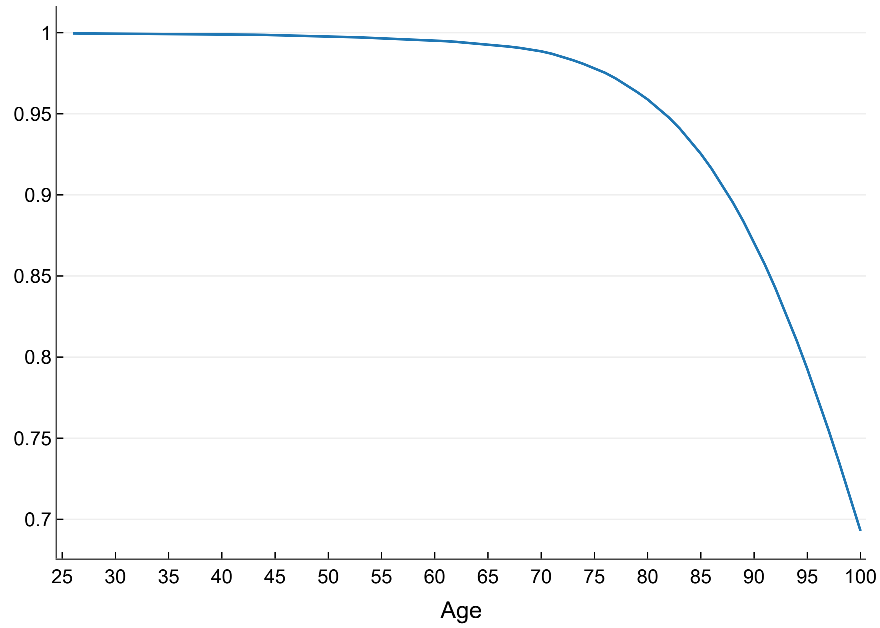


Figure 2: Conditional survival probability by age ϕ_j

Source: Life Table (2015)

and Living Conditions (SHFLC, henceforth) data. The advantage of the SHFLC is that the surveyed information on labor earnings is complemented by administrative data, which allows us to precisely estimate the age-earnings profile. We regress the log of annual labor earnings to age and age squared, then take an exponential to the estimated polynomial function and normalize the productivity at age 25 by one. The result is illustrated in Figure 3, which shows the standard hump-shaped age profile peaking around the mid-forties.

The persistence ρ_z and the variance σ_z^2 of the AR(1) process for idiosyncratic productivity, described in eq. (5), are set to 0.773 and 0.04, respectively. The values are taken from Han et al. (2019).[16,17] The stochastic process is approximated into a 27-state Markov chain following Tauchen (1986). Also, the logarithm of initial productivity $z_{j=1}$ is drawn from the normal distribution with mean 0 and variance $\sigma_z^2/(1-\rho_z^2)$.

[16] They develop a large-scale heterogeneous-agent overlapping-generations model, in which agents differ by sex and marital status and have both extensive and intensive margin labor supply choice, to assess the macroeconomic impact of the EITC reform in Korea. They estimate the persistence of the AR(1) process from a Korean household panel data and find variance that matches income Gini in the data.

[17] The values are also similar to the estimates in Chang and Kim (2006).

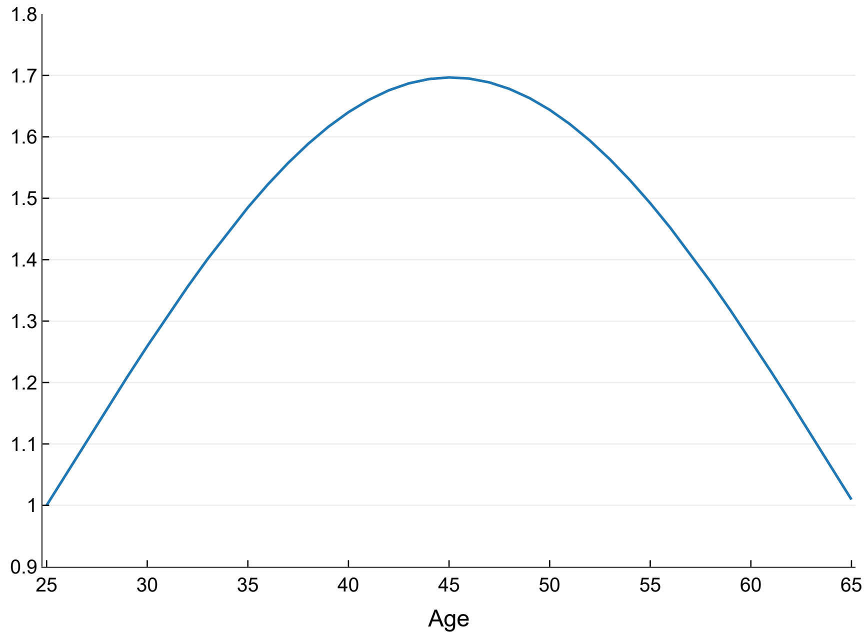


Figure 3: Age productivity profile ϵ_j

Source: SHFLC, 2019

Parameter	Value	Description	Target/source
Demographics			
J_R	42	retirement age	66 years old
J	76	maximum age	100 years old
$\{\phi_j\}_{j=2}^{J}$	-	survival probability by age	Life Table (2015)
Preference			
$\{\nu_j\}_{j=1}^{J_R-1}$	-	disutility of work by age	employment rate by age
β	0.9767	discount rate	$r = 4\%$
Labor Productivity			
$\{\epsilon_j\}_{j=1}^{J_R-1}$	-	average productivity by age	estimated
ρ_z	0.773	persistence of shock	Han et al. (2019)
σ_z^2	0.04	variance of shock	Han et al. (2019)
Initial conditions			
$a_{j=1}$	0.06	initial asset holdings	employment rate at age 25
$\sigma_{z_{j=1}}^2$	0.10	variance of initial productivity	$\sigma_z^2/(1-\rho_z^2)$

Table 1: Parameter values for economic environment

3.3 Tax and transfer

Parameters for the EITC are constructed from the National Tax Service of Korea. Figure 1 graphically illustrates the tax credit schedule for families with a single-earner. Those with (positive) annual labor earnings below 30 million KRW($\approx$ 30,000 USD) and asset holdings lower than 200 million KRW are eligible for the tax credit up to a maximum of 2.6 million KRW.[18]

To account for the progressivity in the labor income tax schedule, we adopt the functional form used in Heathcote et al. (2017) as in eq. (7). The progressivity parameter τ_l in the equation is then estimated using the SHFLC data. The procedure and the results for the estimation are presented in Table A1 in Appendix A.1. The estimate for τ_l is 0.02, which is quite low compared to the literature. This is primarily because our measure of progressivity is for pure tax components, excluding transfer components that make the tax-transfer system substantially progressive. Also, the progressivity of income tax in Korea is known to be quite lower than that of other countries (Chang et al., 2018). The average rate component of the labor income tax schedule, λ_l, is then calibrated to match the ratio of the income tax revenue to GDP.

$$T(y) = \max\{0, y - \lambda_l \cdot y^{1-\tau_l}\} \tag{7}$$

Welfare benefits for the non-employed, Ω, is set to the average difference in public transfer income between workers and non-workers. Using the SHFLC data, we estimate Ω by regressing public transfer income (net of the tax credit) on a dummy for those who earned less than 5 million KRW($\approx$ 5,000 USD) with controls for various socio-demographic factors that could affect eligibility conditions and the benefit amount, such as marital status, number of household members, and housing conditions. The regression result is presented in Table A2 in the appendix. The lump-sum transfer to the working-age individual, tr, is then set to match, together with Ω, total welfare expenditure over GDP. As a result, Ω and tr are set to 3.9 million KRW and 2.6 million KRW, respectively. The basic pension bp is set to match the basic pension expenditure as a percentage of GDP.

3.4 Public pension

Finally, the contribution rate of the public pension system τ_p is set to 12.9%, which satisfies the government pension budget as eq. (IA.4) in Appendix A.2.3. The maximum taxable earnings $\bar{y}$ is

[18] Hereafter, KRW is used to denote the Korean Won and USD denotes the US Dollar. For simplicity, we use the exchange rate of 1,000 KRW = 1 USD, which is close to the historical average.

Parameter	Value	Description	Target/source
EITC			
β_{in}	0.37143	phase-in, slope	National Tax Service, 2019
$\bar{\psi}$	0.026	maximum tax credit	NTS, 2019
α_{out}	0.04875	phase-out, intercept	NTS, 2019
β_{out}	0.16250	phase-out, slope	NTS, 2019
$\{\bar{a_1}, \bar{a_2}\}$	{1.4, 2.0}	asset holdings thresholds	NTS, 2019
Tax and Transfer			
τ_c	10%	consumption tax rate	VAT
τ_k	30%	capital tax rate	literature
τ_l	0.02	progressivity of income tax	estimated
λ_l	0.913	scale parameter of income tax	$T_l/Y = 4.6\%$
Ω	0.039	transfer to non-employed	estimated
tr	0.026	lump-sum transfer	$Welfare/Y = 7.4\%$
bp	0.012	basic pension	$BP/Y = 0.8\%$
Public Pension			
τ_p	12.9%	contribution rate	balanced budget
$\bar{y}$	0.5880	maximum taxable earnings	current system
E	0.4146	economy-wide average earnings	equilibrium outcome
κ	0.005	scale parameter (replacement rate)	current system

Table 2: Parameter values for government policy

determined by multiplying the current system's maximum taxable monthly earnings (4.9 million KRW $\approx$ 4,900 USD) by 12. The economy-wide average taxable earnings E is determined in equilibrium of the baseline economy, as described in eq. (IA.5) in Appendix A.2.3. The scale parameter κ is set to 0.005, which achieves the replacement rate of 40% for retirees whose career average earnings are equal to the economy-wide average and whose contribution period is 40 years, as in the current system.[19,20]

3.5 Model fit

The model economy successfully replicates some salient features in the data. For the targeted moments, the employment rate by age generated by the model well matches the data which shows a hump-shaped profile (see Figure 4). Also, the size of tax revenues and expenditures compared to GDP is quite similar to the data (see Table 3).

[19] One can easily see that $\xi(e = E, n = 40) = 0.4E$ when $\kappa = 0.005$ from eq. (3).

[20] To be precise, the scale parameter κ is under reform so that the average replacement rate gradually goes down to 40% in 2028 (from 50% in 2008). Since the purpose of this study is to analyze the long-term effect of the EITC under a stable public pension system, the average replacement rate is assumed to be constant at 40%.

For the moments that are not targeted, the distribution of income and wealth is replicated quite well by the model economy (rows (1) and (2) in Table 4). The calibrated model also successfully generates the moments related to the EITC (rows (3), (4), and (5) in Table 4). The expenditure for the EITC is about 0.2% of GDP both in the model and the data. In the model economy, EITC recipients account for 11% of the working-age population, which is slightly higher than the data. The data shows that the recipiency rate is the highest at ages below 40, decreases in the 40s, then increases at age 50 or above. Although the model economy overstates the recipiency rate at a younger age and understates it at middle age, the overall pattern is similar to the data. The average tax credit the recipient gets is 1.04 million KRW ($\approx$ 1,040 USD) in the data, and it is 0.80 million KRW in the model.

Finally, how responsive is labor supply to financial incentives in the model economy? We compute the elasticity of labor supply to $\pm$ 2% changes in wage rate holding the wealth distribution (including the public pension wealth, e and n) fixed to the baseline economy. The aggregate elasticity implied by the model is 0.72, which is roughly in line with the estimates in Moon and Song (2016). They estimate the labor supply elasticity in Korea using Fiorito and Zanella (2012)'s methodology and a Korean household panel data set. Their point estimate of the elasticity is 0.23 at the intensive margin (hours of those employed) and 0.93 at the total margin (including both the intensive and extensive margins).[21] Moreover, the model-implied aggregate elasticity at the extensive margin is similar to that found in other structural studies such as Chang and Kim (2006) and Erosa et al. (2016). Furthermore, the elasticity exhibits a U-shaped pattern over the life cycle (see Figure 5), which has been documented in the earlier structural analyses (Rogerson and Wallenius, 2009; Erosa et al., 2016; Fan et al., 2022).[22]

4 Quantitative analysis

In this section, we start by analyzing the effects of the tax credit by removing the existing program from the baseline economy and comparing the two steady-states: one with the EITC and

[21] Note, however, that the estimate for the latter is statistically insignificant, possibly due to the small sample size. Nonetheless, the finding that the elasticity at the total margin is much larger than the one at the intensive margin is consistent with Fiorito and Zanella (2012).

[22] Keane (2022) provides a review of recent research on labor supply, including the extensive margin labor supply elasticity in the aggregate and by age.

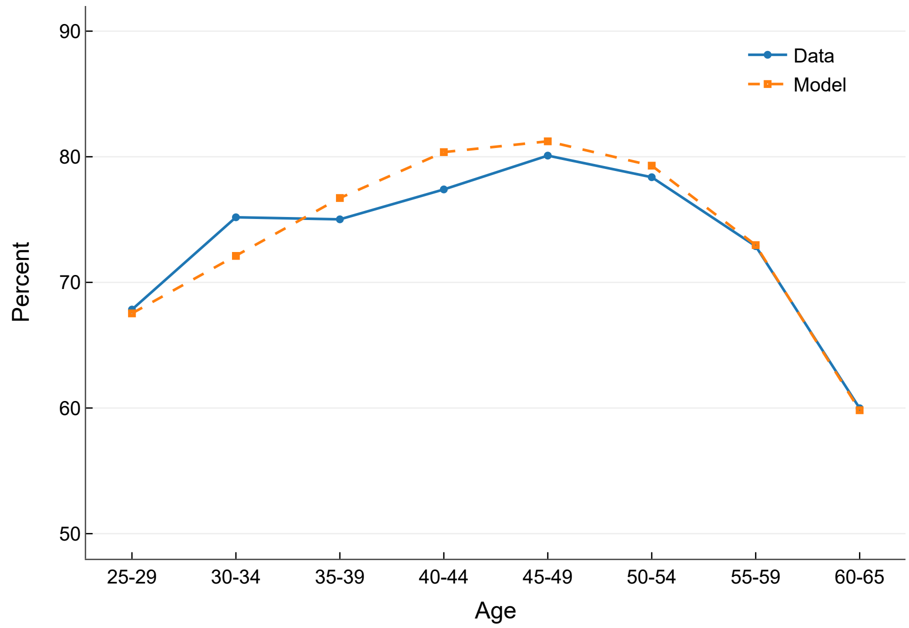


Figure 4: Employment rate by age

Source: Economically Active Population Survey, 2015–2019

	Income Tax	Capital Tax	Cons. Tax	Welfare Benefits	Basic Pension
Data	4.6%	4.1%	4.0%	7.4%	0.8%
Model	4.6%	3.6%	6.5%	7.4%	0.8%

Note: Data refers to 2016–2019 economy.
Source: OECD database, Ministry of Health and Welfare.

Table 3: Government budget relative to GDP

one without the EITC. This allows us to understand how the tax credit policy affects labor supply over the life cycle and the consequent effects on earnings and pension income.

We then repeat the same exercise while shutting down the pension tax-benefit link. By comparing the two results—with and without the pension tax benefit link—we can identify the role of the *public pension channel* in the impact of the tax credit on lifetime income and welfare.

Throughout the analysis, we proceed in partial equilibrium, in which wages, interest rates, and tax rates are held fixed to the baseline economy. This setting is consistent with the previous studies, thus allowing us to concentrate on the role of the pension tax-benefit link in the direct effect of the tax credit.

			Data	Model
(1)	Disposable income Gini		0.339	0.313
		Q1	0.5	0.8
		Q2	5.1	5.2
(2)	Wealth share (%)	Q3	11.5	14.2
		Q4	21.4	27.0
		Q5	61.5	52.8
(3)	EITC to GDP ratio (%)		0.20	0.19
(4)	EITC recipiency rate (%)		10.4	11.4
		<40	12.7	16.0
	by age group	40–49	7.5	3.6
		≥50	9.8	11.2
(5)	Average EITC (million KRW)		1.04	0.80

Note: Data refers to 2019 economy. Data for the EITC expenditure is computed based on recipients aged 69 or below to be consistent with the model. The expenditure for those aged 66–69 is included because the relevant information in administrative data from the National Tax Service is provided based on a 10-year-old basis. Similarly, data for the EITC recipiency rate is computed based on recipients aged 69 or below, the data for ages below 40 is based on those aged 20–39, and the data for ages 50 or above is for those aged 50–69.
Source: National Tax Service 2019, Statistics Korea 2019, SHFLC 2019–2020.

Table 4: Untargeted moments

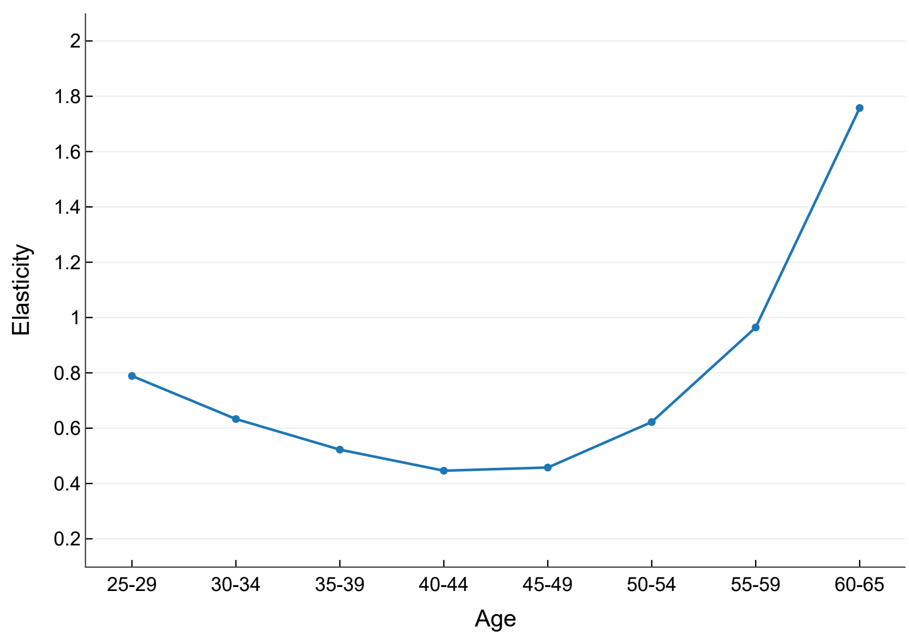


Figure 5: Elasticity by age

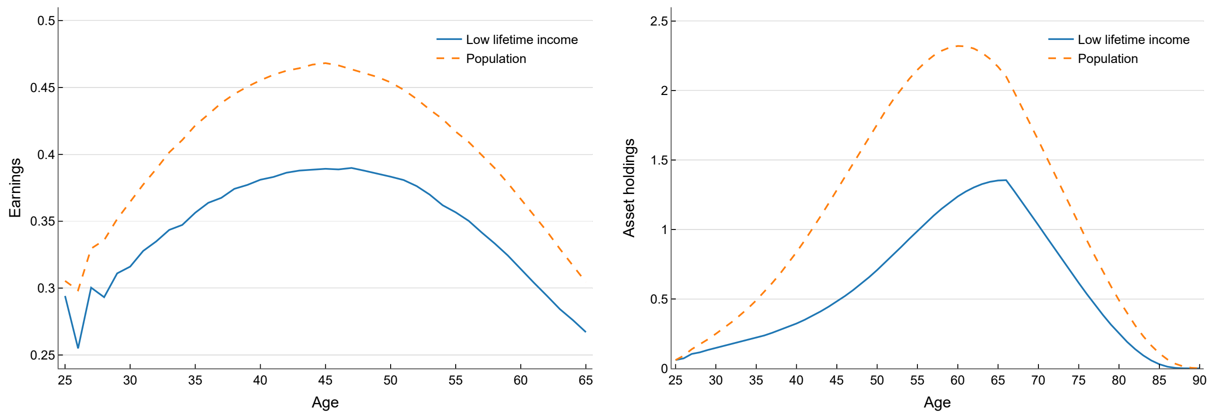
4.1 Who is mainly affected?

Before jumping into the analysis, it is necessary to determine the target population—mainly affected by the tax credit over the life cycle—because we will focus on the direct effect of the EITC, and the model encompasses the entire population of the economy. A natural candidate for the target group is newborns with unfavorable labor productivity histories: their lifetime earnings and wealth would be low and thus likely to satisfy the earnings test and asset test of the tax credit over their lives.

We define *low lifetime income* as newborns whose present value of lifetime disposable income belongs to the lowest 30% in the baseline economy.[23] Figure 6 compares the median age profile of earnings (conditional on employed) and wealth for the low lifetime income group with those of the population. As can be seen from the figures, in comparison to the overall population, their median earnings and wealth are consistently low over their lives. This result suggests that the chosen group is a plausible candidate for the target population.

The bar graph in Figure 7 displays the proportion of the low lifetime income group among the EITC recipients by each age group. As expected, the low lifetime income group accounts for the majority of the EITC recipients. The relatively low share at earlier ages is due to the model environment where every individual enters the economy with the same amount of low initial wealth and age-specific labor productivity is relatively low at earlier ages. Recall that the stochastic process for the idiosyncratic component of productivity is persistent, which implies that a high realization of productivity at an age likely results in high productivity the next year. Therefore, higher lifetime income groups earn more and accumulate more wealth over their lives, which makes them gradually ineligible for the EITC. That is why the low lifetime income group shares most of the recipients after the earlier stage in life. From now on, we will concentrate on the impact of the tax credit on the *low lifetime income*.

[23] The present value of lifetime income is computed as the sum of disposable income at each age discounted by after-tax asset return and survival probabilities.



(a) Labor earnings (b) Asset holdings

Figure 6: Median earnings and assets by age for low lifetime income and population

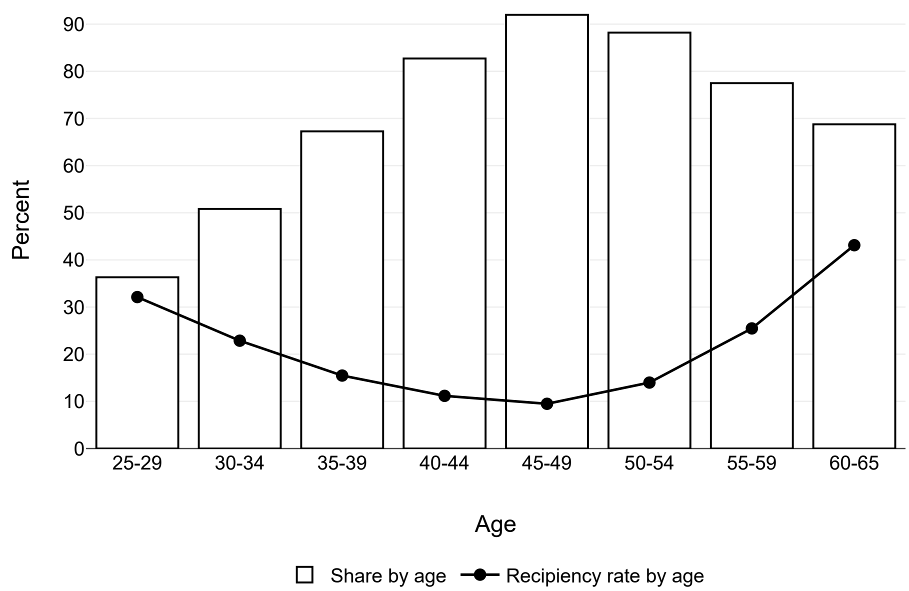


Figure 7: Low lifetime income's share of EITC recipients and recipiency rate by age

4.2 Results with the pension tax-benefit link

In this subsection, we contrast the economies with and without the EITC in the baseline environment where the pension tax-benefit link is present. We first examine the EITC's effects on labor supply and income during working life and show how it affects pension income in retirement. Then the impacts on lifetime income and the importance of the changes in each source of income are analyzed. Note that all the results below show the average effects on the low lifetime income

		By age			Before
		25–39	40–49	50–65	retirement
(1)	Employment rate (pp)	1.90	0.61	3.20	2.09
		(1.72)	(−0.001)	(1.83)	(1.34)
		Unit: million KRW			
(2)	Tax credit	0.219	0.076	0.224	0.186
		(0.183)	(0.037)	(0.053)	(0.097)
(3)	Labor earnings	0.281	0.056	0.648	0.369
		(0.223)	(−0.053)	(0.453)	(0.245)
(4)	Taxes on earnings	0.050	0.009	0.121	0.068
		(0.039)	(−0.011)	(0.086)	(0.045)
(5)	Other transfers	−0.074	−0.024	−0.125	−0.082
		(−0.067)	(0.0001)	(−0.071)	(−0.052)
(6)	Post-tax earnings	0.157	0.023	0.402	0.219
		(0.117)	(−0.042)	(0.296)	(0.148)
(7)	Disposable income	0.352	0.008	0.448	0.306
		(0.277)	(−0.069)	(0.251)	(0.182)

Note: The per-period changes in level compared to the economy without the EITC are reported. The units for incomes and taxes are million KRW (≈ thousand USD). Taxes on earnings include labor income tax and pension contribution. Post-tax earnings (6) are computed as labor earnings (3) plus other means-tested transfers (5) minus taxes on earnings (4). Parentheses are results from a setting without the pension tax-benefit link.

Table 5: Changes in employment rate and income by age

group.

4.2.1 Effects on labor supply and earnings

Table 5 reports the changes in the employment rate, tax credit receipts, labor earnings, taxes on earnings, other means-tested transfers, post-tax earnings, and disposable income compared to the economy without the EITC. The results are presented for the whole working life and by age. It should be noted that the figures in the table show the *per-year* change in *level* during each period of life.

As row (1) of the table shows, the labor supply of the low lifetime income group goes up by 2.09 percentage points and it increases mainly at an earlier stage of life and near retirement. The (annual) employment rate goes up by almost 2 percentage points at ages below 40 and more than 3 percentage points during the 50s and 60s. This is mainly because the recipiency rate at those ages is relatively high, as shown in the solid line in Figure 7. The U-shaped age profile of the recipiency rate stems from the hump-shaped age earnings profile, as in Figure 6a, and the earnings test of the EITC (see Figure 1). In addition, we note that the labor supply near retirement is the most responsive even after controlling for the receipts of tax credits. The average tax credit receipts during the early stages of life and near retirement are similar (row (2) of Table 5), but the increase in employment rate is larger at an older age. Although we do not report in the table, the aggregate employment rate goes by 0.93 percentage points.[24]

The magnitude of the labor supply responses we find using the structural model is roughly in line with the empirical findings of Park and Lee (2018). They exploit the introduction and subsequent reforms of the EITC in Korea to estimate its impact on labor market participation using various household panel data sets, empirical specifications, and sample periods. Their (statistically significant) estimates imply that the program's introduction in 2008 and reforms up to 2016 (or 2013) raised the aggregate employment rate by around 0.19 to 0.54 percentage points.[25,26] Given that further expansions since then had more than doubled the number of recipient households in 2019, our result of a 0.93 percentage point increase in the employment rate due to the introduction of the 2019 EITC is within the range of their estimates.[27] Park and Lee (2018) also find that the labor supply effect on those aged 60–65 is about twice the average effect. This is supporting evidence of the result that the labor supply response at an older age is considerably large.[28] Moreover, the result is consistent with the large elasticity of labor supply near retirement implied by the structural life-cycle model developed in this article (see Section 3.5) and many others (e.g., French, 2005; Erosa et al., 2016; Fan et al., 2022).

The next important step is to evaluate the changes in earnings and income due to the labor supply response to the tax credit. The first column of row (2) shows that the low lifetime income

[24] The contribution of the low lifetime income group's labor supply response to the change in the aggregate employment rate is 67% (computed as 2.09 pp multiplied by 30% over 0.93 pp).

[25] Specifically, they use a linear probability model of labor market participation and exploit individual variations in EITC eligibility (except for the condition of positive earnings below some limit) over time caused by the policy reforms. For example, all singles could not receive the tax credit until 2012, but from 2013, singles aged 60 or above can get the tax credit if satisfying the other qualifications. To infer the impact on the aggregate employment rate from their estimates, let us take an estimate from the sample period of 2005–2013 that shows a 4.4 percentage point increase in the employment rate of the newly eligible. They report that the share of the eligible (again, except for the positive earnings condition) among the sample was about 16% in 2013 (from 0% in 2005). They only include the heads of households as a sample, who account for approximately 60% of the population aged 20–64. By multiplying the three numbers (4.4 percentage point, 16%, and 60%), we can infer that the expansions of the EITC during the period raised the aggregate employment rate by 0.42 percentage points.

[26] The observed aggregate employment rate rose by 2 percentage points from 2007 to 2016.

[27] It should also be noted that the maximum tax credit was raised by 30–95% during this period (depending on the type of household).

[28] Laun (2017) also finds that the Swedish tax credit reform for workers aged 65 or over increased their labor market participation.

group receives tax credits of about 0.22 million KRW per year at ages below 40. In addition, their earnings increase by about 0.28 million KRW per year due to the rise in labor supply (see row (3)). Note that the (per-period) increase in labor earnings is roughly 25% larger than the tax credit receipts. Even after controlling for the rise in labor taxes (row (4)) and the decline in other means-tested transfers (row (5)), the increase in post-tax earnings is more than two-thirds of the receipts of tax credits. The relative importance of the rise in earnings compared to the tax credit receipts becomes even larger at an older age. At ages 50–65, the increase in post-tax earnings is nearly *two times* larger than the receipt of tax credits. The sizable labor supply response at these ages drives the result. Finally, during the whole working life, the per-period increase in post-tax earnings is 18% larger than the receipts of tax credits (the last column of the table). The results show the importance of considering the earnings responses in analyzing the income-increasing effects of the EITC, as emphasized in Hoynes and Patel (2018).

How comparable are the results from the model to the estimates in Hoynes and Patel (2018)? Their reduced-form estimates using the sample aged 24 to 48 imply that the increase in labor-related income (labor income minus taxes on earnings plus other means-tested transfers) is 23% larger than the increase in tax credits net of labor taxes, on average.[29] The magnitude implied by our model is quite larger than theirs. The average increase in labor-related income at ages 25 to 49 is about double the rise in tax credit receipts net of labor taxes. This discrepancy may come from the institutional differences in other means-tested transfers between the two nations. The crowding out of other means-tested transfers due to the labor supply response is much smaller in our case. The decline in other means-tested transfers is smaller than one-third of the increase in earnings in our model, whereas it is greater than 80% in the estimates in Hoynes and Patel (2018). If we control this factor, the magnitudes become quite similar.

4.2.2 Effects on pension income

So far, we have confirmed the previous findings that the EITC increases labor market participation and that the labor supply response amplifies the income-increasing effects of the tax credit. Their magnitudes are also in line with the literature.

We now take a step further and examine how the labor supply response to the tax credit before

[29] See Table 4 in Hoynes and Patel (2018).

	EITC		Change (%)
	without	with	
Contribution periods (years)	29.62	30.48	0.86 (2.9%)
Career average earnings (million KRW)	36.09	35.58	−0.52 (−1.4%)
Pension income (million KRW)	11.49	11.74	0.25 (2.2%)

Note: The units for contribution periods are years, and the units for career average earnings and pension income are million KRW (≈ thousand USD). Contribution periods and career average earnings are as of age 66. Parentheses report proportional changes.

Table 6: Effects on pension income

retirement affects pension income after retirement. First, due to the increase in labor market participation, lifetime earnings and pension contributions go up by 1.4%. How are pension benefits, then, affected by the rise in pension contributions?

Recall that pension benefits are increasing in contribution periods and career average earnings (see eq. (3)). Table 6 reports contribution periods, career average earnings, and pension income—all as of retirement age on average—in the economies with and without the EITC. The last column of the table shows the differences between the two economies. First, due to labor supply responses during working age, contribution periods increase by 0.86 years (2.9%) on average (from 29.62 to 30.48 years).[30] This increase in contribution periods would raise pension income by 0.33 million KRW, assuming average earnings over the contribution period remain unchanged. However, career average earnings slightly go down, which mitigates the rise in pension income. The decrease in career average earnings is because the EITC-induced labor market participation mainly occurs at a lower productivity age. As a result, the annual pension income increases by 0.25 million KRW (2.3%).

How large is the increase in pension income relative to the receipts of tax credits? The increase in annual pension income is 34% larger than the receipts of tax credits per year during working life (the last column of row (2) in Table 5). Considering the per-period increase in post-tax earnings during the working age is 18% larger than the tax credit receipts, the spillover effect on pension income is substantial. The result indicates that ignoring the long-term impact on pension income would considerably underestimate the tax credit's effect on lifetime income.[31]

[30] Notice that one period in the model corresponds to one year, so individuals can choose to work one or two (or more) more years over their lives in response to the introduction of the tax credit, and that we examine the average response of the low lifetime income group. Therefore, a 0.86 years increment in contribution periods means that the low lifetime income group works 0.86 more years *on average*.

[31] Another implication of the results is that the tax credit policy for the working age can be used to prevent elderly

	Tax-benefit link	
	with	without
Tax credit	7.38	3.91
Post-tax earnings	8.59	5.75
Pension income	4.57	-
Disposable income	15.80	7.05
Consumption equivalence (%)	0.73	0.52

Note: Changes in levels compared to the economy without the EITC, except for the consumption equivalence. The units for incomes and taxes are million KRW (≈ thousand USD). Post-tax earnings are computed as labor earnings plus other means-tested transfers minus taxes on earnings. Lifetime incomes are discounted by survival probabilities.

Table 7: Changes in lifetime values compared to the economy without the EITC

4.2.3 Effects on lifetime income and welfare

Next, we examine how the EITC affects lifetime income and decompose the contribution of each income source. The first row in Table 7 shows the overall amount of tax credits received over the life cycle. The second to fourth rows in the table report the level changes in lifetime post-tax earnings, lifetime pension income, and lifetime disposable income. Note that survival probabilities are taken into account when computing the lifetime values.

The left column of the table first shows that the low lifetime income group receives 7.4 million KRW of tax credits over their lives. Due to the employment response to the tax credit, their lifetime post-tax earnings increase by 8.6 million KRW, which is 16% larger than the receipts of tax credits. The increase in post-tax earnings accounts for more than *half* of the increase in lifetime income. This result confirms the argument of Hoynes and Patel (2018) in a life-cycle context. Furthermore, lifetime pension income goes up by 4.6 million KRW, which amounts to 60% of the lifetime receipts of the tax credit. The increase in pension income explains more than a *quarter* of the increase in lifetime income. Due to the pervasive mortality risk during retirement periods, the relative importance of pension income compared to earnings declines significantly in a life-cycle context. Nevertheless, it is still an essential element in understanding how the EITC affects lifetime income.

The last row of Table 7 shows the welfare consequence of the tax credit in terms of consumption equivalence. The value of the existing EITC in Korea is equivalent to a 0.73% increase in per-period

poverty *in advance* through the labor supply responses that interact with the tax-benefit link of public pensions.

consumption for newborns with unfavorable productivity histories.[32]

4.3 Role of the pension tax-benefit link

The previous subsection shows that the spillover effect of the EITC on pension income is quantitatively sizable by comparing the economies with and without the EITC in the presence of the pension tax-benefit link. However, this is not the whole story in the context of structural analyses of the tax credit. If the contribution-benefit link is absent from the model, the EITC's impacts on labor supply and earnings would also be understated. When the pension tax-benefit link exists, labor supply would be more responsive to the tax incentives because a marginal increase in labor supply raises both current earnings and future pension income. This is likely the case, especially for those nearing retirement, because the additional return on labor supply—pension income—is shortly realized as one gets closer to retirement.

In this last subsection, we compare the effects of the EITC with and without the pension tax-benefit link to complete the picture of how much we miss by not accounting for the *public pension channel* in the structural life-cycle model.

The parentheses of Table 5 report the results from a setting without the pension tax-benefit link.[33] Compared to the results from the model with the tax-benefit link, the labor supply responses to the tax credit become smaller. The overall increase in employment rate is 0.8 percentage points lower without the tax-benefit link (the last column of row (1)). While the differences are modest at an earlier age, they get larger nearing retirement, as expected. If the pension tax-benefit link is closed, the employment response becomes 0.2 percentage points lower among the young, 0.6 percentage points smaller at middle age, and 1.4 percentage points smaller near retirement (see row (1) of Table 5). As a result, the impact on post-tax earnings in pre-retirement periods is understated similarly. Moreover, the receipts of tax credits also decline due to the smaller labor supply response.

This result is in line with the empirical findings of Liebman et al. (2009). They estimate the

[32] Consumption equivalence is computed as $CEV = \exp\left[\{\sum_{j=1}^{J} \beta^{j-1} (\prod_{s=1}^{j} \phi_s)\}^{-1} (W^{TC} - W^{NO})\right] - 1$. W^{TC} and W^{NO} represent the ex-ante lifetime expected discounted utility of a newborn in the steady states of the economies with and without the EITC, respectively.

[33] Specifically, we first solve the models with and without the EITC under the setting without the pension tax benefit link to derive decision rules. Then 50,000 individuals are simulated using the decision rules, holding the distribution of (e, n) fixed at the baseline economy (with the EITC and the pension tax-benefit link).

labor supply responses to the tax-benefit link of US Social Security. Their results show that individuals aged 52 or above respond to the Social Security tax-benefit link on the extensive margin of labor supply.[34]

Therefore, by not incorporating the contribution-benefit link into the model, the EITC's effect on pre-retirement income is underestimated, as well as its impact on pension income is overlooked. Taking these together, the increase in lifetime income is 55% smaller in the setting without the pension tax-benefit link (42% in the present discounted value). The welfare effect of the EITC, which also takes into account the changes in the value of leisure, is 29% smaller if the linkage is omitted from the model.

5 Conclusion

In this study, we examine the effects of the EITC on labor supply, income, and welfare over the life cycle and highlight the role of the tax-benefit link of public pensions. Using the structural life-cycle model that is calibrated to the Korean economy, we show that incorporating the pension tax-benefit link into the model is crucial for analyzing the income-increasing and welfare effects, or the *benefit side*, of the EITC. The key factors for the quantitative significance of the tax-benefit link are (1) the spillover effect on pension income and (2) the impact on labor supply responses via the dynamic incentive for labor supply.

An interesting future research avenue would be to examine how robust the importance of the *public pension channel* would be with increasing life expectancy. When people live longer, on the one hand, the spillover effect on pension income would become more valuable, and thus the labor supply effect of the EITC would also become larger. On the other hand, it would induce benefit cuts to balance the pension budget, which weakens the tax-benefit link. Also, it would be interesting to compare the effects of the EITC on retirement income with those of the conventional old-age means-tested income support programs.

[34] The result is also related to Van der Klaauw and Wolpin (2008). They estimate a structural life-cycle model and, using the model, find that the labor supply response of low-income households to the changes in Social Security rules is larger at ages 62–69 than at an earlier age.

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A Appendix

A.1 Estimations

A.1.1 Labor income tax progressivity

- $\log(y - T(y)) = \log \lambda_l + (1 - \tau_l) \log y$
- The after-tax earnings $y - T(y)$ in the LHS is constructed from the data on labor earnings, income tax, employment insurance tax, and health insurance tax.
- When constructing after-tax earnings, all public transfers are excluded, so the estimate for τ_l represents the progressivity of pure tax component.
- Public transfers such as the tax credit and the public pension system are explicitly specified in the model.
- The sample is restricted to individuals who are aged 25–65, whose annual labor earnings are greater than 5 million KRW($\approx$ 5,000 USD), and who have no asset income, pension income, or income from self-employment. As a result, the constructed data for taxes $T(y)$ should only include taxes on labor earnings.
- Regression results are presented in Table A1.

	Estimate
$1 - \tau_l$	0.9796
	(0.0008)
$\log \lambda_l$	0.1126
	(0.0063)
Observations	3,497
R squared	0.9976

Data source: SHFLC, 2019. Sample criteria: individuals who are aged 25–65, earn greater than 5 million KRW, and have no asset income, pension income, or income from self-employment. Standard error estimates are in parentheses.

Table A1: Labor income tax progressivity

A.1.2 Welfare benefits to the non-employed

- The sample is restricted to household heads aged 25 to 65.
- Regression results are presented in Table A2.

	Estimate
$\mathbb{1}$(non-employed)	389.91
	(10.50)
$\mathbb{1}$(married)	28.68
	(9.13)
$\mathbb{1}$(female)	22.67
	(6.21)
$\mathbb{1}$(rent)	32.81
	(5.10)
$\mathbb{1}$(capital region)	-13.35
	(4.56)
Age	-8.69
	(2.28)
Age squared	0.08
	(0.02)
Number of household members	37.76
	(8.84)
Number of household members squared	-2.82
	(1.33)
Asset	-3.48
	(0.65)
Asset squared	0.03
	(0.01)
Constant	170.72
	(52.68)
Observations	12,979
R squared	0.1148

Data source: SHFLC, 2019. Sample criteria: household heads aged between 25 and 65. Unit: 10,000 KRW. Non-employed is defined to those who earned less than 5 million KRW. Standard error estimates are in parentheses.

Table A2: Welfare benefits to the non-employed

A.2 Additional features of the model

A.2.1 Demographics

The size of the entering cohort grows at a rate of n_p and it is set to 1.1%, which is the long-run average population growth rate in Korea (from 1965 to 2020). The population share by age $\{\theta_j\}_{j=1}^{J}$ is calculated as follows using the growth rate n_p and the conditional survival probability by age ϕ_j:

$$\theta_j = \theta_{j-1} \cdot \frac{\phi_j}{1+n_p} \tag{IA.1}$$

for $j \geq 2$, and $\theta_1 = 1$ (normalization).

A.2.2 Firms

Representative firm has an access to CRS technology $Y = AF(K, L) = AK^{\alpha}L^{1-\alpha}$. L is the aggregate labor input in efficiency unit:

$$L = \sum_j \theta_j \int \epsilon_j z h(x)\, d\mu_j(x) \tag{IA.2}$$

where $x = (a, z, e, n)$ is a vector of individual state variables, θ_j is population share of age j, and $\mu_j(x)$ denotes a probability measure of age j individuals with state x.

Aggregate capital K depreciates at rate δ. Depreciation rate δ is set to 0.08 to match capital-output ratio of 3. A is the total factor productivity which is assumed to be constant and calibrated to match per capita GDP of Korea in 2019. Labor share α is set to 0.36 following the literature.

A.2.3 Government budgets

The government balances the tax-transfer system and the public pension system, respectively:

$$G + EITC + Welfare + BP = \tau_c C + \sum_{j=1}^{J_R-1} \theta_j \int T(y)\, d\mu_j(x) + \tau_k r K + Beq \tag{IA.3}$$

$$\sum_{j=J_R}^{J} \theta_j \int \xi(e, n; E, \kappa)\, d\mu_j(x) = \sum_{j=1}^{J_R-1} \theta_j \int \tau_p \cdot \min\{y, \bar{y}\}\, d\mu_j(x) \tag{IA.4}$$

where

$$EITC = \sum_{j=1}^{J_R-1} \theta_j \int \psi(a(x), w\epsilon_j z h(x))\, d\mu_j(x)$$

$$Welfare = \sum_{j=1}^{J_R-1} \theta_j \int tr + \Omega \cdot (1 - h(x))\, d\mu_j(x)$$

$$BP = \sum_{j=J_R}^{J} \theta_j \int bp\, d\mu_j(x)$$

and G is government consumption. Accidental bequests, net of initial wealth of the entering cohort, are assumed to be confiscated by the government, which is denoted by Beq. Note that the public pension system is run in a pay-as-you-go style.

$$E = \frac{\sum_{j=1}^{J_R-1} \theta_j \int \min\{w\epsilon_j z h(x), \bar{y}\}\, d\mu_j(x)}{\sum_{j=1}^{J_R-1} \theta_j \int \mathbb{1}_{\{h(x)=1\}}\, d\mu_j(x)} \tag{IA.5}$$

A.2.4 Definition of equilibrium

A competitive equilibrium in this environment consists of prices $\{r, w\}$, tax-transfer policies $\{\tau_c, \lambda_l, \tau_l, \tau_k, \Omega, tr, bp\}$, the EITC $\{\beta_{in}, \beta_{out}, \alpha_{out}, \bar{\psi}, \bar{a_1}, \bar{a_2}\}$, the public pension system $\{\tau_p, \bar{y}, \kappa, E\}$, government consumption G, and the individual's policy functions $\{c(x), h(x), a'(x)\}$ such that,

- Given prices and government policies, the policy functions of the individual are solutions to optimization problems (4) and (6) formulated in Section 2.4,
- Given prices, firms determine their demand for capital and labor to maximize profit: $w = AF_L(K, L)$ and $r = AF_K(K, L) - \delta$,
- G and τ_p satisfies government budgets eq. (IA.3) and eq. (IA.4), respectively,
- Markets are cleared,
- The measure of individuals is consistent.

A.3 Pension benefit formula

$$\xi(e,n) = \begin{cases} \gamma(E+e)[0.5 + 0.05 \cdot (n-10)] & \text{if} \quad 10 \leq n < 20 \\ \gamma(E+e)[1 + 0.05 \cdot (n-20)] & \text{if} \quad 20 \leq n \end{cases} \tag{IA.6}$$

Note that the terms in the square brackets become $0.05 \cdot n$ for both cases. Defining $\kappa := 0.05 \cdot \gamma$, the formula can be expressed as eq. (3) for $n \geq 10$.