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Generation gap and its impact on economic growth

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ABSTRACT

Workers of different generations often complain about one another as their opinions, values, attitudes, and approaches to work differ. This might lead to a reduction in labor productivity that can negatively impact the economic growth of any nation. In this paper, we used generation mix indices to analyze whether generation gap has any impact on economic growth. Using Thailand's data between 1961 to 2019, we found that when generations were intensely mixed, economic growth did suffer.

1. Introduction

Many studies show that population structural change can have a long-lasting impact on economic growth. Song (2013) finds that the economic growth of 13 ASEAN countries between 1965 to 2009 has a positive relationship with the working population growth, while having a negative relationship with the total number of population. Kim (2016) shows that the population structural change in OECD countries has an impact on its growth in the last decade. The explanation why population structure can have an impact on economic growth is usually explained through the change in labor productivity and labor supply (Fent et al., 2008). With aging and aged society, fertility and mortality declines, dependency ratio increases, the number of working population decreases (a reduction in labor supply), therefore the production possibility in each country reduces. Apart from an increase in dependency ratio, another important factor that can influence economic growth is labor productivity. OECD (2020) states that the labor productivity is determined by 2 components: own individual contribution such as effort and skill, and collective contribution from the interactions with other workers. The current literature explains that a reduction in labor productivity in an aging/aged society comes from a larger share of old workers with low productivity and a smaller share of young workers with high productivity (An and Jeon, 2006; Maestas et al., 2016; Bawazir et al., 2020), evidence of the first component of labor productivity. However, none of the literature considers the second component, the interactions with other workers (OECD, 2020).

Generational differences that lead to generation gap[1] issue has long been discussed in workplaces. Workers of different generations often complain about other generations as their opinions, work values, work attitudes, and approach to work differ. Psychology and sociology literature defined each generation and suggested that their differences can lead to generational tension (Mannheim, 1952; Ryder, 1965; Grenier, 2007, etc.). They suggested that social and historical events often influence and shape social consciousness and perspective of an individual (Mannheim, 1952; Strauss and Howe, 1991, 1997). There were distinct cohorts throughout history that shared characteristics and values. Each of the cohort goes through different phases of life, shares the same historical events making population in the same cohort share distinct set of beliefs, attitudes, values, and behaviors. Strauss and Howe (1991, 1997) also discussed the generation gap idea where different generations developed different ways of looking at the world and the way they work. Therefore, when their work values differ, this can lead to strategic problems in organizations. Research in management discussed ways to mitigate conflicts in workplaces due to generation gaps (Subramanian, 2017; Jirasevijinda, 2018; Cismaru and Iunius, 2020, etc.). In economics, there

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[1] Generation gap refers to the rift that divides the thoughts, actions, beliefs, and tastes exhibited by members of different generations. Generation gap is important in business world as firms need to find ways to balance the needs and views of individuals from different generations, both their clients and their workers (Kenton, 2021).

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were discussions on how different generations vary in their wages, earnings, employment, and financial management (Alfonso and Torrini, 2007; Pisani-Ferry, 2016; Carlin et al., 2019). However, the impact of generational differences on economic growth has been neglected in the literature. Even though there are economic models that take into account of differences in population (such as an assumption of heterogeneous preferences), none focuses on how generation disparity can affect economic outcomes when they are mixed in the labor force.

In this paper, we utilize the generational differences concept in psychology and sociology to see whether conflicts raised when population of different generations are mixed together in a workplace, can lower the economic growth. Since none of the studies done so far, has shown a direct impact of generation differences on economic growth, we aim to be the first analysis in doing so. To this end, we use the generation mix indices calculated in Harnphattananusorn and Puttitanun (2021) that measure the complexity of the generation mix to use them to analyze their impacts on economic growth. Using the population and economic growth data from Thailand between 1961 and 2019, we find that generation gap negatively relates to the economic growth. Therefore, when the world's population is aging, countries in the world is experiencing growth in the number and proportion of older persons in their population, older generation may have to prolong their retirement, and newer generation may have to quickly join the labor force, the generation gap problem can be more intense. It is important to recognize the generational difference as another dimension of population diversity that can have an impact on labor productivity and economic growth.

The rest of the paper is organized as followed: Section 2 provides information on definition of generations and their differences. Section 3 described conceptual framework, methodology, and data. Results are presented in Section 4, and concluding remarks are in Section 5.

2. Generation differences

In defining each generation, the literature generally uses the year that they were born. Even though minor variations exist, we can summarize each generation in Table 1.

Generational cohort theory discussed by researchers in anthropology, sociology, and psychology suggests that people in each cohort exhibit similar characteristics, preferences, and values toward different aspects of life, and each cohort thinks and behaves differently. Not only people of different age group usually have different aspects of life, but their thoughts or how people feel about a given issue is also shaped by their historical and life events when they grow up (Becton et al., 2014; The Pew Research Center, 2015).

Greatest generation was termed for those who were born before 1928. They were the ones that fought in World War II. Silent generations were the children of the Great Depression and World War II. Their "Silent" label refers to their image as conformist and civic minded. Baby boomers were part of the peak in fertility that began in 1949, after the end of World War II. Generation X is defined by the relatively low birth rates compared to the Baby Boom generation. Nimngern (2018) and Francis and Hoefel (2018) describe Baby Boomer generation's behavior as idealism, revolutionary, collectivist, serious, and hard working. Generation Xs are materialistic, competitive, confidence, individualistic, and interested in technology. Generation Ys are globalist, questioning, and oriented to self. They grew up with technology and therefore are technology-able.; Generation Zs are realistic, fast learner, and have a tendency to work in informal sector.

Table 1. Lists of generations.

Generations	Years Born
Greatest Generation	1901–1927
Silent Generation	1928–1945
Baby Boomer	1946–1964
Generation X	1965–1980
Generation Y	1981–1996
Generation Z	1997–2012

Source: The Pew Research Center (2015, 2019).

Since each generation has different work values, different views on what is important in life, their attitudes toward works as well as the working styles can be different (Glass, 2007). This is often referred to as the generation gap. Having a large generation gap can create conflicts, poor performance, and low morale in the workplace. All of these can lower the productivity of workers and in turns hurt the whole economy.

Just as it is important to recognize the many dimensions of diversity including gender, age, race, and culture that shape how workers behave, we must also then recognize that generation gap can influence labor productivity as well.

3. Conceptual framework, data, and methodology

From the literature in Psychology, Sociology, and Management fields, when population of different generations are mixed together in a workplace, they might have conflicts due to their differences (Becton et al., 2014; Dittman, 2005, among others). Hence, we can conclude that:

$$\text{Work conflicts} = \text{f(generation mix)} \tag{1}$$

Once workers have conflicts, the productivity of workers drop because they might have to spend time resolving conflicts, adjusting their working styles, etc. Moreover, work organizations need to find solutions to reduce these conflicts, use resources to mitigate the problems, and therefore having less resources to invest on increase efficiency and other economic outputs. Therefore,

$$\text{Economic output growth} = \text{g(work conflicts, X)} \tag{2}$$

where X contains other factors that influence economic output growth such as work force growth, inflation, technology, saving growth. Combining Eqs. (1) and (2), we can write a reduced form model as Eqn 3:

$$\text{Economic output growth} = \text{G(generation mix, X)} \tag{3}$$

Therefore, the following function (Eqn 4) can be used to explain the direction of the impact of generation mix and other factors on economic output growth.

$$gdpgr_t = a_0 + a_1 \text{inf}lation_t + savgr_t + pop1564gr_t + tech_t + Gindex_t + e_t \tag{4}$$

where *gdpgrt* is the economic output growth measured by real GDP growth rate in year *t*; *inflationt* is the inflation rate in year *t* proxied by consumer price index; *savgrt* is the saving growth rate in year *t*; *pop1564grt* is the working population growth rate in year *t*; *techt* is the technology growth rate in year *t*; *Gindext* is the generation mix measure in year *t*; and *et* is the error term of the model.

To measure the technology growth rate in year *t* ($tech_t$), we can estimate it using the Solow residual concept from estimating the model below:

$$\ln Y_t = C_0 + \hat{b}_1 \ln K_t + \hat{b}_2 \ln L_t + \varepsilon_t \tag{5}$$

where *Kt* is the real gross fixed capital in year *t* (rgfcf); *Lt* is the labor force size in year *t* (labor).

To quantify the level of generation mix, we need a measure that can capture the complexity of generational differences at a point in time. Therefore, such measure must consider the number of generations, the size of each generation, and how they compared to one another. We assume that the generation differences issue becomes more intense when generations are more mixed. Harnphattananusorn and Puttitanun (2021) created several generation mix indices that measure the intensity of generation mix, which takes into account of number of generations, the absolute size of each generation, and the relative size of each generation compared to others in the labor force in a given period of time following methods that Biologists measure the diversity of different species in a community using biodiversity indices.[2] Based on Beals et al. (1999), even though there are many biodiversity indices, four common measures are the Simpson Index (D) (Simpson, 1949), the Shannon Index (HS) (Shannon and Weaver, 1949), the Brillouin Index (HB) (Pielou, 1969), and the Pielou's evenness index (J) (Pielou, 1966).[3]

The data on the number of Thai population born in different cohorts over the years 1960–2019 is collected from the World Bank. Since we are interested in the effect of generation gap on economics outcomes especially on the workplace productivity, we restricted our samples to those population aged between 15 and 60 (based on the working population definition in Thailand). Since our data covers the information since 1960, we have 6 generations in our dataset: Generation Greatest, Generation Silent, Generation Babyboom, Generation X, Generation Y, and Generation Z as shown in Figure 1. As can be seen in Figure 1, our data set is dominated by generation Babyboom that spans out over 59 out of 60 observations. In contrast, generation Z is the smallest group in the data set as they recently started joining the labor force.

Applying these four common methods of calculating biodiversity indices mentioned earlier on Thai population born in different cohorts over the years 1960–2019 data (collected from the World Development Indicators Data Set, World Bank), Harnphattananusorn and Puttitanun (2021) calculated these four generation mix indices to measure how diverse and even the population in different generations are in a given year, or how intense the generation mix is in each period as shown in Figure 2. As can be seen in Figure 2, the generation mix indices move consistently, with Simpson's index move in the opposite direction compared to the other three indices by its design. The Cronbach's alpha coefficient[4] is used to check for the validity and reliability of these 4 indices. Generally, Cronbach's alpha coefficient varies between 0 and 1 where the minimum level of Cronbach's alpha is around 0.65–0.8 to

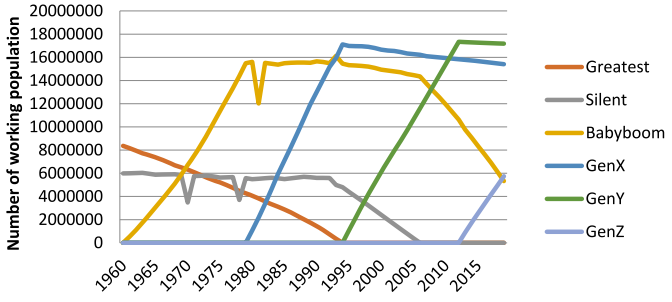

Figure 1. Thai working population by generation.
Data Source: World Development Indicators, World Bank

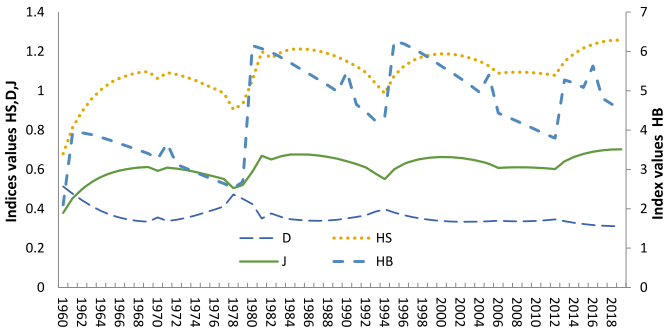

Figure 2. Generation mix indices.
Source: Authors' calculation

accept the validity of these indices (Cronbach, 1951). Our calculation is 0.908 suggested that these 4 indices are valid and reliable.

The data on Thai economy: real GDP growth rate, real gross fixed capital formation to measure capital stock, consumer price index to calculate for inflation, working population growth rate are collected from the Office of the National Economic and Social Development Council, Thailand website (Table A1). Summary statistics of the data used in the estimation are presented in Table 2[5]:

From Table 2, we can see that the average of the GDP growth rate (*gdpgr*) over 59 years is 5.991% with the highest rate being 13.288% and the lowest rate being -7.634%. Moreover, the average inflation rate (*inflation*) over 59 years is 4.174% which had a large variation between -0.9% to 24%, the same as savings growth rate (*savgr*) that varied between -28.601% and 51.602% with the average being 11.637%. These large variation of the GDP growth rate, inflation rate, and savings growth rate could be because the data covers the time before, during, and after the Asian economic crisis. The working population growth rate (*pop1564gr*) varied between 0.038% to 3.44%, with the average of 2.077% annually. The steady working population growth rate in Thailand is one of the reason that Thailand enjoyed an increase in the real GDP growth in Thailand. As for the generation mix indices (*G index*), although all four indices are consistently move in the same direction, the values of *HS*, *J*, and *D* indices vary between 0.312 to 1.258, while the *HB* index varies between 2.10 to 6.262.

Since our data set[6] covers the time span of 59 years from 1961 to 2019, we need to check for stationary in our data set. The results are shown in Table 3.

Even though the majority of the variables are stationary (I(0)), *pop1564gr* and *Gindex (HB)* are not. We simply cannot use OLS method to estimate Eq. (1). To appropriately estimate Eq. (1), we need to use an Autoregressive Distributed Lag (ARDL) model that allows for a combination of I(0) and I(1) variables (Nkoro and Uko, 2016). ARDL approach to cointegration provide realistic and efficient estimates irrespective whether the underlying variables are I(0), I(1), or a combination of both (Pesaran and Shin, 1999; Pesaran et al., 1996). Therefore, based on the unit root test in Table 3, where the variables are of different order of integration, the ARDL Cointegration approach is an appropriate estimation model. Moreover, the ARDL Cointegration approach allows us to examine the impact of the generation mix on economic growth from the short run to the long run.

For the model diagnostic, we use the Durbin-Watson D-statistic and Breusch-Godfrey LM test to perform the Autocorrelation test and use the CUSUM plots to diagnose model stability.

ARDL model for one independent and dependent variables can be written in the following form (Eqn 6):

[2] These biodiversity indices consider the relative abundances of different species as well as species equitability.

[3] Formulae of these indices' calculation are in the Appendix.

[4] Cronbach's alpha coefficient is calculated by $\alpha = \left(\frac{k}{k-1}\right)\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right)$ where k is the number of indices to be tested. σ_i^2 is the variance of index i, and σ_t^2 is the variance of all indices.

[5] Detailed data source for each variable are in Table A1 in Appendix B.

[6] The data set is available upon request.

$$\Delta gdpgr_t = \alpha_0 + \beta_1 gdpgr_{t-1} + \beta_2 \text{inf}lation_{t-1} + \beta_3 savgr_{t-1} + \beta_4 pop1564gr_{t-1} + \beta_5 tech_{t-1} + \beta_6 Gindex_{t-1} + \sum_{i=1}^{p} \delta_i \Delta gdpgr_{t-i} + \sum_{j=0}^{q} \delta_j \Delta \text{inf}lation_{t-j} + \sum_{k=0}^{r} \delta_k \Delta savgr_{t-k} + \sum_{l=0}^{s} \delta_l \Delta pop1564gr_{t-l} + \sum_{m=0}^{u} \delta_m \Delta tech_{t-m} + \sum_{n=0}^{v} \delta_n \Delta Gindex_{t-n} + \mu_t \quad (6)$$

Table 2. Summary statistics.

Variables	Obs	Mean	Std.Dev.	Min	Max
gdpgr	58	5.991	3.603	-7.634	13.288
inflation	60	4.174	4.624	-0.900	24.314
savgr	58	11.637	12.432	-28.601	51.602
pop1564gr	58	2.077	1.126	.038	3.44
Gindex (D)	60	0.362	0.042	0.312	0.514
Gindex (HS)	60	1.101	0.109	0.679	1.258
Gindex (HB)	60	4.507	1.109	2.10	6.262
Gindex (J)	60	0.684	.068	0.422	0.782
Variables used to estimate "tech"					
labor	60	3.18e+07	1.05e+07	1.43e+07	4.39e+07
rgfcf	59	1.17e+12	8.53e+11	6.89e+10	2.71e+12

Table 3. Unit root test.

Variables	Z-statistics	McKinnon p-value	lags	observations	Form	Integrated Order
gdpgr	-4.212	0.004	1	56	Constant and trend	I(0)
inflation	-4.208	0.004	1	58	Constant and trend	I(0)
savgr	-6.205	0.000	0	57	Constant and trend	I(0)
pop1564gr	-2.297	0.436	2	55	Constant and trend	I(1)
tech	-7.462	0.000	0	57	Constant and trend	I(0)
Gindex (D)	-3.634	0.027	1	58	Constant and trend	I(0)
Gindex (HB)	-2.474	0.341	1	58	Constant and trend	I(1)
Gindex (HS)	-3.476	0.042	2	57	Constant and trend	I(0)
Gindex (J)	-3.477	0.042	2	57	Constant and trend	I(0)

where β_1, β_2, β_3, β_4, β_5, and β_6 are the long run coefficients. When cointegration exists, then the equation of ARDL can be expressed as Eq. (5). Note that the critical tests for Bound F-statistic, uses the lower bound and upper bound at the 1 % level are 6.8670 and 7.7748, respectively. The optimal lags in ARDL (p,q,r,s,u,v) are chosen from the AIC, and SBC tests.

If the computed value of the F statistics exceeds the upper critical bound, then there exists cointegration. We need to estimate both the long run and short run models. The short run model is the mechanism of adjustment and the speed of adjustment of the model to a long run equilibrium.

Estimating the short run equation using Error Correction Model (ECM) uses the following form (Eqn 7):

$$\Delta gdpgr_t = \alpha_0 + \sum_{i=1}^{p} \theta_i \Delta gdpgr_{t-i} + \sum_{j=0}^{q} \lambda_j \Delta \text{inf}lation_{t-j} + \sum_{k=0}^{r} \lambda_k \Delta savgr_{t-k} + \sum_{l=0}^{s} \lambda_l \Delta pop1564gr_{t-l} + \sum_{m=0}^{u} \lambda_m \Delta tech_{t-m} + \sum_{n=0}^{v} \lambda_n \Delta Gindex_{t-n} + \gamma ECT_{t-1} + \varepsilon_t \quad (7)$$

where θ, λ are short run coefficients and γ is the speed of adjustment toward long run equilibrium.

4. Results

The results from the ARDL model consist of 3 parts. The first one shows the adjustment coefficient when there is a change that makes variables deviate from the long run relationship. The second part shows the long run relationship of the variables and the last part shows the error correction. Table 4 shows the results from the ARDL model where each of the columns use different generation mix indices described in the last section.

Table 4. Impact of generation mix on economic growth.

	(1)	(2)	(3)	(4)
	Gindex (HB)	*Gindex (HS)*	*Gindex(D)*	*Gindex (J)*
	ARDL(2,0,1,2,0,2)	ARDL(1,0,1,0,0,0)	ARDL(1,0,1,0,0,0)	ARDL(1,0,1,0,0,0)
Adjustment	-0.928***	-0.737***	-0.688***	-0.736***
	(0.134)	(0.125)	(0.119)	(0.125)
Long run relationship part				
inflation	-0.363***	-0.363***	-0.353**	-0.363***
	(0.115)	(0.131)	(0.144)	(0.131)
savgr	0.155***	0.179***	0.190***	0.179***
	(0.054)	(0.065)	(0.070)	(0.065)
pop1564gr	1.320***	1.149**	1.265**	1.149**
	(0.358)	(0.459)	(0.530)	(0.459)
tech	95.540***	112.588**	134.443**	112.734**
	(33.922)	(48.703)	(52.644)	(48.714)
Gindex (HB)	**-0.989****			
	(0.374)			
Gindex (HS)		-7.627		
		(6.978)		
Gindex (D)			1.535	
			(20.867)	
Gindex (J)				-12.239
				(11.243)
Short run error correction model part				
LD.gdpgr	0.162			
	(0.112)			
D.savgr	-0.064*	-0.055	-0.056	-0.055
	(0.035)	(0.034)	(0.035)	(0.034)
D.pop1564gr	1.003			
	(3.384)			
LD.pop1564gr	-7.004**			
	(3.376)			
D.HB	1.506**			
	(0.644)			
LD.HB	1.178**			
	(0.576)			
crisis dummy	2.847	3.648	0.975	3.626
	(5.904)	(6.475)	(6.272)	(6.471)
Constant	-82.131***	-74.564**	-91.234***	-74.663**
	(27.425)	(31.679)	(27.649)	(31.662)
Observation	54	54	54	54
R-squared	0.720	0.635	0.626	0.635
Bound Test				
F-Statistics	12.128***	11.365***	10.930***	11.362***
t-Statistics	-6.933***	-5.915***	-5.785***	-5.914***

Note: Standard errors are shown in parentheses. ***, **, * denote significant levels at 1%, 5%, and 10%, respectively. The crisis dummy variable, the dummy variable taking value 1 during the economic crisis (between 1997-2001) and zero otherwise, to control for unusual data in the model. The optimal lag ARDL(p,q,r,s,u,v) are chosen from the AIC and SBC tests, and D.(variable name) signifies the first difference of the variable, while LD.(variable name) is the lag difference of the variable.

Table 5. Breusch-Godfrey LM test.

chi2	df	Prob > Chi2
0.220	1	0.638

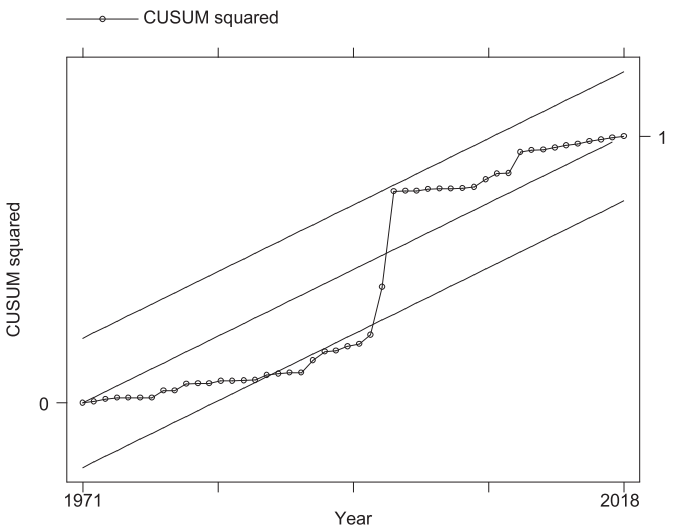

Figure 3. CUSUM Squared.
Source: Authors' calculation.

First, all 4 models passed the Bound test showing the long run relationship among the variables. Second, all adjustment coefficients are negative showing that when there are deviations from the long run equilibrium, variables can adjust to get back to the long run equilibrium path. Our adjustment coefficients are well within the normal speed of adjustment (values between 0 and -2, Loayza and Ranciere (2005)).

In all 4 models, the qualitative results of the long run relationship estimates are similar with one exception. Only the HB generation mix index is negatively significant[7] (in column (1)) which we can interpret as when there is more generation mix in the workforce, it will lead to a reduction in the economic growth as measured by GDP growth rate. To be specific, a one standard deviation increases in the HB generation mix index, the GDP growth rate will be lowered by 18%.[8] This result supports studies in the anthropology, sociology, and psychology literature that suggest that generational differences can negatively impact the work morale and therefore reduces workers' performances at the point where it leads to a reduction in economic growth rate.

Other control variables that influence the economic growth in the model behave as expected. Inflation negatively reduces growth while savings, technological change, working population growth rate can enhance economic growth.

[7] Since only one of the generation mix indices is significant, one might question the robustness of the conclusion. As explained in the text, the reasons might be due to the differences in the size of each index. The HB index is larger and has a larger standard deviation (see Table 2), which allow the model to detect the change in generation mix on economic growth, while the size of the other 3 indices have small standard deviation. However, even though the other indices are insignificant, the direction of their impacts on economic growth is the same as that of HB index. In any case, the interpretation of this results must be done with care. One might also do more analyses covering more years or expand the analysis to other countries for the robustness check.

[8] When there is a 1 standard deviation changes in the HB index, the GDP growth rate will change by = 1.108*(-0.989)*100/5.991 = -18% or reduced by 18%.

The results found in the analysis confirm the findings in economics literature that to enhance economic growth, the main factors are technological change and improved human capital embedded in the labor force. Apart from validating what were found in the literature, our analysis also discovered that another factor that can influence economic growth is generational differences. It is because generational differences can alter workers' performance when they must work with one another. Therefore, organizations and government should also pay attention to this issue and try to amend the differences between generations. Increase communications and allow workers from different generations to learn from and engage with each other might help reduce the tension at work and improve workers' productivities and hence, lead to a positive economic outlook for a nation.

4.1. Model specification test

We use the Durbin-Watson D-statistic and Breusch-Godfrey LM test to perform the Autocorrelation test and found no autocorrelation problem as the Durbin-Watson D statistic (14, 54) is 2.174 and the Breusch-Godfrey LM test shown in Table 5.

To test for the heteroskedasticity, White's test and Breusch-Pagan/Cook-Weisberg test were used[9] and no heteroskedasticity problem was found in our model. To test for the stability, we use the CUSUM squared, as shown in Figure 3. As we can see from Figure 3, the model passed the stability test.

5. Conclusion

Even though generational cohort theory has been discussed in anthropology, sociology, and psychology field, it has been neglected in the economics. Since each generation has different life experience, their views, values, attitudes, and work approaches might differ, these concepts are known as generation gap. When they work with one another, there might be tensions, and arguments, which can lower their labor productivities and therefore, reduces economic growth.

As a first attempt in studying impact of generational differences on economic growth, this paper uses data on the number of Thai working population in each generation to determine the intensity of generation mix in Thailand and use it to analyze its impact on economic growth. We find that when generation are highly mixed, the economic growth tends to be lower. As such, the generation gap should be one of the issues that work organizations and government pay attention to and try to amend the differences between generations. As suggested by studies in Management field, organizations need to recognize their differences and be flexible in their human resources practices and strategies that allow for workers' differences. Increase communications among workers of different generations and programs where workers from different generations to learn from and engage with each other would allow the workers to build relationships with each other. By doing so, it would help reduce the tension at work and improve workers' productivities and hence, lead to a positive economic outlook for a nation.

However, our analysis was only on one country's data, Thailand. Expanding the analysis to other countries would help understanding the impact of generation differences and how they mix in the labor force on economic growth. There might be variations of the impact by countries at different development levels or different regions. Moreover, in extending this work, one might model the pass-through mechanism which generation gap leads to a reduction in economic growth where differences in workers behavior in choosing jobs, conducing work affect their decision to supply work as well as their consumption behavior, which will affect the economic growth.

[9] White's test chi2(53) = 54.00 with Prob > chi2 = 0.4360, while Breusch-Pagan/Cook-Weisberg test chi2(1) = 2.21 with Prob > chi2 = 0.1370 suggesting no heteroskedasticity problem.

Declarations

Author contribution statement

Thitima Puttitanun and Supanee Harnphattananusorn: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Appendix A

Indices Formula:

Simpson's index measures the probability that any two individuals drawn at random from a large community belong to the same species.

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where n = total number of individuals of each species.

N = total number of organisms of all species

The value of D ranges between 0 and 1 where 0 represents infinite diversity and 1 represents no diversity. The drawback of Simpson's diversity index is that it is heavily weighted toward the most abundant species.

Shannon Index accounts for rare species in a community.

$$HS = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i is the proportion of individuals found in the i^{th} species. The values of Shannon index are often found to fall between 1.5 and 3.5.

Brillouin Index is calculated using the following formula:

$$HB = \frac{ln(N!) - \sum ln(n_i!)}{N}$$

where N is the total number of individuals in the community and n_i is the number of individuals in the i^{th} species. This index places more emphasis on species richness and is sensitive to sample size. Since the population in each generation reach millions, therefore, to directly use the index as-is is impossible. Harnphattananusorn and Puttitanun (2021) made an adjustment and calculated it as: $HB = \frac{ln(N^2) - \sum ln(n_i^2)}{N}$ where n_i is the total working population for generation *i* in each year and N is the total working population for each year. The value was extremely small, so they multiply it by -10[6].

Pielou's evenness index measures how close in numbers each species in an environment is. Pielou's evenness ranges between 0 and 1 where 0 means no evenness and 1 means complete evenness.

$$J = \frac{HS}{H_{max}}$$

where *HS* is the Shannon index and H_{max} is the maximum possible value of *HS*, calculated from $H_{max} = lnS$, S is the total number of species.

Appendix B

Table A1. Data Source

Variables	Definition	Data Source
gdpgr	Real GDP growth rate	Office of the National Economic and Social Development Council Database: =https://www.nesdc.go.th/main.php?filename=macroeconomics_page
inflation	Inflation rate proxied by Consumer Price Index	Office of the National Economic and Social Development Council Database: =https://www.nesdc.go.th/main.php?filename=macroeconomics_page

(*continued on next page*)

Table A1 (*continued*)

Variables	Definition	Data Source
savgr	Saving growth rate	Office of the National Economic and Social Development Council Database: =https://www.nesdc.go.th/main.php?filename=macroeconomics_page
pop1564gr	Working population growth rate	Office of the National Economic and Social Development Council Database: =https://www.nesdc.go.th/main.php?filename=macroeconomics_page
labor	Labor force used to estimate technology growth rate variable (*tech*)	Office of the National Economic and Social Development Council Database: =https://www.nesdc.go.th/main.php?filename=macroeconomics_page
rgfcf	Real gross fixed capital used to estimate technology growth rate variable (*tech*)	Office of the National Economic and Social Development Council Database: =http://www.nesdc.go.th/main.php?filename=macroeconomics_page
Gindex	Generation mix index calculated using number of Thai population by cohort data	World Development Indicators Data Set, World Bank: https://databank.worldbank.org/source/world-development-indicators

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