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Original Article

Nurse staffing and life expectancy at birth and at 65 years old: Evidence from 35 OECD countries

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ABSTRACT

Objective: To measure the possible magnitude of the role nurse staffing has on increasing life expectancy at birth and at 65 years old.
Methods: The statistical technique of panel data analysis was applied to investigate the relationship from the number of practicing nurses' density per 1000 population to life expectancy at birth and at 65 years old. Five control variables were used as the proxies for the levels of medical staffing, health care financial and physical resources, and medical technology. The observations of 35 member countries of Organization for Economic Co-operation and Development (OECD) were collected from OECD Health Statistics over 2000–2016 period.
Results: There were meaningful relationships from nurse staffing to life expectancy at birth and at 65 years with the long-run elasticities of 0.02 and 0.08, respectively. Overall, the role of nursing characteristics in increasing life expectancy indicators varied among different health care systems of OECD countries and in average were determined at the highest level in Japan (0.25), followed by Iceland (0.24), Belgium (0.21), Czech Republic (0.21), Slovenia (0.20) and Sweden (0.18).
Conclusion: A higher proportion of nursing staff is associated with higher life expectancy in OECD countries and the dependency of life expectancy to nursing staff would increase by aging. Hence, the findings of this study warn health policy makers about ignoring the effects nursing shortages create e.g. increasing the risk of actual age-specific mortality, especially in care of elderly people.

What is known?

- There is a lack of cross-national research to examine the probable role of nurse staffing on increasing life expectancy as a core indicator of health level.

What is new?

- A 1% increase in the number of practicing nurses per 1000 population would rise life expectancy at birth and at 65 years by 0.02 and 0.08 percentages, respectively.
- The dependency of life expectancy to the level of nursing staff would increase by aging.
- Among OECD countries, the highest effect of practicing nurses on increasing the life expectancy indicators have been investigated in Japan, Iceland, Belgium, Czech Republic, Slovenia and Sweden.

1. Introduction

Life expectancy is known as a core indicator of health level and has increased globally for both genders over time resulting from improvement in quality and quantity of health care services. In member countries of Organization for Economic Co-operation and Development (OECD), there has been significant rises in life expectancy at birth and at age 65 by 10 and 5.4 years on average since 1970, respectively – see OECD [1]. Several factors including rising income and health care expenditures (HCE), better education, healthier lifestyles and the progress in health care and its accessibility can be attributed to the gain in longevity over time [1].

The association between national income with direct effect on

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health care spending and higher life expectancy has been highlighted in previous studies, although there exist some exceptional differences in life expectancy at birth between countries with the same level of financial resources in the health sector, e.g. Japan and Spain vs. Luxembourg and United States [2]. Life expectancy especially at older ages varies by educational status i.e. highly educated people for both men and women mostly live longer and healthier e.g. in Central and Eastern European countries [3]. There are some notable exceptions about the possible effects of education on life expectancy in the elderly population which has been observed in Nordic countries and Portugal [4]. Some of the notable differences between life expectancy indicators can be explained by health-related behaviors such as obesity rates, consumption of prescription and illegal drugs etc. – see National Research Council and Institute of Medicine [5].

Generally, the most important factor on increasing life expectancy over the past few decades in OECD countries is the progress in health care among different health care systems, i.e. advanced medical care combined with greater access to health care services as well as healthier lifestyles [1]. Indeed, the role of health care services on healthy life years would be greater at older ages because the health level of elderly people is more sensitive to the quality of health care [6]. Hence, in response to proper care delivery and to enhance the quality of care in health facilities in OECD countries, it is important for governments, policy makers together with researchers to seek for more efficient services aimed at enhancing the health level of developed countries as the main goal of OECD health policy reformation [7].

Nurses with the largest health care professional grouping play a significant role in enhancing health outcomes and providing affordable care to the fast-growing health care demands [8]. The overall impacts of nursing-related services on patient outcomes and the quality of hospital care have been confirmed by numerous multinational hospital-based studies; such as Aiken et al. [9–13], Estabrooks et al. [14], Rafferty et al. [15], Van den Heede et al. [16], Poghosyan et al. [17], Suhonen et al. [18], Wu et al. [19], You et al. [20], Ausserhofer et al. [21], Cho et al. [22,23], Manojlovich [24], Amiri and Solankallio-Vahteri [25] and Amiri et al. [26].

In the following study, we plan to go further and investigate the possible role of nursing competencies in overall health level of developed countries by analyzing the association between the level of nurse staffing and life expectancy. Using the statistical approach of panel data analysis, we are able to estimate the effect of nursing staff on increasing life expectancy at birth and at 65 years in long-run. The cross-national statistics of 35 OECD countries were collected from OECD iLibrary during the period of 2000–2016. In order to investigate the exact magnitude of the relationship from the level of nurse staffing to life expectancy at birth and at older ages, five control variables were used as the proxies for the levels of; medical staffing, health care financial and physical resources, along with medical technology.

2. Data description

In this study, the observation of practicing professional nurses, who deliver clinical and hospital care services directly to patients, density per 1000 population was applied as an index for nurse-staffing level [27]. The data of general care nurses, specialist nurses, clinical nurses, district nurses, nurse anesthetists, nurse educators, nurse practitioners and public health nurses were collected in 35 OECD countries for the period of 2000–2016 available at OECD [28].

Life expectancy at birth is clarified as the average number of years which is expected for a newborn to live and life expectancy at 65 years old is defined as how long (in average) can be expected to live for a person at 65 years of age, if current age-specific death rates remain constant. The observations of life expectancy at birth as well as at 65 years of age – as the proxy for health level and health care outcomes – were collected from OECD [29,30] among 35 OECD countries from 2000 to 2016.

In order to investigate the role of nursing characteristics in increasing life expectancy at birth and at 65 years old five control variables were added in panel models including: the number of practicing doctors per 1000 population [31] as a proxy for medical staffing, total expenditures on health care per capita (i.e. aggregate of public and private HCE) based on current US dollars [32] as a

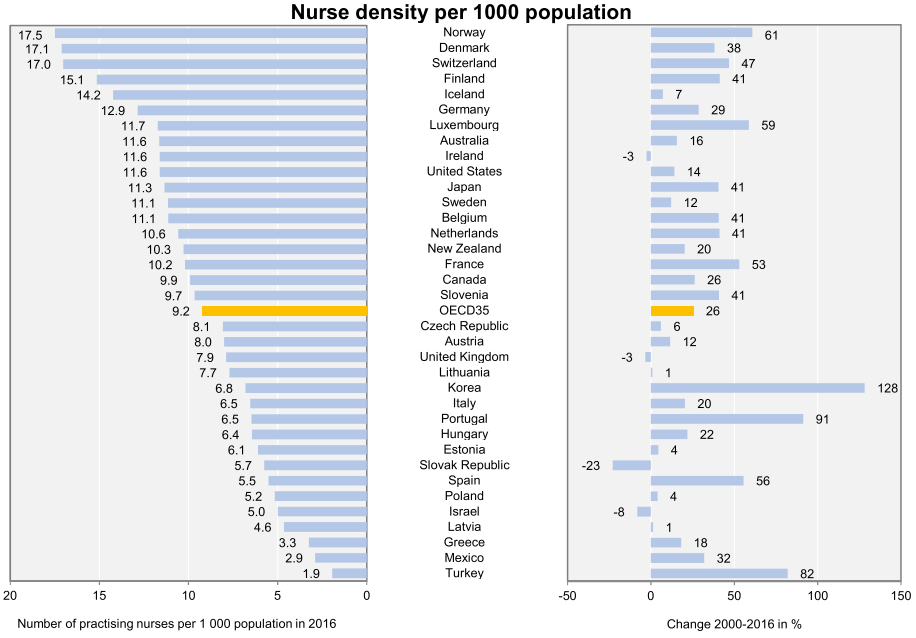

Fig. 1. Number of practicing nurses per 1000 population, 2016 and change 2000-2016 in OECD countries. Source: OECD [28].

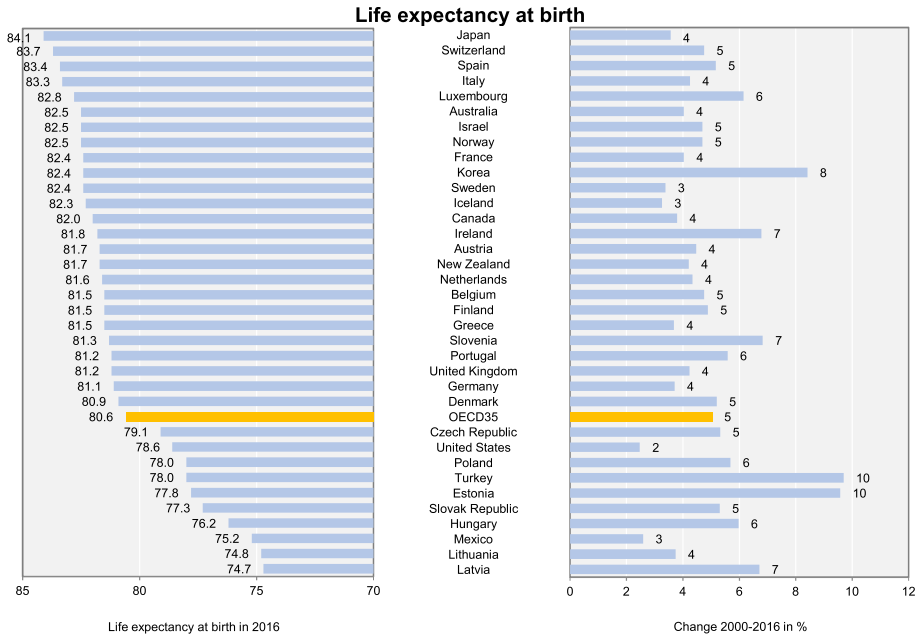

Fig. 2. Life expectancy at birth, 2016 and change 2000-2016 in OECD countries. Source: OECD [29].

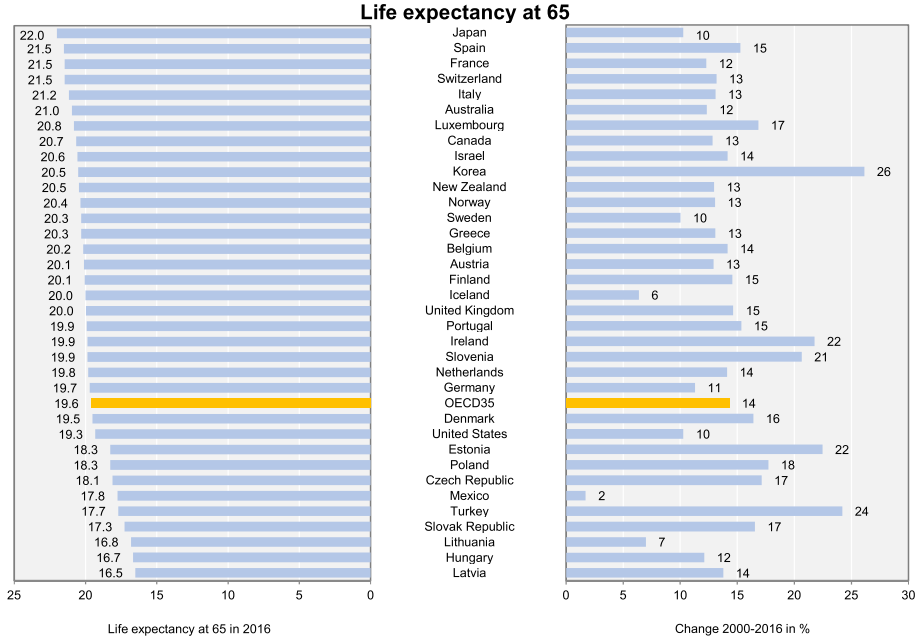

Fig. 3. Life expectancy at 65 years, 2016 and change 2000-2016 in OECD countries. Source: OECD [30].

proxy for financial resources in health care services, the number of hospital beds per 1000 population[1] [33] as a proxy for the health care resources available for delivering services, total number of in-hospital and in-ambulatory care providers Computed Tomography (CT) scanners [34] as well as Magnetic Resonance Imaging (MRI) units [35] per 1000,000 population as proxies for medical technology. The logarithm amounts of all series were used in panel data analysis to find the elasticity of the role nurse staffing had on life expectancy in long-run. Moreover, few missed observations were predicted by Artificial Neural Networks (ANNs) model.

To follow the first step of data analysis which is visualization of the data, column chart of nurse-staffing level and life expectancy at birth and at 65 years of 35 OECD countries in year 2016 along with changes from 2000 to 2016 are available in Figs. 1–3. As can be seen, nurse staffing and life expectancy levels differed from various health care systems in OECD countries.

Fig. 4 depicts the level of practicing nurses together with life expectancy at birth and at 65 years of age (all in real amounts) within orthogonal linear regression curve and confidence ellipse 95%. Despite that there exists a clear positive relationship from the level of nurse staffing to life expectancy indicators, this conclusion may be spurious on account of the possibility of stochastic trends in

[1] Including curative care beds, rehabilitative care beds, long-term care beds and other beds in hospitals.

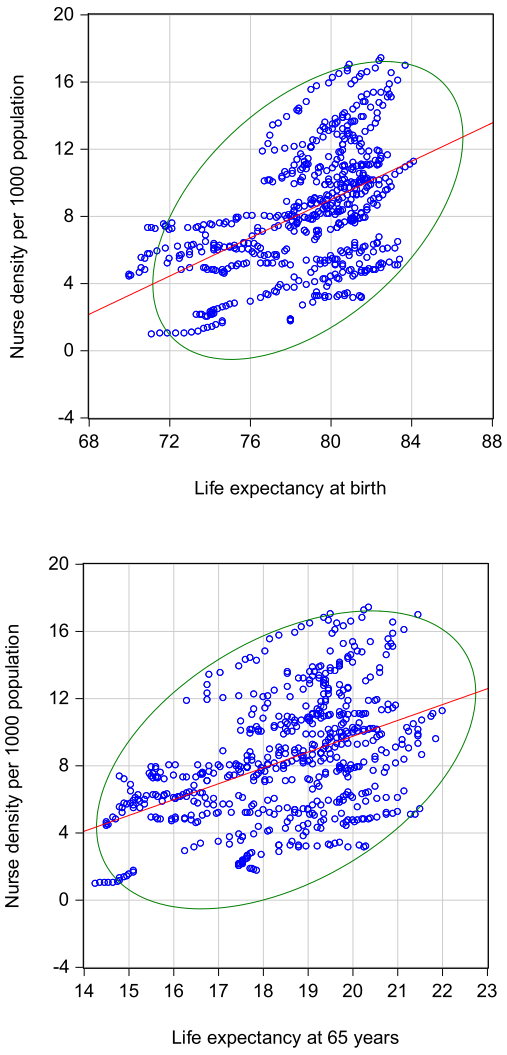

Fig. 4. Cross plot of life expectancy at birth and at 65 years with nurse density per 1000 population in 35 OECD countries 2000–2016, included confidence ellipse 95% and regression line.

panels of these series. Hence, to have statistical arguments about the plausible effect of nurse-staffing level on increasing life expectancy rates the information of unit root test and co-integration analysis in the framework of panel data analysis should be estimated to evaluate the plausible generic relationship between these series.

3. Panel data analysis

Based on the nature of our data, i.e. cross-sectional observations varied during time period, there is a possibility to investigate the possible effect of nurse-staffing level on increasing life expectancy in long-run using the statistical technique of panel data analysis. The information of statistical behavior of variables during the time period resulting from unit root tests, the possibility of long-run relationships between non-stationary series investigated by co-integration analysis, along with the magnitude of such meaningful relationships in the form of dynamic long-run analysis are provided here.

3.1. Unit root test

The first step in panel data analysis is to identify whether series are stationary, i.e. their mean and variance are unchanged during time, or non-stationary and possesses a unit root and their mean and variance differ in long-run. Unit root test is the statistical approach for recognizing the stationarity of time-series with the null hypothesis of the presence of stationarity based on intercept and trend stationarity resulting from different test models. The information of stationarity is essential in statistical analysis because time series are sensitive to trend presentation; the results of common regression analyses are biased and unreliable.

Statistics and probabilities of several panel unit root tests are available in Table 1 and based on significant statistics of level and 1st difference of integration tests, we argue that all variables were non-stationary and integrated in order one $I(1)$, except HCE and MRI units which were stationary and integrated in order zero $I(0)$. Thus, co-integration analysis and dynamic long-run models are the efficient statistical approaches to investigate the existence of significant relationship from the nurse staffing to life expectancy in long-run.

3.2. Co-integration analysis

Here, we estimate the possibility of significant relationships between the level of practicing nurses and life expectancy indicators in long-run using co-integration analysis. The results of Pedroni panel co-integration test based on Engle-Granger model are presented in Table 2 and verify that nurse-staffing level and life expectancy variables were significantly co-integrated according to the result of both bivariate and multivariate[2] models in long-run.

3.3. Dynamic long-run analysis

As the results of Pedroni panel co-integration test confirmed the existence of co-integration relationships between practicing nurses' ratio and life expectancy indicators, the magnitude of these relationships can be measured by dynamic long-run analysis. To find more reliable coefficients of such relationships, the level of medical-staffing, HCE per capita, hospital beds, CT scanners and MRI units were added in panel model as the control variables. Results of dynamic long-run panel models are available in Table 3 and verify that long-run elasticities of impact of nurse-staffing level on increasing life expectancy at birth and at 65 years were 0.02 and 0.08, respectively, i.e. 1% increase in the number of practicing nurses per 1000 population would raise life expectancy at birth and at 65 years by 0.02 and 0.08 percentages, respectively. Thus, the results of dynamic long-run analysis argue that the dependency of life expectancy to nursing staff would increase by aging process. Moreover, the elasticities of effect of nurse staffing on life expectancy at birth and at 65 years were higher than other control variables.

Dynamic long-run model analysis based on pooled framework may be used to simulate the coefficients of the effect of nurse-staffing level on increasing life expectancy in cross-sectional units. The result of dynamic long-run model based on the pooled fixed effect method is available in Table 4 and Fig. 5.

As can be seen, the highest magnitude of practicing nurses on life expectancy at birth in long-run was calculated in Sweden with 0.18, followed by Lithuania with 0.14, Japan with 0.11 and Estonia with 0.07. At the other end of the range, the lowest magnitudes of this relationship were investigated in Australia, Portugal, Finland and Norway. There was not any meaningful relationship from the level of nurse staffing to life expectancy at birth in Belgium, Greece,

[2] Medical-staffing level, HCE per capita, hospital beds, CT scanners and MRI units were added as control variables in multivariate model.

Table 1
Panel unit root test results (35 OECD countries, 2000–2016).

Null hypothesis: Unit root	Level						1st difference	
Method	Intercept		Intercept & trend		None		Intercept	
	Stat.	*P*	Stat.	*P*	Stat.	*P*	Stat.	*P*
Life expectancy at birth								
Levin, Lin & Chu	−7.64	0.000	0.90	0.817	16.15	1.000	−4.91	0.000
Im, Pesaran and Shin W-stat	1.47	0.930	3.48	0.999			−7.71	0.000
ADF - Fisher Chi-square	61.16	0.765	47.20	0.983	0.76	1.000	192.20	0.000
PP - Fisher Chi-square	351.09	0.000	115.63	0.000	0.19	1.000	476.46	0.000
Life expectancy at 65								
Levin, Lin & Chu	−6.24	0.000	−0.66	0.252	10.12	1.000	−8.74	0.000
Im, Pesaran and Shin W-stat	2.13	0.983	2.01	0.977			−9.59	0.000
ADF - Fisher Chi-square	49.92	0.966	60.94	0.771	0.85	1.000	225.63	0.000
PP - Fisher Chi-square	142.83	0.000	135.38	0.000	0.25	1.000	517.98	0.000
Nurse-staffing level								
Levin, Lin & Chu	−1.34	0.089	−3.31	0.000	6.14	1.000	−5.84	0.000
Im, Pesaran and Shin W-stat	2.24	0.987	0.21	0.586			−5.22	0.000
ADF - Fisher Chi-square	70.41	0.463	69.44	0.496	13.67	1.000	143.48	0.000
PP - Fisher Chi-square	144.96	0.000	84.02	0.121	15.40	1.000	203.84	0.000
Medical-staffing level								
Levin, Lin & Chu	−2.26	0.011	−1.69	0.044	7.53	1.000	−8.94	0.000
Im, Pesaran and Shin W-stat	2.14	0.983	0.58	0.720			−6.61	0.000
ADF - Fisher Chi-square	82.86	0.139	73.82	0.354	5.08	1.000	170.07	0.000
PP - Fisher Chi-square	105.29	0.004	64.05	0.677	3.92	1.000	285.97	0.000
Health care expenditures								
Levin, Lin & Chu	−9.74	0.000	−0.72	0.235	10.63	1.000	−3.97	0.000
Im, Pesaran and Shin W-stat	−2.06	0.019	4.84	1.000			−2.89	0.001
ADF - Fisher Chi-square	100.11	0.010	36.19	0.999	2.64	1.000	97.09	0.017
PP - Fisher Chi-square	247.02	0.000	42.25	0.996	0.25	1.000	202.84	0.000
Hospital beds								
Levin, Lin & Chu	−3.30	0.000	−5.97	0.000	−6.48	0.000	−10.21	0.000
Im, Pesaran and Shin W-stat	3.17	0.999	0.90	0.816			−6.35	0.000
ADF - Fisher Chi-square	52.41	0.942	65.05	0.644	175.17	0.000	164.66	0.000
PP - Fisher Chi-square	76.48	0.278	60.29	0.789	394.98	0.000	260.31	0.000
CT scanners								
Levin, Lin & Chu	−2.48	0.006	0.21	0.583	8.55	1.000	−3.86	0.000
Im, Pesaran and Shin W-stat	1.62	0.948	2.53	0.994			−5.16	0.000
ADF - Fisher Chi-square	72.86	0.384	51.03	0.957	6.81	1.000	141.70	0.000
PP - Fisher Chi-square	259.26	0.000	62.06	0.739	3.94	1.000	289.70	0.000
MRI units								
Levin, Lin & Chu	−7.88	0.000	−6.39	0.000	10.31	1.000	−7.81	0.000
Im, Pesaran and Shin W-stat	−2.79	0.002	−1.40	0.080			−7.26	0.000
ADF - Fisher Chi-square	145.38	0.000	111.73	0.001	5.95	1.000	179.38	0.000
PP - Fisher Chi-square	484.29	0.000	102.36	0.007	2.50	1.000	314.38	0.000

Notes: Null hypothesis was no integration and the optimum lag lengths were calculated by Schwarz Information Criterion (SIC) from 0 to 3 to reach white noise residuals. Newey-West automatic criterion estimated bandwidth and Bartlett window to calculate kernels.

Hungary, Ireland, Italy, Korea, Netherlands, Slovak Republic and United States and for the rest of OECD countries, the range of this coefficient was between 0.06 in Turkey and 0.01 in Slovenia with an average of 0.03 for all OECD countries.

Iceland with 0.44, followed by Belgium with 0.42, Japan with 0.40 and Slovenia with 0.39 had the highest magnitudes of nursing effect on increasing life expectancy at 65 years old among OECD countries in long-run. By contrast, United States (0.03), New Zealand (0.03), Canada (0.02), Ireland (0.01) had the lowest magnitudes of this relationship. There was no evidence for the possibility of nurse-staffing→life expectancy at 65 years relationship in Greece, Mexico and Netherlands. For the rest of OECD countries, the range of this coefficient was calculated from 0.36 in Czech Republic to 0.03 in Norway with the average of 0.13 for all OECD countries.

In all, nursing characteristics had the highest effect on increasing the overall life expectancy indicators in Japan with 0.25, followed by Iceland with 0.24, Belgium with 0.21, Czech Republic with 0.21, Slovenia with 0.20 and Sweden with 0.18. On the other hand, the lowest effect of practicing nurses on life expectancy in long-run were investigated in Norway with 0.02, United States, Mexico and Ireland with 0.01. Also, there was not any evidence for concluding the existence of long-run relationship between these series in Greece and Netherlands.

4. Discussion

There has been much interest in estimating the role of nurse staffing in increasing life expectancy which is known as a core indicator of health level. To our knowledge, the effect of nurse staffing on increasing health outcomes [8–16,22,24], patient safety [7,11,19,21,23,26] and quality of care [11,17,18,20,23,25] have been well confirmed in previous studies [27,36]. However, there is a need of research to investigate the effect of nursing-related services on overall health level of different health care systems in national and global levels [25–27].

In this study, we expanded the traditional research in nursing to investigate the effect of nurse staffing on increasing life expectancy at birth and at 65 years old using the statistical technique of panel

Table 2
Pedroni (Engle-Granger based) co-integration test (35 OECD countries, 2000–2016).

Co-integration test between	Pedroni's criteria	Unweighted		Weighted		Conclusion
		Stat.	*P*	Stat.	*P*	
Nurse-staffing level & life expectancy at birth	Panel v-Statistic	4.06	0.000	4.20	0.000	Co-integrated
	Panel rho-Statistic	−1.52	0.064	−1.70	0.044	
	Panel PP-Statistic	−2.53	0.005	−2.77	0.002	
	Panel ADF-Statistic	−1.37	0.084	−1.61	0.052	
	Group rho-Statistic	0.95	0.831			
	Group PP-Statistic	−1.82	0.034			
	Group ADF-Statistic	−0.88	0.187			
Nurse-staffing level & life expectancy at 65	Panel v-Statistic	2.96	0.001	3.95	0.000	Co-integrated
	Panel rho-Statistic	−1.63	0.050	−1.96	0.024	
	Panel PP-Statistic	−3.25	0.000	−3.26	0.000	
	Panel ADF-Statistic	−1.60	0.054	−1.74	0.040	
	Group rho-Statistic	0.45	0.674			
	Group PP-Statistic	−2.88	0.002			
	Group ADF-Statistic	−1.53	0.061			
Nurse-staffing level together with control variables & life expectancy at birth	Panel v-Statistic	−2.39	0.991	−4.23	1.000	Co-integrated
	Panel rho-Statistic	5.25	1.000	4.92	1.000	
	Panel PP-Statistic	−1.80	0.035	−10.83	0.000	
	Panel ADF-Statistic	2.91	0.998	−2.04	0.020	
	Group rho-Statistic	7.43	1.000			
	Group PP-Statistic	−18.74	0.000			
	Group ADF-Statistic	−0.73	0.230			
Nurse-staffing level together with control variables & life expectancy at 65	Panel v-Statistic	−1.16	0.877	−3.42	0.999	Co-integrated
	Panel rho-Statistic	5.79	1.000	6.03	1.000	
	Panel PP-Statistic	−1.70	0.043	−6.25	0.000	
	Panel ADF-Statistic	1.25	0.894	−2.76	0.002	
	Group rho-Statistic	8.61	1.000			
	Group PP-Statistic	−10.60	0.000			
	Group ADF-Statistic	−1.86	0.031			

Notes: Null hypothesis was no co-integration and trend assumption was deterministic intercept and trend group-statistics based on common AR coefficient in within-dimension as well as individual AR coefficients in between-dimension. The optimum lag length was selected by SIC and Newey-West automatic criterion was applied to investigate bandwidth with Bartlett window.

Table 3
Dynamic long-run model: panel fixed-effect (35 OECD countries, 2000–2016).

Dependent Variable	Variable	Coefficient	Std. Error	*t*	*P*	r^2	Durbin-Watson
Life expectancy at birth	*Constant*	0.9415	0.10	8.61	0.000	0.99	2.40
	Trend	0.0001	0.00	1.10	0.269		
	Nurse-staffing level (-1)	0.0045	0.00	1.86	0.062		
	Medical-staffing level (-1)	−0.0031	0.00	−0.89	0.368		
	Health care spending (-1)	0.0050	0.00	2.83	0.004		
	Hospital beds (-1)	0.0008	0.00	0.50	0.614		
	CT scanners (-1)	−0.0006	0.00	−0.49	0.621		
	MRI units (-1)	0.0029	0.00	4.22	0.000		
	Life expectancy at birth (-1)	0.7730	0.02	30.08	0.000		
Long-run elasticity of effect of nurse-staffing level on life expectancy at birth: 0.004585/(1−0.773066) = **0.0202**							
Life expectancy at 65	*Constant*	0.7288	0.09	7.97	0.000	0.98	2.45
	Trend	0.0011	0.00	2.58	0.010		
	Nurse-staffing level (-1)	0.0233	0.00	2.65	0.008		
	Medical-staffing level (-1)	−0.0167	0.01	−1.36	0.174		
	Health care spending (-1)	0.0154	0.00	2.41	0.015		
	Hospital beds (-1)	0.0073	0.00	1.25	0.210		
	CT scanners (-1)	−0.0002	0.00	−0.05	0.955		
	MRI units (-1)	0.0060	0.00	2.44	0.014		
	Life expectancy at 65 (-1)	0.6892	0.03	22.08	0.000		
Long-run elasticity of effect of nurse-staffing level on life expectancy at 65 years: 0.023325/(1−0.689237) = **0.0751**							

Notes: "(-1)" used after variables to express one year lagged variable. Cross-section weights were applied to investigate the coefficients.

data analysis. The largest cross-national observations of 35 OECD countries were collected from OECD iLibrary during the period of 2000–2016. To simulate a reliable magnitude of the role of nurse staffing in increasing life expectancy indicators, five control variables were added to our analysis, including the number of practicing doctors as a proxy for medical staffing, HCE per capita as a proxy for financial resources in health care services, the number of hospital beds as a proxy for the health resources available for delivering services, total number of CT scanners and MRI units as proxies for medical technology.

According to the result of unit root test, all variables except HCE and MRI units were non-stationary, and this finding opened the way to panel dynamic long-run analyses. Results of co-integration analysis as well as panel dynamic long-run models proved that there were significant relationships from the level of nurse staffing to life expectancy at birth and at 65 years of age in long-run and the

Table 4
Dynamic long-run model: pooled fixed-effect (35 OECD countries, 2000–2016).

Countries	Magnitude of the effects nurse-staffing level had on increasing life expectancy indicators		
	life expectancy at birth	life expectancy at 65	Average
Australia	0.006105	0.037138	0.021622
Austria	0.022992	0.055915	0.039454
Belgium	0.000000	0.420766	0.210383
Canada	0.032774	0.016378	0.024576
Czech Republic	0.062675	0.355036	0.208856
Denmark	0.012755	0.219834	0.116295
Estonia	0.074013	0.100799	0.087406
Finland	0.003725	0.096649	0.050187
France	0.012016	0.110496	0.061256
Germany	0.046207	0.230270	0.138239
Greece	0.000000	0.000000	0.000000
Hungary	0.000000	0.148227	0.074114
Iceland	0.043923	0.444314	0.244119
Ireland	0.000000	0.014165	0.007083
Israel	0.034951	0.079034	0.056993
Italy	0.000000	0.091762	0.045881
Japan	0.107619	0.399058	0.253339
Korea	0.000000	0.043822	0.021911
Latvia	0.043054	0.084005	0.063530
Lithuania	0.142966	0.048818	0.095892
Luxembourg	0.020444	0.115786	0.068115
Mexico	0.020570	0.000000	0.010285
Netherlands	0.000000	0.000000	0.000000
New Zealand	0.012532	0.025551	0.019042
Norway	0.002446	0.034450	0.018448
Poland	0.039628	0.087940	0.063784
Portugal	0.005279	0.115624	0.060452
Slovak Republic	0.000000	0.040513	0.020257
Slovenia	0.008438	0.387975	0.198207
Spain	0.023928	0.086084	0.055006
Sweden	0.181321	0.178562	0.179942
Switzerland	0.049538	0.127506	0.088522
Turkey	0.064094	0.250070	0.157082
United Kingdom	0.034526	0.114954	0.074740
United States	0.000000	0.026368	0.013184
OECD35	0.031672	0.131082	0.081377

Notes: The following autoregressive models used to estimate long-run elasticity of nurse-staffing level on life expectancy at birth and at 65 years, respectively (based on SIC). "(-1)" used after variables to express one year lagged variable and α_i is the expression of coefficients.

$$\textit{Life expectancy at birth} = \textit{Constant} + \alpha_1 \textit{Trend} + \alpha_2\ \textit{Nurse-staffing level} + \alpha_3\ \textit{Nurse-staffing level (-1)} + \alpha_4\ \textit{Life expectancy at birth (-1)} + \textit{Error term}$$

$$\textit{Life expectancy at 65} = \textit{Constant} + \alpha_1 \textit{Trend} + \alpha_{22}\ \textit{Nurse-staffing level (-1)} + \alpha_3\ \textit{Life expectancy at 65 (-1)} + \textit{Error term}$$

elasticity of these relationships in OECD countries were 0.02 and 0.08, respectively. Hence, the findings of dynamic long-run analysis argued that the dependency of life expectancy to nurse-staffing level would increase by age. Interestingly, the elasticities of the effect of nurse staffing on life expectancy at birth and at 65 years old were higher than other control variables.

Overall, the role of nurse staffing in increasing the average of life expectancy indicators in long-run were determined at the highest level in Japan (0.25), followed by Iceland (0.24), Belgium (0.21), Czech Republic (0.21), Slovenia (0.20) and Sweden (0.18). By contrast, the lowest effect of practicing nurses on life expectancy in long-run were investigated in Norway (0.02), United States, Mexico and Ireland (0.01). For the rest of OECD countries, the magnitudes of this relationship had the range from 0.16 to 0.19 and there was not any evidence for concluding the existence of long-run relationship between these series in Greece and Netherlands. Thus, the role of nurse staffing in increasing life expectancy varies between different health care systems of developed countries which is a logical result considering the effect of other determinant factors on life expectancy indicators, such as national income and aggregate HCE [37–41], better education, healthier lifestyles [2] and the progress in health care [1,3] and its accessibility [36]. According to the available health data at a cross-national level, the limitation of this study is the lack of other nursing competency indicators like working environment [42], job satisfaction [43] and use of technology [44] in our analysis.

In all, the results of this study confirm the association between higher proportion of nurse staffing and higher life expectancy at birth and at older ages in OECD countries. Hence, our findings alert health policy makers along with governments to ponder the deleterious effects of nursing shortage on increasing the risk of actual age-specific mortality at a national level. As the lack of available data is the largest obstacle in nursing science, the recommendation is to co-operate with global organizations such as OECD, World Health Organization (WHO), World Bank and other relevant organizations as well as researchers to support, collect and analyze cross-national data to be used in further research seeking to measuring the interaction between nursing competencies and health outcomes.

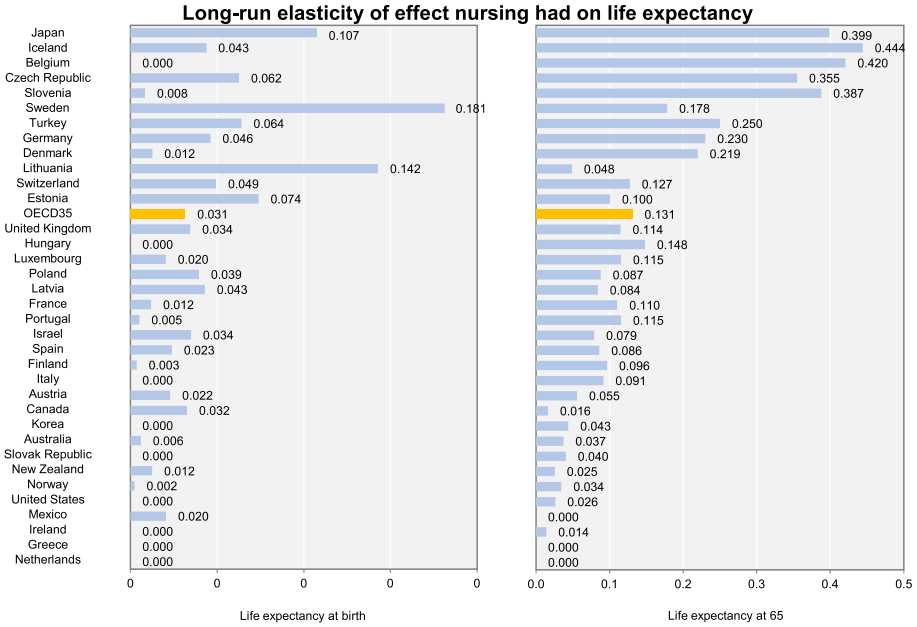

Fig. 5. Long-run elasticity of effect of nurse-staffing level on life expectancy at birth and at 65 years (2000-2016) based on the results of dynamic long-run model.

5. Conclusion

There exists a positive association between the level of nurse staffing and life expectancy at birth and at 65 years old in OECD countries in the long-run.

Conflicts of interest

The authors have declared that no conflicts of interest exist.

Authors' contributions

Both authors contributed to the study design and drafting of the paper. Amiri has done data analysis and both authors approved the final version of article.

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Appendix A. Supplementary data

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