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Evaluating Lost Earnings Using Longitudinal Age Earnings Profiles: The Case of Korea

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Introduction

Personal injury claims consist of general damages and special damages. Between both of them, general damages refer to compensation for PSLA (pain, suffering and loss of amenity) as a result of injuries suffered and special damages refer to compensation for out-of-pocket expenses or financial losses resulting from a direct result of injuries. So, we can say that a typical example of special damages is lost earnings. In almost all personal injury cases, a key component of injured persons' damages is the incomes they have lost and the incomes they can expect to lose due to their injuries.

In Korea, when evaluating the present values of future lost earnings, Leibniz method or Hoffman method which uses 5% of legal interest rate as a discount rate have been used customarily. However, we can confirm that the present values of future lost earnings have been underestimated by using these two methods under the Korean economic environment. Using workers wages and interest rates data from 1983.01-2000.12, Ma (2001) showed that a single level of net discount rate[1] which can be replaced to 5% of legal interest rate on calculating present values of lost earnings was 1%. In Korea, there was a structural change in the time series of interest rates before and after 2000 and up until now the levels of interest rates have dropped to a much lower level than the levels prior to 2000. Recently related to this, Ma and Kim (2014) reconfirmed the appropriate single level of net discount rate using workers wages and interest rates data from 1993.01-2013.12 and then showed the proper level was 0%. The levels of net discount rates from both Ma and Kim (2014) and Ma (2001) show us that the current Leibniz method or Hoffman method which uses 5% of legal interest rate on calculating present values of lost earnings should not be used to guarantee the victim's full compensation.

Haslag et al. (1991) has found that the net discount rate was stationary using the method of unit root tests for the first time and then concluded that the mean value of net discount rates could be used with confidence to forecast the present value of expected future earnings. After Haslag et al. (1991), forensic economists has focused on the relationship between interest rates and wage growth rates by testing for stationarity of the net discount rate. For example, Gamber and Sorensen (1993, 1994), Haslag et al. (1994), Payne et al. (1999a, 1999b), Sen et al. (2000), Ma (2001), Clark et al. (2008), Ma and Kim (2014) belong to this kind of analysis.

As we can see in Ma and Kim (2014) and Ma (2001) as well as previous studies, all of the estimates of the net discount rate from these studies usually generated the time series of net discount rates using linear age-earnings profiles through using mean values of all workers' wage growth rates. However, it is well known that the earnings for the typical person follow an inverted U pattern with respect to age. That is, earnings increase rapidly earlier in the life cycle due to continued investments

[1] Net discount rate (d) represents the discount rate which include the effect of wage growth rate. To put it roughly, if we subtract wage growth rate (g) from interest rate (r), we can have net discount rate ($d \cong r - g$).

in human capital, level off in the middle years, and then decline due to the depreciation of human capital as well as declines in hours of work (Lambrinos and Harmon (1989)). So, the failure to account for the shape of age-earnings profiles might result in underestimate or overestimate of the present values of future lost earnings. One of the alternative approaches that will be compared to single net discount rate is using an age-earnings profiles considering different growth rates of earnings for each year. Representatively, Lane and Glennon (1985), Lambrinos and Harmon (1989), Rodgers et al. (1996), Gilbert (1997), Christensen (1999) considered age-earnings profiles in the calculation of lost earnings.

The purpose of this article is to explore varied net discount rates for each year after considering the shape of longitudinal age-earnings profiles in the case of typical Korean male workers. To generate future longitudinal age-earnings profiles, it is necessary to forecast future cross sectional age-earnings profiles through forecasting each age group's wage growth rates. However, we cannot find any generalized model to forecast longitudinal age-earnings profiles. In recent study related to this, Ma (2014) directed his attention to the fact that the structure of matrix is equal between age-earnings profiles and age-mortality profiles. He generated longitudinal age-earnings profiles through applying Lee-Carter (LC) model to forecast each age group's wage growth rates. In this analysis, we will use random walk (RW) model additionally as well as LC model to forecast each age group's wage growth rates and then generate varied net discount rates for each year after considering the shape of longitudinal age-earnings profiles created by these two forecasting models respectively.

Finally, we will compare the present values of future lost earnings derived from RW model and LC model with the present values from single net discount rate methods including current Leibniz method and Hoffman method.

Methodology and Data

Forecasting Model

Lee-Carter Model

The LC model used to forecast each age group's wage can be expressed as in equation (1). As we can see in equation (1), unlike the original LC model, we do not transform the values of wages into log ones[2].

[2] The original LC model used log transformed mortality data in the analysis to avoid negative values of mortality in the forecasting. However, if we use log transformed wages as in original LC model, the forecasted values of wages will be showed overestimated results due to the final process of exponential transformation. So, when we want to forecast future wages using LC model, it is reasonable to use non-transformed raw data of wages because the forecasted values of k_t will not show negative values.

$$w_{x,t} = a_x + b_x k_t + \varepsilon_{x,t} \quad (x = 1,2,\cdots,n; \quad t = 1,2,\cdots,T) \tag{1}$$

with restrictions such that $\sum_{x=1}^{n} b_x = 1, \quad \sum_{t=1}^{T} k_t = 0$.

In equation (1), the vector a refers to an average age profile, the vector k tracks wage changes by passage of time, and the vector b determines how much each age group changes when k_t changes. The error term $\varepsilon_{x,t}$ reflects age-period effects not explained by the model.

Random Walk Model

In this analysis, we confirmed that all the time series of each age group's wage could be described by the model known as the random walk with drift[3]. We can express RW model with drift as below.

$$y_t = \delta + y_{t-1} + \varepsilon_t \quad \Leftrightarrow \quad dy_t = \delta + \varepsilon_t \quad (dy_t = y_t - y_{t-1}) \tag{2}$$
$$\varepsilon_t \sim WN(0, \sigma^2)$$

Equation (2) shows that each realization of the random variable (y_t) contains a drift (δ) plus last period's value (y_{t-1}) plus the error term (ε_t). In the RW with drift, because on average it grows each period by the drift (δ), it is effectively a model of stochastic trend driven by stochastic shocks.

Data

Worker's Wage

In this analysis, to forecast each age group's future wages, we use all male workers' average wage data classified into 8 age groups from the DB provided by Ministry of Employment and Labor in Korea. As we can see in <Table 1>, worker's wage data are categorized into 5-year age intervals except for those aged 60 years and over.

<Table 1> Age Groups

A1	:	Age 25~29	A5	:	Age 45~49
A2	:	Age 30~34	A6	:	Age 50~54
A3	:	Age 35~39	A7	:	Age 55~59
A4	:	Age 40~44	A8	:	Age 60+

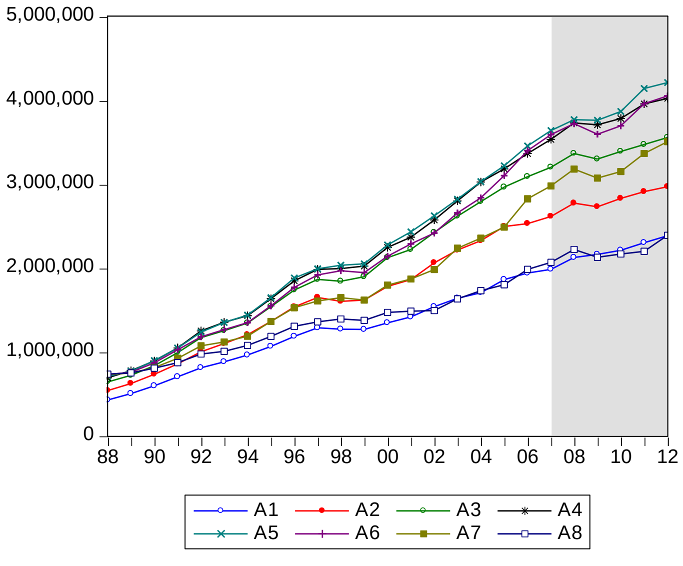
3 In addition, the time series of k_t in LC model also confirmed RW process with drift. So, we will use RW model to forecast future k_t series as well.

<Table 2> shows cross sectional time series data from 1988 to 2012 we use in this analysis. That is all male workers' average nominal wage data over 25years according to 8 age groups. <Figure 1> shows the trends of each age group's nominal wages from 1988 to 2012.

<Table 2> All Male Workers' Average Nominal Wage (1988-2012 (25years)) (unit: Korean won)

obs	A1	A2	A3	A4	A5	A6	A7	A8
1988	428416	541686	643117	694021	710035	732920	730156	738383
1989	506089	624686	723440	779525	771918	759962	750675	752375
1990	597265	734056	836761	893023	897554	871428	814368	808617
1991	704277	860329	993078	1049059	1047581	1028997	924697	873609
1992	811852	1004805	1171236	1252198	1237253	1181473	1075781	977556
1993	884208	1100896	1254484	1354626	1353633	1268945	1120109	1009260
1994	964842	1206276	1345251	1433716	1441418	1350376	1189179	1079344
1995	1067645	1365406	1541215	1637846	1649796	1551703	1365615	1187846
1996	1186335	1539153	1738769	1850659	1882775	1772563	1530409	1306148
1997	1289347	1651161	1867834	1987469	1992976	1919641	1609061	1360229
1998	1271428	1605135	1845938	1995791	2036287	1969887	1650014	1394631
1999	1268969	1619919	1899414	2025134	2053604	1946240	1618938	1376834
2000	1348205	1783275	2126854	2247350	2277498	2142574	1797402	1473394
2001	1419411	1865370	2222888	2369686	2434587	2289418	1871141	1486679
2002	1542751	2064093	2427844	2575223	2623476	2418726	1984976	1494304
2003	1641906	2215776	2619600	2802353	2823349	2660045	2238925	1634865
2004	1708817	2329580	2792714	3029347	3032108	2839949	2358970	1731163
2005	1864871	2497747	2966468	3184374	3220269	3104487	2489951	1803775
2006	1942411	2530886	3090701	3369033	3459626	3401581	2828182	1986928
2007	1986367	2616794	3204268	3535990	3642260	3594092	2982863	2070378
2008	2127712	2775177	3367179	3731764	3771389	3725134	3182238	2223123
2009	2165620	2731763	3301349	3710198	3764769	3598782	3075033	2130960
2010	2213128	2832013	3392882	3786249	3869903	3698343	3152251	2169187
2011	2305594	2913999	3475762	3959865	4143879	3962309	3368361	2200581
2012	2386939	2970935	3559456	4024705	4215113	4054025	3508679	2392916

Note: US $1= about 1,100 Korean won.



<Figure 1> Each Age Group's Nominal Wage (1988-2012)

Comparing Accuracy of Forecasting Model

To confirm the accuracy of forecasting results, we compare forecasted values with actual ones from 2008 to 2012. To do this, we forecast the wages from 2008 to 2012 after estimating two forecasting models using the data from 1988 to 2007.

Estimating Result of LC Model

<Table 3> shows the estimated values of a_x and b_x. In <Table 3> we can see the estimated values of b_x satisfy the condition that $\sum_{x=1}^{n} b_x = 1.0$.

<Table 3> Estimated Values of a_x and b_x.

	A1	A2	A3	A4	A5	A6	A7	A8
a_x	1221771	1587851	1865594	2003321	2029400	1940250	1646571	1327316
b_x	0.083687	0.115452	0.142469	0.155467	0.159677	0.153553	0.119448	0.070247

<Table 4> shows estimated wage index k_t from 1988 to 2007. In <Table 4> we can see the estimated values of k_t satisfy the condition that $\sum_{t=1}^{T} k_t = 0$.

<Table 4> Estimated Wage Index k_t (1988-2007)

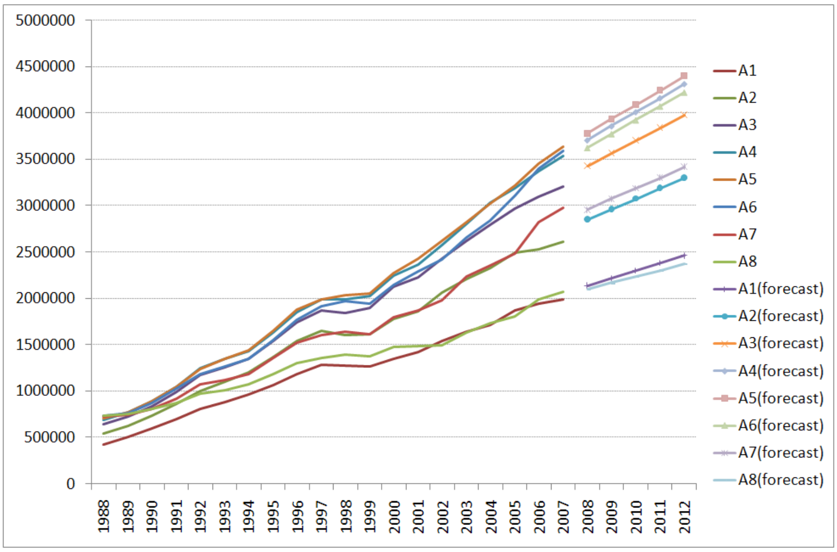
year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
k_t	-8403340	-7953404	-7169002	-6140447	-4909920	-4275913	-3611672	-2255002	-815263	55644
year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
k_t	147037	186978	1574478	2337106	3509319	5014745	6200574	7509868	8987274	10010938

To forecast future wages using LC model, beyond all things, we should forecast the future values of k_t. The shape of k_t series showed upward stochastic trend over time and the first differenced dk_t series showed more stationary pattern. We created the correlogram of k_t and dk_t series respectively and confirmed that the correlogram of k_t showed the pattern of non stationary time series but that of dk_t showed stationary ones which represent white noise process. This result tells us that the time series of k_t represent the process of RW with drift. <Table 5> shows the estimated dk_t process using RW model.

<Table 5> Estimation Result of RW model

Estimated Equation	Coefficient of δ	
	t-Statistics	Prob.
$dk_t = 969172 + \varepsilon_t$	9.4906	0.0000

If we use the estimated result in <Table 5>, we can forecast future k_t time series from 2008 to 2012. <Figure 2> shows future wages from 2008 to 2012 by age group which forecasted through using forecasted k_t time series and estimated values of a_x and b_x in <Table 3>.



<Figure 2> Future Wages from 2008 to 2012 Forecasted by Using LC Model

Estimating Result of RW Model

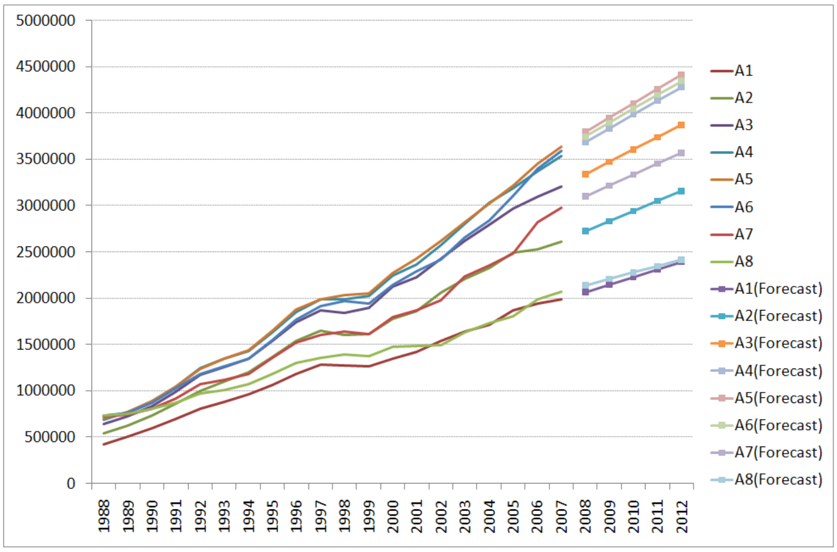
We additionally considered RW with drift model to compare with the results from LC model. According to the shape of correlogram of k_t time series, all age group's wages showed the feature of random walk with drift. <Table 6> shows the estimated RW processes of $dA1_t$ through $dA8_t$.

<Table 6> Estimation Result of RW model by Each Age Group

Estimated Equation	Coefficient of δ	
	t-Statistics	Prob.
$dA1_t = 81997 + \varepsilon_t$	8.7372	0.0000
$dA2_t = 109216 + \varepsilon_t$	7.8980	0.0000
$dA3_t = 134797 + \varepsilon_t$	9.3524	0.0000
$dA4_t = 149577 + \varepsilon_t$	9.7936	0.0000
$dA5_t = 154328 + \varepsilon_t$	10.1599	0.0000
$dA6_t = 150588 + \varepsilon_t$	7.9920	0.0000
$dA7_t = 118563 + \varepsilon_t$	6.0610	0.0000

$dA8_t = 70105 + \varepsilon_t$	6.0787	0.0000

If we use the estimated result in <Table 6>, we can forecast all age group's future wages from 2008 to 2012. <Figure 3> shows future wages from 2008 to 2012 by age group forecasted by using RW model.



<Figure 3> Future Wages from 2008 to 2012 Forecasted by Using RW Model

Accuracy of Forecasting Results

One of the most common measure of forecast error is MAPE (Mean Absolute Percentage Error) as in equation (3).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \quad (3)$$

In equation (3), A_t is the actual value and F_t is the forecast value. In this analysis, to compare forecasting accuracy between LC model and RW model, we calculated the value of MAPE using the data from 2008 to 2012. <Table 7> shows the calculated MAPE by age group.

<Table 7> MAPE by Age Group

2008-2012	A1	A2	A3	A4	A5	A6	A7	A8
MAPE_RW	**0.0103**	**0.0416**	**0.0582**	**0.0414**	0.0384	0.0626	0.0354	0.0412
MAPE_LC	0.0279	0.0819	0.0833	0.0457	**0.0351**	**0.0411**	**0.0253**	**0.0317**

RW model showed superior results compare to LC model in lower age groups (A1 through A4). But, on the contrary, RW model showed inferior results in higher age groups (A5 through A8) compare to LC model. From the results of <Table 7>, we can say that LC model is relatively more accurate for age 30 and over(age group A2 through A8). However, regardless of the results in <Table 7>, we will report the evaluated present values of lost earnings which using RW model as well as LC model in the forecasting of future wages.

Generating Longitudinal Age-Earnings Profiles

For example, if we assume that a person aged 30 died in 2013 resulting from a traffic accident and the remained years until the fixed retirement age was 30 years, we have to forecast future 30 year's wages up until 2042 to evaluate lost earnings. In actual analysis, to forecast each age group's future wage series after 2013, we will use the full data from 1988 to 2012.

Estimated Result of RW model

<Table 8> shows the results of RW model estimated by using each age group's first differenced wage data ($dA1_t$ through $dA8_t$) from 1988 to 2012.

<Table 8> Estimation Result of RW model by Each Age Group (1988 to 2012)

Estimated RW Model	Coefficient of δ	
	t-Statistics	Prob.
$dA1_t = 81605 + \varepsilon_t$	9.9833	0.0000
$dA2_t = 101219 + \varepsilon_t$	7.7926	0.0000
$dA3_t = 121514 + \varepsilon_t$	8.4176	0.0000
$dA4_t = 138778 + \varepsilon_t$	9.3516	0.0000
$dA5_t = 146045 + \varepsilon_t$	9.6116	0.0000
$dA6_t = 138379 + \varepsilon_t$	7.0306	0.0000
$dA7_t = 115772 + \varepsilon_t$	6.0840	0.0000
$dA8_t = 68939 + \varepsilon_t$	5.2256	0.0000

Estimated Result of LC model

<Table 9> shows the estimated a_x and b_x and <Table 10> shows estimated k_t in LC model.

<Table 9> Estimated Values of a_x and b_x.

	A1	A2	A3	A4	A5	A6	A7	A8
a_x	1221771	1587851	1865594	2003321	2029400	1940250	1646571	1327316
b_x	0.083687	0.115452	0.142469	0.155467	0.159677	0.153553	0.119448	0.070247

<Table 10> Estimated Wage Index k_t (1988-2012)

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
k_t	-10796496	-10346560	-9562158	-8533603	-7303076	-6669069	-6004828	-4648158	-3208419	-2337512
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
k_t	-2246119	-2206178	-818678	-56049.7	1116163	2621589	3807418	5116712	6594118	7617782
Year	**2008**	**2009**	**2010**	**2011**	**2012**					
k_t	8888486	8463244	9098726	10315120	11097538					

<Table 11> shows the estimated RW model of dk_t. If we use the estimated result in <Table 11>, we can forecast future k_t series which can be used to forecast each age group's future wages after 2013.

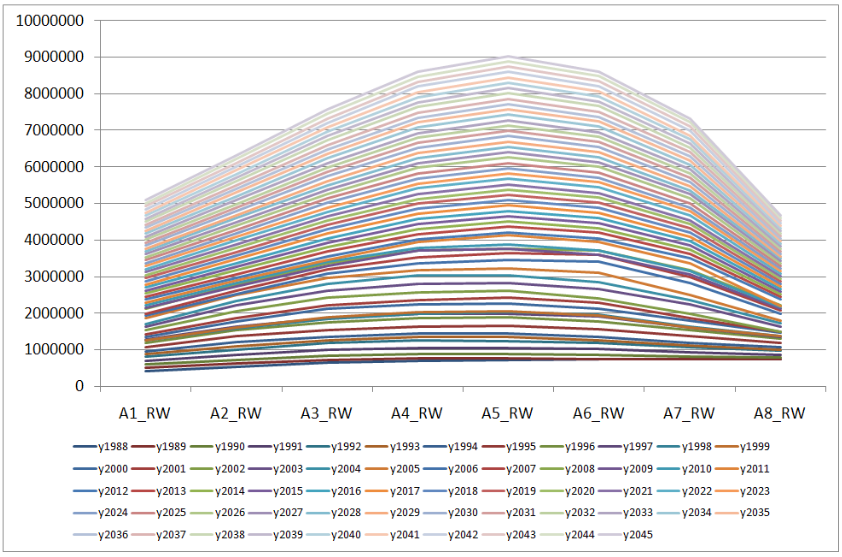
<Table 11> Estimation Result of RW Model for forecasting k_t in LC Model (1988-2012)

Estimated RW Model	Coefficient of δ	
	t-Statistics	Prob.
$dk_t = 912251 + \varepsilon_t$	8.9527	0.0000

Forecasting Cross Sectional Time Series Age-Earnings Profiles

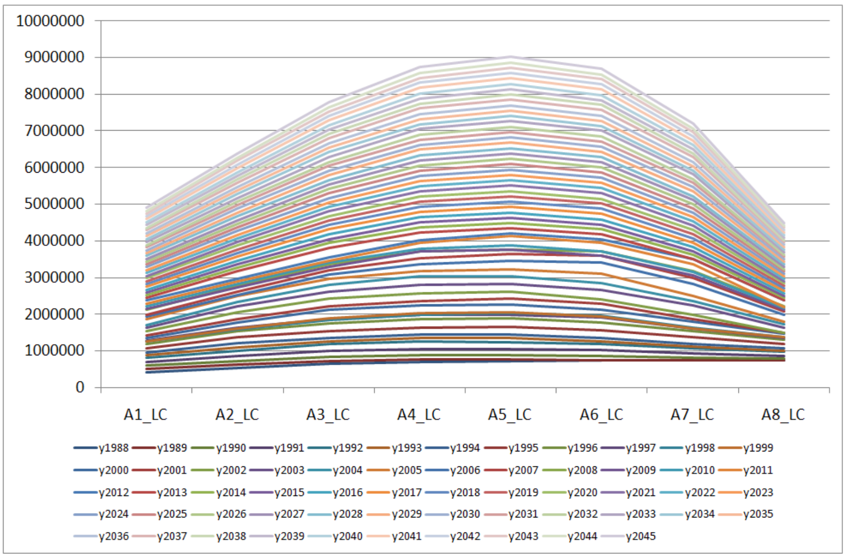
We can forecast each age group's future wages from 2013 to 2045 by using RW models in <Table 8>. And we can also forecast each age group's wages by using forecasted k_t time series and estimated values of a_x and b_x in LC model.

Using each age group's forecasted future wages, we created cross-sectional time series age-earnings profiles from 2013 to 2045. <Figure 4> shows cross-sectional time series age-earnings profiles from 1988 to 2045 which including forecasted future values by using RW model.



<Figure 4> Forecasted Cross-Sectional Age-Earnings Profiles by using RW Model

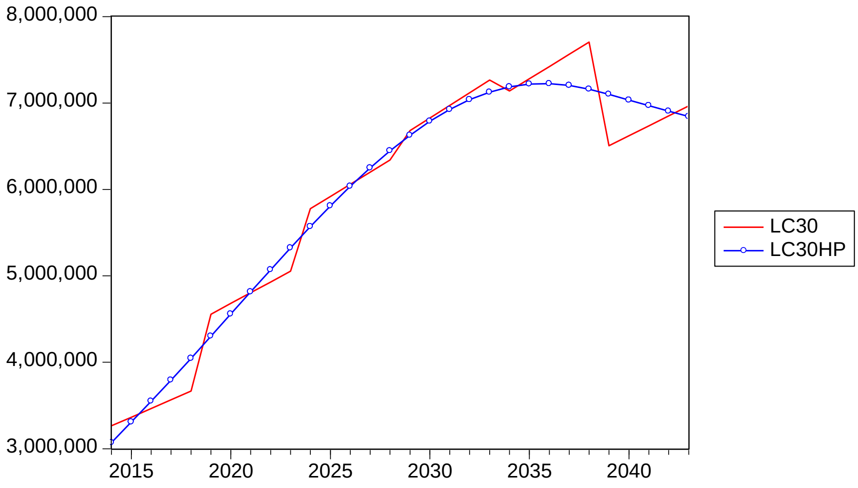
<Figure 5> shows cross-sectional time series age-earnings profiles from 1988 to 2045 which including forecasted values by using LC model.



<Figure 5> Forecasted Cross-Sectional Age-Earnings Profiles by using LC Model

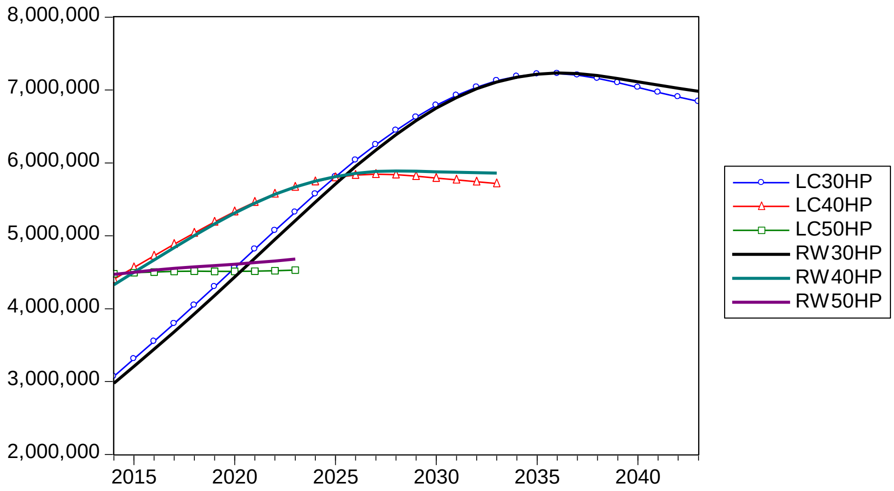
Generating Longitudinal Age-Earnings Profiles

If we use the forecasted cross-sectional time series age-earnings profiles in <Figure 4> or <Figure 5>, we can generate longitudinal age-earnings profiles which considering cohort age-earnings cycles. As we know, the age groups we use in this analysis classified into 5 year age intervals. So, if we track future 30years wages for a person aged 30 at 2014 from cross-sectional time series age-earnings profiles in <Figure 5>, the longitudinal age-earnings profiles can be generated as the solid line in <Figure 6>. So, to generate more reasonable longitudinal age-earnings profiles, it is necessary to transform the profile into more smoothed shape. To do this, we use HP (Hodrick-Prescott) trend in this analysis. <Figure 6> shows HP trend applied to the longitudinal age-earnings profiles.



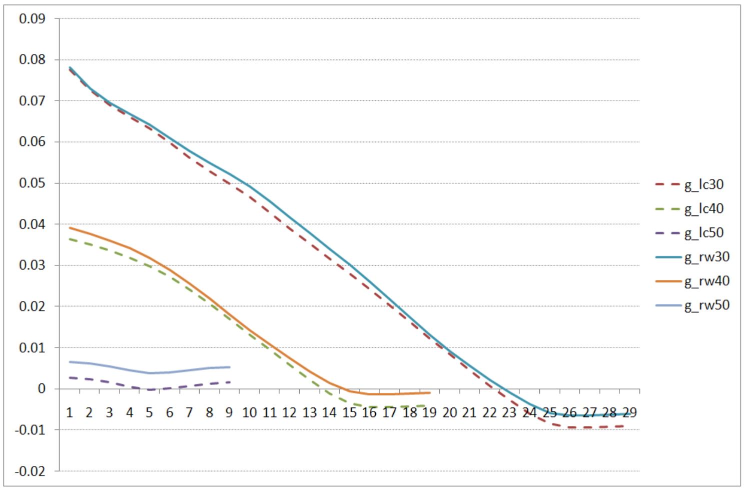
<Figure 6> Longitudinal Age-Earnings Profiles for Age 30 at 2014 and its HP Trend

<Figure 7> shows HP trends applied to longitudinal age-earnings profiles generated by using RW model and LC model for each cohort (age 30, 40, 50 at 2014) simultaneously. In real analysis, we will calculate present values of lost earnings using these HP trends.



<Figure 7> HP Trends (Longitudinal Age-Earnings Profiles) for Age 30, 40, 50 at 2014

We confirmed the growth rates of HP trends in <Figure 7>. <Figure 8> represent the growth rates of HP trends for each cohort (age 30, 40, 50 at 2014) generated by using RW model and LC model. As we mentioned before, we could confirm that earnings increase rapidly earlier in the life cycle due to continued investments in human capital, level off in the middle years, and then decline due to the depreciation of human capital as well as declines in hours of work.



<Figure 8> Cohort(Age 30, 40, 50 at 2014) Wage Growth Rates over Years

Results of Evaluating Lost Earnings

Models for Calculating Present Value of Lost Earnings

We can calculate present values of lost earnings using the equation below.

$$PV_{LE} = \sum_{t=1}^{n} \frac{E_0 \prod_{\alpha=1}^{t}(1+g_\alpha)}{\prod_{\alpha=1}^{t}(1+r_\alpha)} = E_0 \sum_{t=1}^{n} \frac{1}{\prod_{\alpha=1}^{t}(1+d_\alpha)} = E_0 \times CDF \tag{4}$$

where

where	PV_{LE}	=	present values of lost earnings
	n	=	maturity of loss period
	E_0	=	Base earnings at $t=0$
	g_α	=	earnings growth rate at $t=\alpha$
	r_α	=	interest rate at $t=\alpha$
	d_α		net discount rate at $t=\alpha$
			$d_\alpha = (r_\alpha - g_\alpha)/(1+g_\alpha)$
	CDF	=	cumulative discount factor

In equation (4), if the time series of net discount ratio ($(1+g_\alpha)/(1+r_\alpha)$) is confirmed stationary or the time series of net discount rate (d_α) is confirmed stationary, we can simplify equation (4) into equation (5) which uses the mean value of net discount ratio or net discount rate respectively.

$$PV_{LE} = E_0 \sum_{t=1}^{n} \left(\frac{1+g}{1+r} \right)^t = E_0 \sum_{t=1}^{n} \left(\frac{1}{1+d} \right)^t \quad (5)$$

As we mentioned before, Ma and Kim (2014) and Ma (2001) confirmed that the time series of net discount rate was stationary and the mean values of net discount rate were 0% and 1% respectively. However, we cannot say that the time series of net discount rates will also represent stationary processes if we use longitudinal age-earnings profiles in the course of generating net discount rates.

Generating Net Discount Rates

To generate net discount rates (d_α), we use wage growth rates (g_α) derived from longitudinal age-earnings profiles created by using LC model and RW model and the mean value of 5 year maturity national housing bond's yields(HB5) as interest rates (r_α). Ma and Kim (2014) forecasted future 30 year's processes of HB5 using stochastic interest model and showed the mean value after tax was 3.66% per annum. For convenience of the analysis, we use the fixed interest rate of 3.66% in the creation of net discount rates as in equation (6).

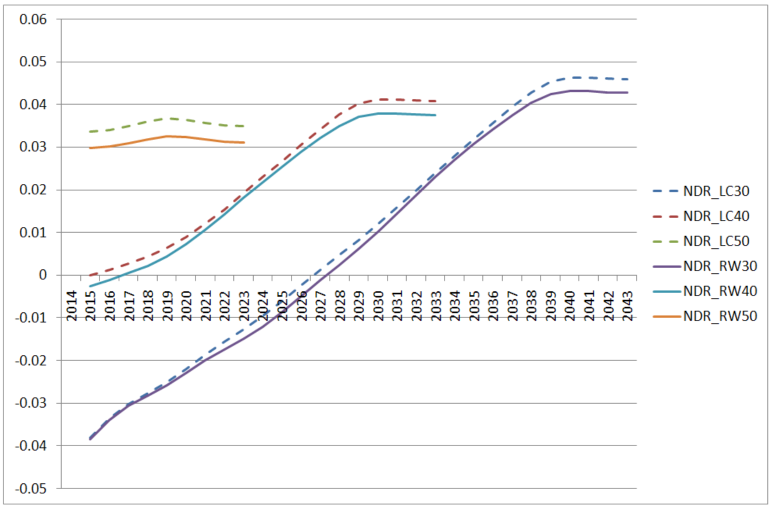
Net Discount Rate: $d_\alpha = (r - g_\alpha)/(1 + g_\alpha) = (0.0366 - g_\alpha)/(1 + g_\alpha)$ (6)

<Table 12> and <Figure 9> show the net discount rates (NDR) from 2015 to 2043 generated by using equation (6).

<Table 12> Net Discount Rates by Age Groups

N	Yr	NDR_LC Model			NDR_RW Model		
		Age 30	**Age 40**	**Age 50**	**Age 30**	**Age 40**	**Age 50**
1	2015	-0.03804	8.82E-05	0.033715	-0.0385	-0.00256	0.029868
2	2016	-0.03356	0.001406	0.034102	-0.03398	-0.00108	0.03023
3	2017	-0.03024	0.00282	0.034947	-0.03069	0.000473	0.030974
4	2018	-0.02765	0.004467	0.036033	-0.02821	0.002254	0.031912
5	2019	-0.02513	0.006499	0.03684	-0.02591	0.004467	0.03261
6	2020	-0.02188	0.00908	0.036524	-0.02298	0.007338	0.032376
7	2021	-0.01858	0.012114	0.035828	-0.02007	0.01067	0.031831
8	2022	-0.01549	0.015522	0.035231	-0.01738	0.014309	0.031369
9	2023	-0.01258	0.01921	0.034951	-0.01481	0.018114	0.031169
10	2024	-0.00957	0.02305		-0.01204	0.021916	
11	2025	-0.00602	0.026836		-0.00856	0.025485	
12	2026	-0.00235	0.03064		-0.00488	0.028927	
13	2027	0.001256	0.03438		-0.0012	0.03221	
14	2028	0.004783	0.037781		0.002458	0.035129	
15	2029	0.008332	0.040326		0.006219	0.037272	
16	2030	0.012078	0.041205		0.010305	0.037983	
17	2031	0.015956	0.04124		0.01454	0.037979	
18	2032	0.019935	0.041015		0.018818	0.037762	

19	2033	0.023981	0.040867		0.023045	0.037618	
20	2034	0.028023			0.027101		
21	2035	0.031907			0.03079		
22	2036	0.035744			0.034271		
23	2037	0.039487			0.037549		
24	2038	0.042886			0.040448		
25	2039	0.045436			0.042568		
26	2040	0.046313			0.043238		
27	2041	0.046351			0.043195		
28	2042	0.046145			0.042959		
29	2043	0.046043			0.042827		



<Figure 9> Time Series of Net Discount Rates

The patterns of net discount rates in <Figure 9> tell us that the time series of net discount rates are no longer stationary time series. We calculated the values of CDF using net discount rates in <Table 12>. As we can see in <Table 13>, the magnitude of CDFs calculated using net discount rates generated by RW model show a little bit bigger than those calculated by using LC model.

<Table 13 > Values of CDF

	Age 30	Age 40	Age 50
RW Model	34.2242	17.9587	8.74619
LC Model	33.5302	17.6437	8.60476

If we use the values of CDF in <Table 13>, through the method of trial and error, we can derive the mean values of net discount rate (d), in other words internal rate of return, which can show the same values of CDF in <Table 13> using the relationship in equation (7).

$$CDF = \sum_{t=1}^{n} \frac{1}{\prod_{\alpha=1}^{t} (1+d_{\alpha})} = \sum_{t=1}^{n} \left(\frac{1}{1+d} \right)^{t} \tag{7}$$

<Table 14> represents the values of single net discount rate we derived from the relationship in equation (7).

<Table 14> Single Net Discount Rate (d)

	Age 30	Age 40	Age 50
RW Model	-0.88%	1.16%	3.11%
LC Model	-0.75%	1.36%	3.51%

Due to the shape of longitudinal age-earnings profiles, when we evaluate single net discount rate by age group, the magnitude of relatively younger age group's net discount rate shows lower than that of older age group's one. So, if we do not consider the shape of longitudinal age-earnings profiles on the calculation of lost earnings, the values can be underestimated in younger age group and on the contrary the values can be overestimated in older age group because the appropriate level of single net discount rate was confirmed 0% or 1% when we use linear age-earnings profiles which using mean values of all workers' wage growth rates as we can see in the analysis of Ma and Kim (2014) or Ma (2001).

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Evaluating Lost Earnings

To evaluate future lost earnings, we assume the injured persons are deceased at age 30, 40, 50 at 2014 respectively and their earnings in the year prior to injury are as in the mean values of forecasted wages as in <Table 15>.

<Table 15> Wages in the Year Prior to Injury (E_0) (Unit: Korean won)

	LC Model	RW Model	Mean
Age 30	3071391	2976328	3023860
Age 40	4403128	4328498	4365813
Age 50	4479608	4470923	4475265

Then, we can calculate each age group's present values of future lost earnings just multiplying E_0 and CDF together ($PV_{LE} = E_0 \times CDF$). We compare each age group's present values of future lost earnings among varied calculating methods including Leibniz method and Hoffman method. The Leibniz and Hoffman methods use the legal interest rate of 5% per annum as the compounding net discount rate and the simple net discount rate respectively on calculating the present values of lost earnings. Automobile insurance companies generally use the Leibniz method while the courts have adopted the Hoffman method to evaluate lost earnings in Korea (Ma (2006)). The present value of

Leibniz method (PV_L) can be expressed as in equation (8) and the Hoffman method (PV_H) can be expressed as in equation (9).

- Leibniz Method: $PV_L = \sum_{t=1}^{n}\left(\frac{1}{1+d}\right)^t = \sum_{t=1}^{n}\left(\frac{1}{1+0.05}\right)^t$ (8)

- Hoffman Method: $PV_H = \sum_{t=1}^{n}\left(\frac{1}{1+d\cdot t}\right) = \sum_{t=1}^{n}\left(\frac{1}{1+0.05\cdot t}\right)$ (9)

<Table 16> shows the present values of future lost earnings evaluated by using varied models.

<Table 16> Present Values of Lost Earnings (Unit: Korean won)

		RW Model	LC Model	Total Offset	Leibniz	Hoffman
Age30	CDF	34.2242	33.5302	30.0000	16.1411	18.6293
	PV_{LE}	827,913,462	811,124,992	725,726,353	390,466,749	450,659,461
Age40	CDF	17.9587	17.6437	20.0000	13.0853	14.1161
	PV_{LE}	627,234,599	616,232,750	698,530,071	457,024,505	493,024,886
Age50	CDF	8.7462	8.6048	10.0000	8.1078	8.2783
	PV_{LE}	313,132,525	308,070,105	358,021,226	290,277,226	296,380,096

Note: 1. All the present values show the values after deducting 1/3 of wages as the living costs.

2. Total Offset method: the method assuming 0% of net discount rate ($r-g=0\%$).

According to the results of <Table 16>, we compared the amount of money calculated by varied methods with that calculated by Hoffman method. <Table 17> shows the differences compare to the present value of lost earnings calculated by using Hoffman method.

<Table 17> Differences Compare to the Present Value of Hoffman Method (Unit: Korean won)

	RW Model	LC Model	Total Offset	PV_L	PV_H
Age30	377,254,001	360,465,531	275,066,892	-60,192,712	0
Age40	134,209,713	123,207,864	205,505,184	-36,000,381	0
Age50	16,752,429	11,690,009	61,641,130	-6,102,870	0

In <Table 17>, the results show that the current discounting methods, Leibniz and Hoffman methods, are excessively underestimating future lost earnings in the real world situation. <Table 18> shows the ratios compare to the present values calculated by using Hoffman Method.

<Table 18> Ratios Compare to Hoffman Method

	RW Model	LC Model	Total Offset	PV_L	PV_H
Age30	1.84	1.80	1.61	0.87	1.00
Age40	1.27	1.25	1.42	0.93	1.00
Age50	1.06	1.04	1.21	0.98	1.00

In <Table 17> and <Table 18>, we can confirm that if we use Total offset method derived from Ma and Kim (2014), the result will be overestimated in the relatively older age groups (age 40 and 50 in this analysis), while the result will be underestimated in the relatively younger age group (age 30 in this analysis).

Conclusion

The evaluation of economic damages resulting from a reduction in earning capacity is based upon several factors. Among them, one of the most important is the net discount rate which the loss is calculated. Two customarily used methods of calculating present values of lost earnings are the Leibniz and Hoffman methods which use 5 % of legal interest rate as the net discount rate in Korea. However, the current two methods do not have reasonable economic certainty because the evaluated present values are underestimated. According to the levels of net discount rates derived from both Ma and Kim (2014) and Ma (2001) show us that the current Leibniz or Hoffman method which uses 5% of legal interest rate on calculating present values of lost earnings should not be used to guarantee the victim's full compensation in Korea.

As we can see in Ma and Kim (2014) and Ma (2001), they generated the net discount rates just using linear age-earnings profiles through using mean values of all workers' wage growth rates. However, it is well known that the earnings for the typical person follow an inverted U pattern with respect to age. As a result, the failure to account for the shape of age-earnings profiles might result in underestimate or overestimate of the present value of future earnings. So, one of the alternative approaches that will be compared to single net discount rate is using an age-earnings profiles to adjust the growth rates of earnings for each year. In this analysis, we explored varied net discount rates for each year after considering the shape of longitudinal age-earnings profiles in the case of typical Korean male workers. We used RW model and LC model to forecast each age group's longitudinal age-earnings profiles and then generated varied net discount rates after considering the shape of longitudinal age-earnings profiles created by these two forecasting models respectively.

We compared the present values of future lost earnings derived from RW model and LC model with those from single net discount rate methods including current Leibniz method and Hoffman method. The results show that the current discounting methods, Leibniz and Hoffman methods, are excessively underestimating future lost earnings in the real world situation.

In addition, we can confirm that if we use Total offset method derived from Ma and Kim (2014), the results will be overestimated in the relatively older age groups (age 40 and 50 in this analysis), while underestimated in the relatively younger age groups (age 30 in this analysis). So, considering the results from this analysis, it is necessary to apply longitudinal age-earnings profiles on calculating the present value of lost earnings to raise the accuracy of calculation.

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