TAF

Journal of Administrative and Business Studies

JABS

2021, **7**(2): 12-20

PRIMARY RESEARCH

The effect of different variables on the value of statistical life across developing countries

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Keywords

Value of statistical life
Developing countries
Meta-regression
Correlation

Received: 04 December 2020
Accepted: 29 February 2021
Published: 19 May 2021

Abstract

Value of Statistical Life (VSL) benefits from saving one life stated in monetary terms at a specific risk level. This concept is an essential tool for policymakers in the cost-benefit analysis used in many developed countries. However, the VSL concept is still missing or less applied to developing countries where people are exposed to various risks compared to developed countries. This study employed a meta-regression analysis using VSL in developing countries and some developed countries to clarify the effects of different variables such as annual income, annual work hours, and age on VSL. Meta-regression analysis was decided based on the distribution of each variable. Across all the studies, annual working hours and age were distributed normally. In contrast, VSL and annual income had a logarithmic distribution, leading to applying a log-log model using logarithmic transformation of VSL and annual income in the analysis. The results indicate that the VSL in developing countries has a positive and strong correlation with income, while the correlation between VSL and annual working hours is negative, meaning that with increasing annual working hours, the VSL will decrease.

INTRODUCTION

VSL is the source of financial data in cost-benefit analysis conducted by the government, and the concept monetizes the benefits of saving one's life. It can be utilized in any issue relating to life, including clean air, water, food, and humans, safely stating how much money needs to be spent to save one life at a designated level of stringency and judgment (Sunstein, 2018). Based on empirical data, a middle estimate of the VSL for reducing the mortality risk for real people was set to 7 million USD. However, similar to public misinterpretation on VSL, the concept of VSL is sometimes misunderstood or misinterpreted in a wide range of opinions, objections, and emotions leading to a decision by the U.S. Environmental Protection Agency to decrease the estimation of VSL from 7.8 million USD to 6.9 million USD (Cameron et al., 2010). Each terminology in the VSL reflects a specific meaning. The word "Value" reflects an individual's Willingness To Pay (WTP) for risk reduction; "Statistical" implies probable death rather than certain death, and "Life" does not refer to one whole life when a small risk is being sought for many different people (what non-economists think). Still, it would be a WTP in terms of an arbitrary aggregated risk reduction (Cameron et al., 2010).

VSL is also known as a local trade-off rate between fatality risk and money—an important tool for understanding the amount of benefit that people derive by spending money for their safety and health. This can be estimated using labor market and occupational risk data for countries in which the data is available or hypothetical decisions are known as revealed preference evidence and stated preference evidence, respectively. Considering that the monetary term of VSL is the largest part of the benefits that regulations

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achieve, it is also an important aspect of cost-benefit analysis in government policy and private sector firms. The absence of homogeneity, which makes it an interesting aspect of VSL, has been observed in many empirical studies. Age variation and income elasticity are heterogeneous aspects of VSL, which are important, among other aspects, because they are the key to understanding how the VSL varies across countries and how policymakers adjust it in each country (Viscusi & Kniesner, 2019). In many developing countries that are facing a lack of appropriate data, to set a standard amount for VSL rather than using revealed preferences such as the hedonic wage method in the U.S., or the stated preference method in Europe, it is suggested to apply an extrapolation method from other countries by incorporating gross domestic product per capita (Mardones & Riquelme, 2018).

Developing countries, especially developing small island and landlocked developing countries with low and low-middle income, are more exposed to disaster risk. This is due to the increasing exposure and vulnerability to natural hazards. In this context, investment in disaster risk reduction programs can mitigate and limit the extent of disaster risk. However, because of the global economic crisis, it is difficult to cover the additional cost of disaster risk countermeasures, especially in developing countries. In other words, developing countries must enhance the governance capacity to invest correctly in such programs so that greater benefits can be achieved by the lowest investment in disaster risk reduction programs (United Nations, 2009).

Considering the high number of casualties in developing countries due to due to natural disasters, the importance of benefits achieved via implementing countermeasures to reduce mortality risk is highlighted in the literature. During the 50 to 90 years period, high-income countries have managed disaster risk and reduced the number of casualties from 12000 to 2000. while in developing countries, there were no specific changes in the mentioned number (Department for International Development, 2005).

The extent of disaster risk in developing countries, e.g, Afghanistan, is higher than in other neighboring countries, and this is because of Iherethe high vulnerability of people and assets and their exposure to emergency situation where the coping capacity in the country is not at an acceptable level. It is estimated that the average annual economic losses in Afghanistan are 147 million USD, 92 million USD, and 239 million USD owing to earthquakes, floods, and multi-hazards, respectively. If an earthquake strikes the country every 50 years, it will cause an economic loss of USD 638 million estimated damage only to properties (United Nation Office for Disaster Risk Reduction, 2015).

A review of the effect of disaster risk reduction projects in some case studies of developing countries states that investment in disaster risk reduction projects is as important as post-disaster operations because the achieved benefits are higher than costs, and it encourages governments to invest more in Disaster Risk Reduction (DRR) projects. However, the employed cost-benefit analysis shows some limitations in monetizing some of the benefits achieved via DRR projects; hence, it does not cover all the costs and benefits of a DRR project.

Some uncertainties in assessing indirect losses, such as the value of human life, cannot be resolved because death and injuries are generally not interpreted in monetary terms in developing countries (KC, 2013) preventing the loss of life is vital for implementing DRR projects across countries. Such projects need to be assessed using an essential policy tool, a cost-benefit analysis. To proceed with such an analysis, the reduced number of mortalities owing to a DRR implementation project needs to be calculated and converted into monetary terms using the VSL, which can be transferred from high-income to low-income countries using income elasticity (Cropper & Sahin, 2009). However, VSL is missing or has been identified in many developing countries. Experiences of previous disasters in developing countries with abundant human and property loss because of high exposure, vulnerability, and low capacity urges government officials and policymakers to have a more integrated benefit-cost analysis using VSL.

This study aims to develop a model to estimate the VSL in developing countries. Data for this purpose are extracted from other related studies in developing countries and some developed countries, mainly VSL, average annual income, average age, and average working hours per year, clearly described in Section 2. Then, the meta-regression methodology and variables are defined in Section 3. Section 4 presents the results, including two models for estimating VSL in developing countries. Finally, in Section 5, the effects of variables on VSL are presented and interpreted.

DATA

This research considered 19 observations of VSL from 13 studies around the world via different methods and cases. Various data and observations in countries reflect various VSLs. The United States is categorized as a developed country (UN, Country Classification). Still, the estimated VSL for countries with different economic groups using U.S. data shows a trend of increasing VSL when income increases. Viscus and Master man estimate VSL for 189 countries around the world by using 9.6 million USD for U.S. VSL

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

as a base, and develop four categories of VSL for lower-income, lower-middle-income, upper-middle-income, and upper-income countries, which varies from 107 thousand USD to 6.4 million USD (Viscusi & Masterman, 2017). Rafiq (2011) has set an estimate of 775 thousand USD for VSL in Pakistan by compensating wage differential among blue-collar workers in Lahore, Pakistan (Rafiq, 2011), while Madheswaran (2007) estimate for India, informed by a similar methodology, reflects a VSL of 375,000 USD for workers in Chennai and Mumbai (Madheswaran, 2007) and 640,000 USD in Ahmedabad, India, because of the hedonic wage model; both of these represent lower values than Pakistan. Concerning income, both Pakistan and India categorized as lower-middle-income countries—have estimated higher VSL than what is reported by Viscusi and Masterman. However, it is noteworthy that separate studies in India and Pakistan have focused on specific targeted areas and sampling. In Iran, the estimate of VSL based on the contingent valuation method in a certain health problem focused on the Tehran area, is set to 100,000 USD (Brajer & Rahmatian, 2004). Estimates of VSL for Chile in 1998 and 2018 show a dramatic increase from 675,000 USD to 3,730,000 USD. Other estimates of the VSL are summarized in Table 1 . Our study extracts the VSL and annual income from each study. Age and annual working hours were also extracted from each study where data was available and from other sources where data was not available in the study.

TABLE 1. Summary of data extracted from related studies on VSL for some countries

No	Author(s)	Title of Study	Country	Concept and Method	Average Work Hours Per Year	Average Age	Annual Income (USD)	VSL (USD)
1	Rafiq (2011)	Estimating the VSL in Pakistan	Pakistan	Using the hedonic wage model Assessing the demand for safety by estimating the relationship between wage and job-related risk Implementing questionnaire survey for 680 industrial workers	2,000	27	1,031	775,193
2	Majumder and Madheswaran (2018)	VSL in India: A Hedonic Wage approach	India	VSL using hedonic wage model in Ahmedabad India	2,160	27*	1,237	640,000
3	Simon, Cropper, Alberini, Arora, et al. (1999)	Valuing Mortality Reductions in India A Study of Compensating Wage Differentials	India	VSL using hedonic wage model in India	2,083*	22*	7,650	153,000
					2,083*	22*	7,458	358,000
4	Madheswaran (2007)	Measuring the VSL: estimating compensating wage differentials among workers in India	India	Indian risk preferences based on a survey of 550 workers in Chennai and 535 workers in Mumbai	2,098*	24*	3,333*	375,000
5	Brajer and Rahmatian (2004); Mardones and Riquelme (2018)	From Diye to VSL: A case study for I.R. Iran	Iran	Using contingent valuation method based on people's WTP to estimate VSL	1,872***	37	3,316****	100,000
6	Bowland and Beghin (1998)	Robust Estimates of Value of A Statistical Life For Developing Economies: An Application To Pollution And Mortality In Santiago	Chile	Conducting meta-analysis of VSL using robust regression technique	2,299*	29	10,636	675,000
7	Mardones and Riquelme (2018)	Estimation of the VSL in Chile and Extrapolation to Other Latin American Countries	Chile	Using hedonic wage method to estimate VSL in Chile	2,390	35	4,468	3,730,000

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

TABLE 1 Continue....

No	Author(s)	Title of Study	Country	Concept and Method	Average Work Hours Per Year	Average Age	Annual Income (USD)	VSL (USD)
8	Viscusi and Kniesner (2019); Viscusi and Masterman (2017)	Income elasticities and global values of statistical life	U.S. and World	Using meta-analysis approach for estimating VSL for U.S. and	1,757*	38*	55,980	9,631,000
				lower income countries	2,212**	18*	621	107,000
				lower middle-income countries	2,156**	25*	2,441	420,000
				upper-middle-income countries	1,924**	34*	7,146	1,200,000
				upper income countries	1,841**	39**	37,173	6,400,000
9	Rosalina (2008)	VSL Estimates for Children In Metro Manila, Inferred From Parents' WTP For Dengue Vaccines	Philippines	Using contingent valuation method to estimate VSL for children	2,093*	14	5,904	800,000
10	Gibson et al. (2007)	The VSL and the economics of landmine clearance in developing countries	Thailand	Applying contingent valuation questionnaire for low-income rural communities adjacent to landmine affected areas and estimating VSL	2,384*	43	630	250,000
11	He and Wang (2010)	The VSL: a contingent investigation in China	China	Estimating Individual's "WTP for cancer risk prevention in 3 Provinces in China" using contingent valuation method	2,178*	35*	2,150	129,000
12	Cameron et al. (2010)	The VSL and cost-benefit evaluations of landmine clearance in Cambodia	Cambodia	Using Contingent valuation method in two provinces for estimating benefits of landmine clearance	2,390*	23*	2,000	400,000
13	K., Jin-Tan, and Jin-Long (2000)	Survival is a luxury good: The increasing value of statistical life	Taiwan	Estimating VSL using compensating wage differential model	2,327	29	4,272	410,000
					2,285	33	8,985	4,500,000

Note: *Missing data regarding average work hours per year are extracted from the website ourworldindata.org
**The data reflects mean values from the website: ourworldindata.org for some countries (categorized by Viscusi and Masterman, 2017)
***The data was extracted from: www.mcls.gov.ir (Ministry of Cooperatives Labour and Social Welfare of Iran)
****The data was extracted from: www.amar.org.ir (Statistical Center of Iran)

The World Economic Situation and Prospects (WESP) of the United Nations (2014) Secretariat have classified all countries across the world into three main groups: developed countries, economies in transition, and developing countries, where composites are based on basic economic conditions in each country. However, it is remarkable that per capita GNI for each of the countries may differ, creating yet another classification of countries, including low-income countries with GNI per capita less than 1,035 USD, lower-middle-income countries with GNI per capita between 1,036 to 4,085 USD, upper-middle-income countries with GNI per capita between 4,086 and 12,615 USD, and high-income countries with GNI per capita of more than 12,615 USD. Based on the WESP classification, all countries in Table 1, except the U.S., are categorized as developing countries. Table 2 adopted from the WESP, shows the list of countries included as developing countries for our analysis (United Nations, 2014).

TABLE 2. List of developing countries considered for the current study (adopted from WESP/UN 2014)

Asia		Latin America and the Caribbean
East Asia	South Asia	South America
China	India	Chile
Philippines	Iran (Islamic Republic of)	
Taiwan Province of China	Pakistan	
Thailand		
Cambodia		

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

METHDOLOGY

According to Table 1, a linear relationship between VSL and income can be defined. This relationship can be explained using a simple linear regression model. A simple regression model can explore the relationships between the two variables. Although it has some limitations, it can sometimes be an empirical tool. An econometric analysis clarifying the relationship between income and VSL indicates how VSL varies if changes occur in income. In other words, we explain VSL in terms of income. However, it must be considered that this relationship shows an estimation value of VSL based on changes in income, and a functional equation can be a good definition between these two variables. This relationship can be represented in a linear model as follows:

$$VSL = \beta_0 + \beta_1(\text{ income }) + u \quad (1)$$

In Equation1, VSL is the dependent variable defined by an independent variable, income. In other words, changes in income affect changes in VSL. β0 and β1 are coefficients that have to be estimated via the ordinary least squares method, and u is the error term (Wooldridge, 2013). Besides, income for predicting the changes in VSL, incorporating other variables, including age and annual working hours, will lead to the development of a multiple regression analysis that can define the relationship between VSL and other variables. In a simple regression model, when the changes in VSL are predicted only by income, it is assumed that all other factors are uncorrelated with VSL—called ceteris paribus, and they are considered to be constant in parameter u. In multiple regression analysis, this issue is amended, and the effect of other dependent variables, such as age and annual working hours, is controlled. When more dependent variables are considered in the analysis, more variation and better estimation of the VSL can be developed. A multiple regression model for the estimation of VSL is explained in the following model (Wooldridge, 2013):

$$VSL = \beta_0 + \beta_1 \text{ (income) } + \beta_2 \text{ (age) } + \beta_3 \text{ (annual working hours) } + u \quad (2)$$

where

β0 is the intercept.

β1 measures the changes in VSL regarding income and holding other fixed factors.

β2 measures changes in VSL regarding age and holding other fixed factors.

β3 measures changes in VSL regarding annual working hours and holding other fixed factors.

Focusing on the linear regression model and considering the distribution of variables, the logarithmic transformation may be incorporated into the regression analysis—making four models including the model with no transformation, the linear-log model,the log-linear and the log-log model. This issue is also compatible with multiple regression analysis. Table 3 shows the different modes of logarithmic transformation of the linear regression model (1), which estimates VSL based on changes in income (Benoit, 2011).

TABLE 3. Different modes of log transformation of a linear regression model (Adopted from Benoit 2011)

VSL	**Income**	
	Income	**Log(Income)**
VSL	Linear	Linear-Log
	VSL = $\beta_0+\beta_1$ (income)	VSL = $\beta_0+\beta_1$ Log(income)
Log(VSL)	Log-Linear	Log-Log
	Log(VSL) = $\beta_0+\beta_1$ (income)	Log(VSL) = $\beta_0+\beta_1$ Log(income)

The logarithm used here is a natural logarithm with an e = 2.718828 base. We use logarithmic transformation when there is no linear relationship between the dependent and independent variables (Benoit, 2011).

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

RESULTS AND DISCUSSION

Fig 1 (a) to 1 (d) shows a picture of the data distribution via histogram across the various studies mentioned in Table 1. Among all variables, the distribution of age and annual working hours is normal, meaning that across all the studies, age and annual working hours are the data that have been accumulated near the mean value of 29 and 2133, respectively, and make an approximate symmetric bell-shaped distribution.

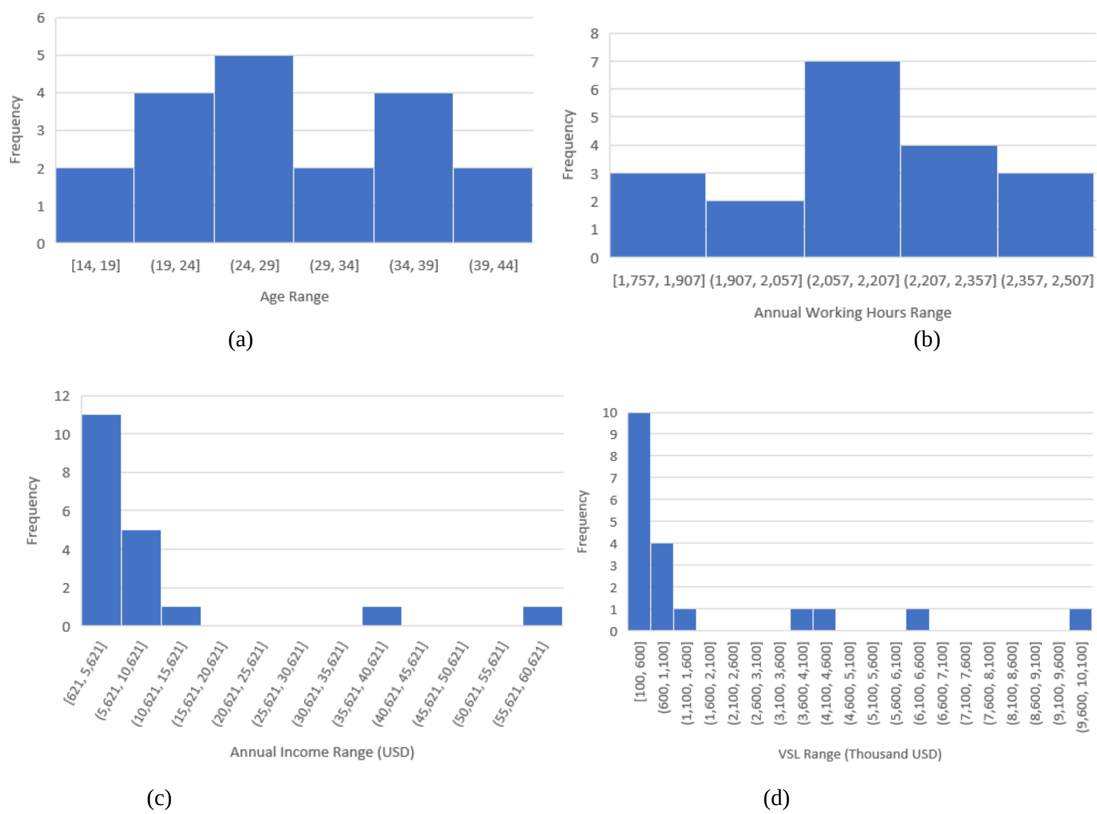

FIGURE 1. Distribution of dependent and independent variables associated with Table 1, (a) Distribution of age, (b) Distribution of annual working hours, (c) Distribution of annual income, (d) Distribution of VSL

Conversely, VSL and annual income distribution are not normal. Most of the data have been accumulated on one side of the diagram, making an asymmetric and right-skewed shape with a lognormal distribution. This means that the logarithmic distribution of the mentioned data is normal and accumulates near the mean value. In this case, based on Table 3, our regression model to estimate VSL with single and multiple variables is transformed to a log-log model as follows:

$$\log(VSL) = \beta_0 + \beta_1 \log(\text{ income }) + u \quad (3)$$

$$\log(\text{ VSL }) = \beta_0 + \beta_1 \log(\text{ income }) + \beta_2(\text{ age }) + \beta_3(\text{ annual working hours }) + u \quad (4)$$

The coefficients for linear regression and multiple regression are calculated by running the regression model, as shown in Tables 4 and 5:

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

TABLE 4. Calculation of coefficients for equation 3

Variables	Equation 3
Intercept	6.966
Ln(income)	0.768
$R2$	0.460
Observation	19

TABLE 5. Calculation of coefficients for equation 4

Variables	Equation 4
Intercept	3.261
Ln(income)	0.800
Age	0.038
Annual working hours	0.001
R^2	0.520
Observations	19

Both models were developed using 19 observations across 13 studies of VSL. The coefficients of determination for both models are presented in Tables 4 and 5. It seems that the incorporation of income, age, and annual working hours in Equation 4 creates a better relationship explaining 52% of the variation in the data, while in the case where the only income is an explanatory variable, it decreases to 46%.
The Pearson coefficient correlation between the variables used for the analysis was calculated in Table 6. It seems that among the dependent variables used for estimating VSL, income has the highest positive correlation with VSL, meaning that increasing income leads to increased VSL. Conversely, average annual working hours negatively correlated with VSL, stating that increasing annual working hours leads to a decrease in VSL across the studies.

TABLE 6. Pearson correlation coefficient between variables

Pearson Correlation Coefficient	VSL	Income	Age	Work Hours
VSL	1			
Income	0.91	1		
Age	0.47	0.38	1	
Work Hours	-0.44	-0.61	-0.16	1

A similar study by Miller (2000) conducted a regression analysis of VSL encompassing 68 studies in 13 countries. The data included 47 VSL estimates (Miller, 1990) and 21 additional estimates, excluding the United States. The extracted VSL data across the literature were mainly based on contingent valuation surveys, wage-risk studies, and consumer behavior studies. Estimating VSL for countries where it is difficult to apply direct measurement methods was facilitated using a benefit transfer approach (Miller, 2000). The transfer of existing VSL data to the countries where VSL is unavailable was conducted with benefit transfer functions with validation in some low-income countries. The study used a log-log regression analysis as Equation 5 for the two individual-study and country-level regressions cases. To ensure consistency among VSLs, the after-tax values were considered for the wag-risk studies.

$$\ln(VSL) = a + b\ln(Y) + cZ \tag{5}$$

In Equation 5, VSL is the value of statistical life, Y is income, and Z is the explanatory variable. Most VSLs in the study Miller (2000) have an annual income of 120 times. Meanwhile, the methodology provides an affordable way to estimate VSL nationwide (Miller, 2000). The summary of the data analysis (Miller, 2000) denotes higher expectations of richer countries on risk reduction and a better life—leading to a higher VSL. Conversely, death risk reduction is less valued in developing and least developed countries. This issue reflects the effect of income on VSL, meaning that higher income increases VSL.
The study Organization for Economic Co-operation and Development (OECD) (2012) conducted another similar meta-

ISSN: 2414-309X
DOI: https://doi.org/10.20474/jabs-7.2.2

analysis research work for estimating VSL. It includes 366 observations on contingent valuation across 34 studies, in which VSL ranges from 4,450 to 22,100,000 USD. The study also applied a log-log meta-analysis that included the logarithmic transformation of VSL, income, and risk reduction in contingent valuation. The analysis revealed a high R-squared between 0.719 and 0.855, meaning that meta-analysis explains 72% to 86% of variations across the studies, and it does a good job. Moreover, it states that VSL is largely affected by national wealth and the extent of risk reduction, which is used in the contingent valuation method. It also mentions that VSL increases among the wealthiest in rich countries, willing to pay more for risk reduction (Organization for Economic Co-operation and Development (OECD), 2012).

CONCLUSION

VSL is an essential concept for developing countries that face various risks. VSL importance is especially highlighted in developing countries, where the majority population is poor, resulting in higher exposure and vulnerability to natural hazards. In such situations, DRR countermeasures programs need to be managed, and investment in such programs in any region at any time requires a comprehensive cost-benefit analysis. VSL, which is missing or less studied in many developing countries, plays a key role in conducting such an analysis. This study contributes to the development of a model for estimating VSL. It used a meta-regression analysis by incorporating the data of developing countries and some developed countries to form a model for estimating VSL. Annual income, average age, and average working hours per year were the main predictors of VSL. The linear regression model with the effect of income on VSL and multiple regression analysis considering the effect of all variables were used. Because of the lognormal distribution of VSL and income across the studies, the models were developed with the logarithmic transformation of VSL and income. Our analysis showed that by incorporating all variables for estimating VSL, the model explains 52% of the variation in the data, and by using only income as an explanatory variable, the model explains 46% of the variation. Although this study has a lower coefficient of determination than similar studies with meta-analysis methods, it still can serve as a reliable method to fill the gap in estimating VSL in developing countries with lacking data. Our results also showed that income is an important predictor of VSL in developing countries, and this issue was reflected in the literature with a similar analysis. Across all the studies, VSL has a strong positive correlation with income, meaning that increasing income leads to increases VSL while working hours negatively correlate with VSL. It seems that in many developing countries, because of the low income and high working hours, VSL is lower than in developed countries. It is also remarkable that our study faced many limitations in collecting homogeneous data to analyze it better. Besides, the lack of related research on VSL for developing countries and lack of the same sort of data across all the studies in our model led to the relay of other sources for missing data. Future studies looking to estimate VSL for developing countries need to consider incorporating data in developed countries and, they should scale it reasonably for it to apply to other countries.

ACKNOWLEDGMENT

The author would like to thank Professor Fujimi and Professor Kakimoto for their kind contributions and effective feedback to support this study. Additionally, we would like to thank Editage (www.editage.com) for English language editing.

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ISSN: 2414-309X
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