Aging and Population Policy in Developing Economies: Welfare Implications across Generations

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Abstract

This paper constructs a two-sector general-equilibrium overlapping-generations model with endogenous fertility and education choices to investigate the impacts of aging in a developing economy, corresponding tax financing approaches and population policies. We focus on those developing economies with low fertility and rapid population aging. The existence of a large informal sector in developing economies is particularly characterized in the model. We find that population aging may enlarge the formal sector and benefit economic development although it increases the fiscal burden in a developing economy. Related policy reforms to alleviate tax burden and their welfare implications across generations along the transitions are further discussed. We find that a policy reform that aims to increase fertility by reducing child-rearing cost will be beneficial only in the short run. By contrast, a policy that subsidizes the educational cost of children will encourage the accumulation of human capital, enlarge the formal sector, and reduce the tax burden. It benefits both current and future generations, except skilled workers in the first few decades if no compensation is provided. We further find that without considering the informal sector in developing countries, the policy suggestion will be significantly biased.

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1 Introduction

Population aging and corresponding fiscal challenges have attracted global attention. In contrast to the common impression that aging is an issue only in developed countries, it is actually becoming an issue in many developing countries, even for those with much lower income levels, because of a sharp fertility decline and an extended life expectancy observed in recent decades.[1] This paper aims to investigate the issue of rapid aging in developing economies with a focus on fiscal and population policies. The analysis is challenging because of the existence of a large informal sector in developing economies, which is usually not considered in studies that target developed countries. Our approach is to develop a two-sector general-equilibrium overlapping-generations model for a structural analysis. We incorporate endogenous choices on fertility, education investment, and labor allocation between formal and informal sectors in the theoretical framework.[2] We calibrate the model to a real economy, quantitatively explore the impacts of aging, and assess related taxation and population policies. Welfare implications across generations along with the transitions of policy reforms in particular are discussed.

Table 1 presents the fertility and life expectancy between 1960 and 2014 in selected countries with various income levels. In 1960, the total fertility rates (TFRs) in developing countries were in general above 6, and the life expectancies at birth were below 60 years (some even below 50 years), whereas in developed countries (e.g., the U.S., Japan, Germany, and France), TFRs were relatively low, and their life expectancies were above 65 years. However, the TFRs and life expectancies of these countries, regardless of income level, seem to be in a trend of convergence. In 2014, the TFRs of these countries were generally at around 2 or lower, and the life expectancies were all above 70 years. The only exception is Myanmar, whose life expectancy was shorter than that of other countries but still largely improved by 23 years from 42.7 years in 1960. Table 2 further provides the average TFRs for countries classified into three income groups according to the report in Lee et al. (2014). The average TFR in middle-income developing countries was already below the replacement level during 2005–2010.[3]

To illustrate the trend clearly, Figure 1 shows that the TFRs in the developing countries

[1] For example, Vietnam and Myanmar, as shown in Table 1.

[2] The informal sector is defined as an underground economy, in which economic activities are performed by companies or agents not officially registered with the government. Incomes earned in the informal sector are not taxed by the government, and workers are not protected by the labor law.

[3] There were 53 economies included in this income group ($4,125 to $12,735). The income group classification is based on the criteria of World Bank in 2014.

Table 1: Total Fertility Rate and Life Expectancy by Income Level (1960 v.s. 2014)

	TFR		Life expectancy		GDP per capita*
Country	1960	2014	1960	2014	(in 2010 US$)
U.S.	3.7	1.9	69.8	78.9	50,728
Japan	2.0	1.4	67.7	83.6	46,519
Germany	2.4	1.4	66.8	78.6	44,878
France	2.9	2.0	66.6	79.3	41,204
Korea	6.2	1.2	53.0	82.2	26,901
Taiwan	5.6	1.2	62.3	79.8	21,782
Brazil	6.2	1.8	54.2	74.4	11,705
Malaysia	6.2	1.9	59.5	74.7	10,512
Mexico	6.8	2.2	57.1	76.7	9,403
China	5.8	1.6	43.4	75.8	6,108
Thailand	6.1	1.5	54.7	74.4	5,636
Vietnam	6.3	2.0	59.1	75.6	1,596
Myanmar	6.1	2.2	42.7	65.9	1,230

Source: World Bank. *GDP per capita in 2014

rapidly declined from around 6 to around 2 within 30 to 50 years. The sharp decrease in fertility implies that the percentage of labor force will shrink rapidly (and the share of the elderly will go up rapidly) in the near future.

In addition, the extended longevity implies an increasing demand on social welfare. Medical care for the elderly is one of the most important issues: an old individual's annual medical expenditures are two to six times more than a young individual's.[4] The increase in elderly care with a decline in the share of working-age population due to the low fertility is expected to soon bring a fiscal challenge in developing countries.

Unlike in developed countries, a common feature in developing countries is the existence of a large informal sector that further worsens the fiscal problem caused by aging. Figure 2 presents ratios of informal employment to total non-agriculture employment in selected developing countries in 2009. The informal employment ratios were even higher than 70% in several countries, such as India, Indonesia, Paraguay, and the Philippines.[5] The

[4]See the report in Hsu, Huang, and Yupho (2015) about medical expenditures for the elderly based on the data in Japan, Taiwan, Thailand, and the US during 2003–2007.

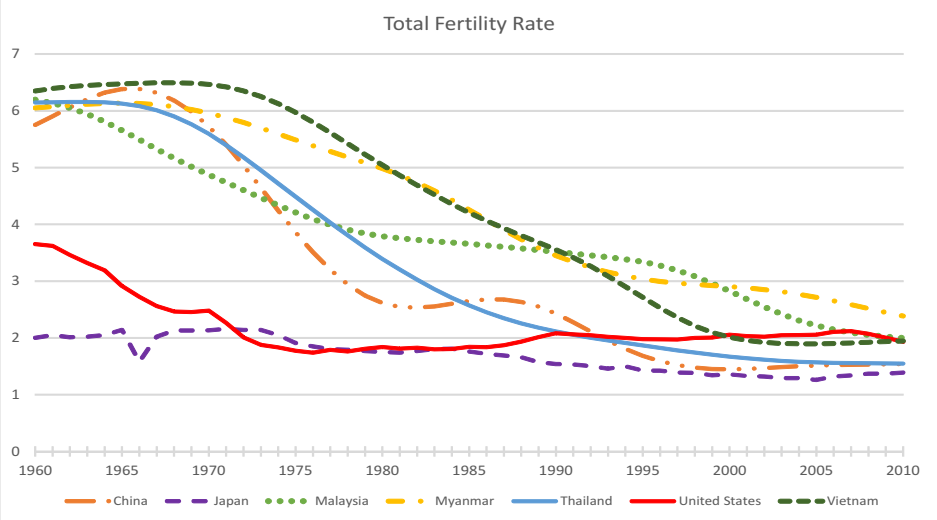
[5]The informal employment ratio in Turkey, whose income level was the highest among the middle income

Table 2: Total Fertility Rate during 2005-10

Lower income (<$4125)				
	Some selected countries			
Group average	India	Indonesia	Philippines	Vietnam
4.03	2.66	2.50	3.27	1.89
Upper-middle income ($4125-12735)				
	Some selected countries			
Group average	Brazil	China	Mexico	Thailand
2.09	1.90	1.63	2.37	1.49
High income (>$12735)				
	Some selected countries			
Group average	Australia	Japan	UK	US
1.65	1.89	1.34	1.88	2.06

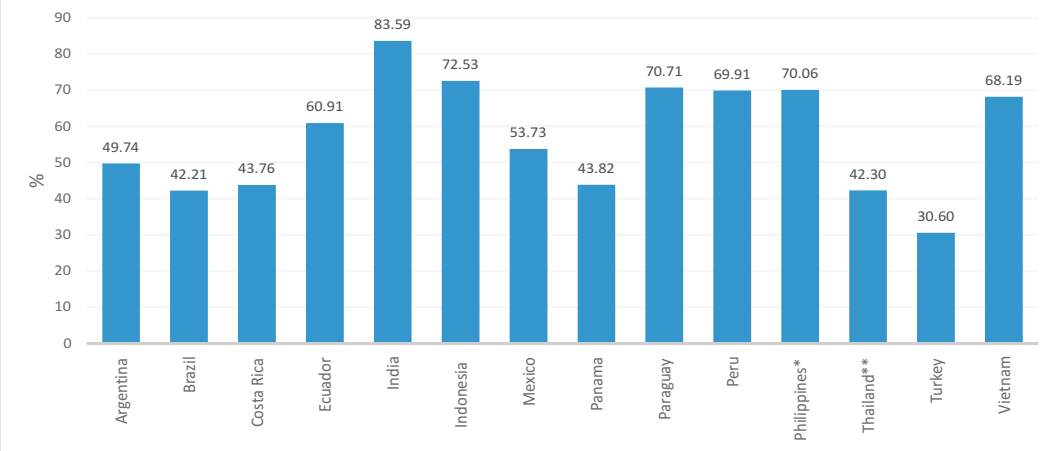
Source: Lee et al. (2014) and United Nations.
Note: There were 82 economies in the lower-income group, 53 economies in the upper-middle-income group and 80 economies in the high-income group.

Figure 1: Total Fertility Rate 1960–2010



Source: World Development Indicators (WDI), World Bank.

Figure 2: Informal Employment Share (non-agriculture, 2009)



Note: "*" denotes the data of 2008 and "**" is the data of 2010. Source: International Labor Organization.

ratio could be even higher (generally higher than 50%) if the agricultural sector is included.

Informal incomes are difficult to monitor, thereby further constraining the government's ability to collect tax to finance extra costs. Besley and Persson (2014) documented that income taxes contribute less to total tax revenue when an economy's informal sector is large.[6] Gordon and Li (2009) also documented that consumption and production taxes are more important for government revenue than income taxes in developing countries with large informal sectors, while high-income countries' major government revenue comes from income taxes.[7] Furthermore, in the data (World Bank), we observe that the ratios of consumption tax revenue to GDP are similar across OECD, high-, middle-, and low-income countries.[8] However, the ratios of income tax revenue to GDP in high-income or OECD countries are 50% higher than that in low- and middle-income countries (i.e., developing countries).[9] This feature indicates that the ability of governments in developing economies to collect

countries, can be treated as the lower bound at 30%.

[6]Using data from 75 countries around 2000, Besley and Persson show a negative correlation between share of income taxes in tax revenue and size of informal economy (Figure 7 in the article).

[7]Please refer to Table 1 in Gordon and Li (2009).

[8]Consumption tax here includes taxes on goods and services and export/import duties. Keen (2008) has reported that VAT from imports is a major part of total VAT revenues in developing countries and suggested that both formal and informal sectors in developing countries require imported intermediate goods for their productions.

[9]Detailed information is provided in Appendix A.

income taxes is significantly constrained. By contrast, the ability of consumption tax collection in developing countries is not different from that in developed countries.

To capture the features of rapid aging and the existence of an informal sector in developing countries, we develop a two-sector general equilibrium overlapping generations model, in which individuals endogenously allocate labor/assets (capital) between the formal and informal sectors. The government has three tax tools to generate its revenue, namely, labor income, capital income, and consumption taxes, and it is not able to monitor labor/capital incomes from the informal sector. We simply assume that consumption tax is not constrained by the existence of an informal sector on the basis of the above empirical findings. In addition, we assume that frictions and institutional distortions exist in the labor market. The assumption allows us to have informal workers in equilibrium with a large wage gap between formal and informal workers, as found in empirical studies. Furthermore, we endogenize individuals' fertility and education decisions such that the quantity–quality tradeoff of children is taken into account when we evaluate potential population policy reforms.

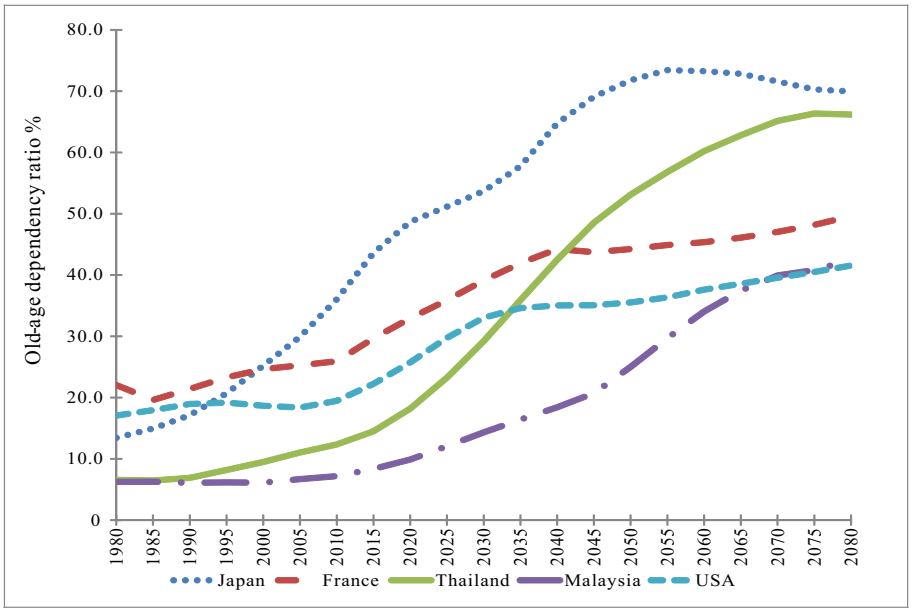
Quantitative exercises, including steady state comparisons and transitional analysis, are provided to deliver clear policy and welfare implications. Our strategy is that we establish the theoretical model to present a representative developing economy as a benchmark. Thailand in the 2000s is selected because: (1) Thailand has experienced a dramatic demographic transition. As Figure 3 shows, the old-age dependency ratio of Thailand was below 10% in the 1980s but is expected to increase rapidly to more than 60%, and (2) the ratio of workers in the informal sector of Thailand is large and stable at 62% to 64%.[10]

On the basis of the benchmark model, quantitative impacts of population aging are first explored. We assume that the government will adjust tax rates to balance its budget in response to the reduction in the population share of workers and more social insurance expenditures caused by population aging. Simulations with alternative financing tools, including consumption, labor, and capital income taxes, are performed.

Although the tax burden is likely to increase (consumption tax rate will increase by 8 percentage points in our baseline aging scenario), we find aging is not entirely detrimental to economic development. The extended longevity requires more savings and makes educational investment in children attractive, thereby improving both physical and human capital accumulations. The increased skilled labor enlarges the formal sector and allows the allocation of more resources to the formal sector, thereby improving aggregate production efficiency. The informal sector shrinks accordingly. The negative relationship between human capital and the size of the informal sector is consistent with empirical findings in the

[10] Please see Appendix B for more information.

Figure 3: Old-age Dependency Ratio



Source: United Nations.

literature.[11] Our analysis further suggests that using labor income tax or capital income tax alone will not be feasible to finance the extra cost of aging because labor and capital will escape to the informal sector if the corresponding tax rates are high.[12]

Under the baseline scenario of aging, we evaluate two types of population policy. We first study a policy reform, which provides a subsidy for general child-rearing cost to encourage fertility, such as Child Allowance in Japan or Child Benefit in the UK.[13] We find that this policy is costly, and its effect on fertility is small in a reasonable subsidy range. In the long run, however, the policy will have a negative effect on economic development.

[11] In the literature, the informal sector is usually characterized by small firm sizes, unskilled jobs, low wages, and loose government regulations. The experience of industrialization, skill upgrading, urbanization, and the shrinkage of the informal sector usually come together. See, for example, Marcouiller, de Castilla, and Woodruff (1997), Ranis and Stewart (1999), Gibson (2005), and Yuki (2007).

[12] We assume that the social security or pension system is fully funded because these social welfare programs are usually underdeveloped in developing countries. Therefore, the government does not need to finance the cost with its revenue. For countries with unfunded pension systems, the cost of aging in our analysis could be interpreted as a lower bound.

[13] Similar payment schemes to help families to have children are generally observed in major developed economies, as well as in newly industrialized economies such as Korea, Singapore, and Taiwan.

Both human capital (measured by skilled-labor share) and physical capital levels are lowered under the child-allowance policy reform because this type subsidy distorts the relative price between having skilled and unskilled children and the relative price between having children and savings. In particular, it encourages households with lower education (low income) to have more children without providing higher education to their children, but it is not effective in improving fertility for households with higher education (high income). Along with the transition of this policy reform, we find that the current generation (when the policy is implemented) enjoys child allowance with a positive welfare gain, but the benefit will be offset by worse economic outcomes, thereby hurting future generations.

We then alternatively consider a policy that subsidizes children's educational cost, for example, tuition subsidy/waiver and government-sponsored student loans. Although the population age structure is not improved, the policy encourages educational investment, and the consequence of having additional skilled workers enlarges the formal sector, thereby improving aggregate production efficiency. We find that the provision of education subsidy, rather than a pure child allowance, in the long run can help to alleviate the extra tax burden caused by population aging because of the expansion of the tax base. Our transitional analysis shows that skilled laborers will suffer in the first few decades because of more competition, whereas unskilled laborers will benefit. Nevertheless, some redistribution (to compensate the skilled laborers) is possible to make everyone happy in the short run. In the long run, both skilled and unskilled laborers enjoy welfare gains because of the improved economic development.

We also find that the existence of a large informal sector is important for policy implications. If the informal sector is not taken into account, then the above education policy reform will not reduce the tax burden and will instead cause a large welfare loss for the skilled workers in the long run. The difference comes from the effect of reallocation of resources between the informal and formal sectors.

Our work integrates a few separate bodies of literature. First, the theoretical model of this paper builds on the literature that explores quantity–quality tradeoff of children, demographic change, and economic growth. This model was pioneered by Becker (1960), and follow-up studies have attempted to link fertility and demographic changes to economic growth based on the mechanism of quantity–quality tradeoff, such as Becker, Murphy and Tamura (1990), Galor and Weil (1996), Zhang (1997), Doepke (2004), Doepke and Zilibotti (2005), and Liao (2011). These studies typically focus on the early stage of economic development with the demographic transition from high to low fertility and emphasize the importance of human capital accumulation for growth. This paper focuses on developing

economies in a stage of low fertility and facing incoming challenges of aging. We take into account both physical and human capital accumulations and show that the existence of a large informal sector is crucial for policy design.

Second, this paper sheds light on understanding the implications of the informal sector on optimal taxation and fiscal policy. Most studies in the literature target developed countries. The following are some exceptions: Peñalosa and Turnovsky (2005) studied optimal taxation on labor and capital incomes in a standard growth model with the addition of an informal sector; Jung and Tran (2012) discussed the potential effects of the extension of social security to informal workers in developing countries to reduce the poverty problem for the elderly. To complement the literature on policy design with an informal sector, we further explore the implications of aging for fiscal and population policies in developing countries by allowing endogenous fertility and educational choices.

With regard to population policy, Lee et al. (2014) conducted a study similar to ours and suggested that fertility rates should be even lower in some low-fertility countries, such as Brazil and Thailand, to improve living standards and fiscal burdens. Their focus is on optimal fertility rates for each country given current population age structures and fiscal conditions with a wide-ranging international comparison. They did not directly discuss specific policy issues. We particularly focus on population aging in developing economies, which have experienced sharp demographic changes, and further consider the existence of a large informal sector. In addition, we characterize the joint fertility/education decisions in the model such that we are able to asses alternative population policies.

The rest of this paper is organized as follows: In Section 2, we construct a two-sector general-equilibrium overlapping-generations model. The equilibrium features of the framework are explained. Section 3 describes the parameter selection/calibration for the benchmark economy. In Section 4, we perform quantitative analysis and present the results. Section 5 concludes this paper.

2 The Model

We develop a two-sector general-equilibrium overlapping-generations model with endogenous fertility and education choices. Individuals also choose labor allocation between formal and informal sectors. The life cycle is characterized by three stages: childhood, young adulthood, and old adulthood. A child relies on parents (young adults) without making any decisions. Parents care for their children, and they make decisions on the number of children, education investment in children, and their own labor allocation and savings. Old

adults are assumed to be retired. They consume their own savings and pay for medical care. Human capital is modeled in a discrete way such that children will become skilled workers if parents invest in their education; otherwise, children will become unskilled workers. Physical capital is freely mobile between the formal and informal sectors. Skilled labor is necessary for production in the formal sector, but it is highly substitutable by the unskilled labor in the informal sector. We assume that frictions and institutional distortions exist in the labor market such that labor mobility between the two sectors is constrained. The settings are important to capture some labor market features that we observe from the data: wage rates in the informal sector are much lower than those in the formal sector; and the informal employment share is large.[14]

2.1 Demographics

Total population N at a time point consists of the population of children N^c, young adults N^y and old adults N^o:

$$N = N^c + N^y + N^o.$$

Population dynamics are determined by endogenous fertility choices and exogenous survival rates. Total number of children is determined by the fertility decisions of young adults. n denotes the average fertility per young adult. N^c is then given by:

$$N^c = nN^y.$$

We assume that children survive to young adulthood with a probability π^c, and young adults survive to old adulthood with a probability π^y. Therefore, the population of young adults in the next period $N^{y\prime} = \pi^c N^c$, and the old population in the next period $N^{o\prime} = \pi^y N^y$.

2.2 Education Investment and Human Capital Accumulation

Human capital is modeled discretely with two levels: skilled (s) and unskilled (u). If parents decide to invest in their children's education on top of the basic level with a cost $e = \bar{e}$, then their children will become skilled workers in the next period. By contrast, children who do not receive higher education (with $e = 0$) will become unskilled workers. N_s^y denotes the population of skilled young adults, and N_u^y is the population of unskilled young adults. The young population can be expressed by $N^y = N_s^y + N_u^y$. According to the setting, human

[14] We use the data of Household Socio-Economic Survey (HSES) from Thailand to illustrate the labor market features in developing economies with a large informal sector. Please see Appendix C for more details.

capital accumulation is represented by an increase in the proportion of skilled young adults to total young adults (N_s^y/N^y).

2.3 Production and Labor Market

Two production sectors, namely, formal and informal sectors, produce one type of final goods. We use superscript f to denote variables in the formal sector and superscript x for those in the informal sector. In both sectors, perfectly competitive firms use physical capital (K), skilled labor (L_s), and unskilled labor (L_u) as inputs to produce the final goods. However, the degree of substitution between skilled labor and unskilled labor varies across sectors. They are perfectly substitutable in the informal sector although an efficiency difference may exist, which is governed by the parameter η. The production technologies are summarized as follows:

$$Y^f = A^f (K^f)^{\alpha_1} (L_s^f)^{\alpha_2} (L_u^f)^{\alpha_3}; \tag{1}$$

$$Y^x = A^x (K^x)^{\gamma_1} (\eta L_s^x + L_u^x)^{\gamma_2}, \tag{2}$$

where Y^f and Y^x are outputs in the formal and informal sectors, respectively. A^f and A^x are the total factor productivity (TFP) in the formal and informal sector, respectively. α_1, α_2 and α_3 are income shares of physical capital, skilled labor, and unskilled labor in the formal sector, respectively. γ_1 and γ_2 are income shares of physical capital and total labor in the informal sector, respectively. The total output Y of the economy is then given by:

$$Y = Y^f + Y^x. \tag{3}$$

Without distortion, firms' profit maximization in the two sectors imply that:

$$w_s^f = \alpha_2 A^f (K^f)^{\alpha_1} (L_s^f)^{\alpha_2 - 1} (L_u^f)^{\alpha_3}; \tag{4}$$

$$w_u^f = \alpha_3 A^f (K^f)^{\alpha_1} (L_s^f)^{\alpha_2} (L_u^f)^{\alpha_3 - 1}; \tag{5}$$

$$w_s^x = \eta \gamma_2 A^x (K^x)^{\gamma_1} (\eta L_s^x + L_u^x)^{\gamma_2 - 1}; \tag{6}$$

$$w_u^x = \gamma_2 A^x (K^x)^{\gamma_1} (\eta L_s^x + L_u^x)^{\gamma_2 - 1}. \tag{7}$$

As we describe in Appendix C and later in Section 3, the data show large wage gaps between skilled and unskilled workers (which is significantly larger in the formal sector) and

between formal and informal workers.[15] To capture the wage patterns, we introduce two market imperfections in the model. First, market frictions exist such that at any time point, a maximum probability of job matching exists in the formal market $\bar{\theta}_i$ for type-i workers. Therefore, even if all type-i individuals would like to work in the formal sector, a fraction $(1-\bar{\theta}_i)$ of the type-i labor will have to be allocated in the informal sector. Second, the formal sector is subject to more government regulations in addition to income taxes. For example, the minimum wage regulation in the formal sector will prevent the wage rates in the two sectors from converging. We assume the institutional distortions mainly affect unskilled workers because the skilled wage rate is higher than the minimum wage. Therefore, we assume a distortion X_u, which further enlarges the unskilled wage gap between formal and informal sectors in addition to the tax effect:

$$(1-\tau_L)w_u^f = X_u w_u^x, \tag{8}$$

where τ_L is the tax rate on formal labor income.

2.4 Government

The government taxes consumption, labor income, and capital income with rates τ_C, τ_L, and τ_K, respectively. The government cannot monitor labor and capital income from the informal sector. As discussed in the introduction, we assume that the government is not constrained on consumption tax collection.[16]

The government runs a public medical care program and covers a fraction ω of total medical expenditures M. The public medical expenditure M_g is given by:

$$M_g = \omega M.$$

A budget balance is required to be maintained in each period. The budget constraint for the government is given by:

$$G + M_g = T_C + T_L + T_K, \tag{9}$$

[15] According to the HSES data of Thailand, the wage rates in the model should be able to present:

$$\frac{w_s^f}{w_u^f} = 2.4; \ \frac{w_s^x}{w_u^x} = 1.4;$$
$$\frac{w_s^f}{w_s^x} > \frac{w_u^f}{w_u^x} = 1.7.$$

[16] In our model, consumption tax includes value-added taxes (VAT), import/export duties, and other indirect taxes. The assumption implies that consumptions are taxed either directly or indirectly and are thus less avoidable.

where G denotes total non-medical government expenditures (net after other government revenues).

2.5 Individual's Problem

A young adult with a skill type $i = \{s, u\}$ cares about her/his own lifetime consumption (current consumption c_i^y and consumption at old age $c_i^{o\prime}$) and his children, and make decisions on amount of current consumption, assets in the formal and informal sectors ($a_i^{f\prime}$ and $a_i^{x\prime}$) carried to the old age, number of children (n_i), and education investment in children (e_i).

Each young adult is endowed with one unit of time. Raising a child costs a fraction ϕ of a young adult's time. The rest of the time can be supplied to labor markets for earnings. Individuals also choose the allocation of labor between the formal/informal sectors; θ_i denotes the fraction of labor supplied to the formal sector ($1-\theta_i$ in the informal sector).[17] In their old age, individuals use the savings from when they were of working age to pay for consumption and out-of-pocket medical expenditures $(1-\omega)m'$.

The individual's maximization problem can be expressed as follows:

$$V_i = \max_{\{c_i^y, a_i^{f\prime}, a_i^{x\prime}, n_i, e_i, \theta_i\}} \left\{u(c_i^y) + \beta \pi^y u(c_i^{o\prime}) + \psi n_i^{-\varepsilon}[\pi^c n_i V_j']\right\}, \tag{10}$$

subject to

$$\begin{aligned}
&(1+\tau_C)c_i^y + \pi^y(a_i^{f\prime} + a_i^{x\prime}) + e_i n_i = (1-\phi n_i)[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x];\\
&(1+\tau_C)c_i^{o\prime} = [1+(1-\tau_K)r^{f\prime}]a_i^{f\prime} + [1+r^{x\prime}]a_i^{x\prime} - (1-\omega)m';\\
&j = s, \text{ if } e_i = \overline{e};\ j = u, \text{ if } e_i = 0;\\
&0 \le \theta_i \le \overline{\theta_i};
\end{aligned}$$

where V_j' is a child's lifetime value given the skill level $j = \{s, u\}$; $r^{f\prime}$ and $r^{x\prime}$ are capital return rates in the formal and the informal sectors, respectively. We assume a perfect annuity market in the economy to prevent accidental bequests because some young individuals do not survive to the next period. A young adult, who holds $\pi^y a_i'$ annuity assets in each sector will receive $(1+(1-\tau_K)r')a_i'$ next period if she/he survives. In addition, education investment is discrete, $e_i = \{0, \overline{e}\}$, and all children are identical and receive the same e_i in

[17] The model period is 30 years. Thus, the setting implies that individuals work in both sectors during their lifetime. We take this simple setting to show that at a time point, a fraction of workers work in the formal sectors and the rest are in the informal sector within each education level. In addition, we observed that people switch jobs between the formal and informal sectors in the data.

the family. $\bar{\theta}_i$ represents the maximum fraction of the working-age period in which a type-i individual successfully finds jobs in the formal sector due to market frictions.

2.6 Equilibrium Features

2.6.1 Individual Optimal Decision Rules

- Asset holdings/savings ($a_i^{f\prime}$ and $a_i^{x\prime}$):
  Intuitively, an individual will only hold the asset with a higher rate of return. The optimal rule of asset holdings is:

$$u_{c_i^y} = \beta(1+(1-\tau_K)r^{f\prime})u_{c_i^{o\prime}}, \qquad \text{if } (1-\tau_K)r^{f\prime} \geq r^{x\prime}; \tag{11}$$

$$u_{c_i^y} = \beta(1+r^{x\prime})u_{c_i^{o\prime}}, \qquad \text{if } r^{x\prime} \geq (1-\tau_K)r^{f\prime}; \tag{12}$$

  where $u_{c_i^y}$ and $u_{c_i^{o\prime}}$ are marginal utilities of consumption at young adulthood and at old adulthood, respectively. Capital moves freely between two sectors in equilibrium.Thus, after-tax capital returns from the two sectors must be equal: $(1-\tau_K)r^f = r^x = r$. Therefore, individuals are indifferent between the two assets.

- Labor allocation (θ_i):
  Similarly, an individual will supply labor to a sector with a higher wage rate only if no mobility constraints and distortions exist. Therefore, in equilibrium, $(1-\tau_L)w_i^f = w_i^x$ if the mobility constraint is not binding $\theta_i \leq \bar{\theta}_i$. If the constraint is binding, then $\theta_i = \bar{\theta}_i$ and $(1-\tau_L)w_i^f > w_i^x$.[18]

  As mentioned, the formal wage rate is significantly higher than the informal wage rates in the data. Institutional distortions affect skilled workers least (zero in the model); thus, we require the mobility constraint for skilled workers to be binding, $\theta_s = \bar{\theta}_s$, such that the model can generate a sufficient wage gap.

  With regard to the allocation of unskilled labor, Equation (8) has to be satisfied in equilibrium. Together with Equations (5), (7) and the labor market clearing conditions (15) to (18), we can have

$$\theta_u = \frac{\eta(1-\bar{\theta}_s)l_s + l_u}{(1+B)l_u}, \tag{13}$$

  where $B = \frac{X_u \eta \gamma_2 y^x}{(1-\tau_L)\alpha_3 y^f}$, $y^f = \frac{Y^f}{N^y}$, $y^x = \frac{Y^x}{N^y}$, $l_s = \frac{L_s}{N^y}$ and $l_u = \frac{L_u}{N^y}$.

[18] To be consistent with data, the model parameters are set to prevent $(1-\tau_L)w_i^f < w_i^x$ from happening.

- Fertility (n_i):
  The first-order condition with respect to n_i in the individual's problem can be expressed as follows:

$$\psi(1-\varepsilon)(n_i)^{-\varepsilon}V_j' = (\frac{u_{c_i^y}}{1+\tau_C})\{\phi[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x] + e_i\}. \qquad (14)$$

  The left-hand side of Equation (14) is the marginal benefit of having an additional child. On the right-hand side is the marginal cost of having an additional child. Given the decision of e_i, the young individual chooses the number of children such that the marginal benefit is equal to the marginal cost.

- Education investment in children (e_i):
  e_i is a discrete choice; thus, the optimal decision depends on which of $V_i(e_i = \overline{e})$ and $V_i(e_i = 0)$ is greater. In addition, because we require the skilled wage rates to be always higher than the unskilled wage rates in both formal and informal sectors ($w_s^f > w_u^f$ and $w_s^x > w_u^x$), education investment is relatively cheaper for skilled workers. If unskilled workers choose to invest in children's education ($V_u(e_u = \overline{e}) > V_u(e_u = 0)$), then for skilled workers, $V_s(e_s = \overline{e}) \leq V_s(e_s = 0)$ will be impossible, and the only possibility is that they also choose the positive education investment ($e_s = \overline{e}$). However, in this case, the economy will only have skilled workers after the initial period. If unskilled workers always choose not to invest in their children's education, then even all skilled workers choose to invest in education, because the number of skilled children per family will be less than the number of unskilled children per family; thus, the skilled labor share will eventually converge to zero.

  The only feasible equilibrium, in which both skilled and unskilled workers exist, is that skilled parents always invest in children's education, whereas some unskilled parents invest in education and the others do not. This condition implies that, in equilibrium, unskilled parents are indifferent between investing and not investing in children's education, $V_u(e_u = \overline{e}) = V_u(e_u = 0)$. Furthermore, an impossible situation is for both types of parents to be indifferent on education choices. The proof is provided in Appendix D.

2.6.2 Markets Clearing Conditions

- Labor markets

$$L_s^f = \theta_s(1-\phi n_s)N_s^y; \tag{15}$$

$$L_s^x = (1-\theta_s)(1-\phi n_s)N_s^y; \tag{16}$$

$$L_u^f = \theta_u\{\lambda_{us}[1-\phi n_{u|(e_u=\bar{e})}] + (1-\lambda_{us})[1-\phi n_{u|(e_u=0)}]\}N_u^y; \tag{17}$$

$$L_u^x = (1-\theta_u)\{\lambda_{us}[1-\phi n_{u|(e_u=\bar{e})}] + (1-\lambda_{us})[1-\phi n_{u|(e_u=0)}]\}N_u^y. \tag{18}$$

L_i^f and L_i^x are aggregate type-i labor in the formal and informal sectors, respectively. In Equations (17) and (18), λ_{us} represents the fraction of unskilled workers who invest in children's education ($e_u = \bar{e}$) and have skilled children, and $n_{u|(e_u=\bar{e})}$ denotes the number of children per parent for them. Similarly, $n_{u|(e_u=0)}$ denotes the number of children per parent for unskilled workers without education investment. A unique λ_{us} exist such that, in equilibrium, unskilled workers are indifferent between the education choices.

- Capital markets:
  No mobility constraint on physical capital exists. Thus, the no-arbitrage condition must hold: $(1-\tau_K)r^f = r^x$. Therefore, the equilibrium capital allocation between the two sectors is given by:

$$\frac{(K^f)^{1-\alpha_1}}{(K^x)^{1-\gamma_1}} = (1-\tau_K)\frac{\alpha_1 A^f (L_s^f)^{\alpha_2}(L_u^f)^{\alpha_3}}{\gamma_1 A^x(\eta L_s^x + L_u^x)^{\gamma_2}}. \tag{19}$$

3 Parameter Selection and the Benchmark Economy

As mentioned in the introduction, Thailand is selected as a representative developing economy for our quantitative analysis because it currently has a very low fertility rate and a large informal sector. The model is calibrated to match data from Thailand during 2000–2012 as a benchmark. Based on the benchmark economy, quantitative analyses on aging and related policy experiments are performed in the next section.

3.1 Parameters

Our parameter selection strategy includes two steps: 1) some parameters are identified directly from data or empirical findings, and 2) others are calibrated such that some moments in the benchmark economy match the counterparts in the data. Table 3 summarizes the parameters for indentification/calibration.

The model period is 30 years. According to the estimate of World Development Indicators (WDI, World Bank), the life expectancy at birth for Thailand during 2010–2012 is 74.1. The survival probability from childhood to young adulthood π^c is close to one, and we set it at one in the model. The survival probability from young adulthood to old adulthood π^y is set at 0.47 such that the life expectancy at birth in the model is 74.1. Medical expenditure per old adult m is set at 0.077 to match the ratio of total medical expenditures to GDP equal to 5.5% in Thailand during 2007–2010 according to WDI.

Four preference parameters exist: β, σ, ε, and ψ. The annual discount factor is 0.951 to match the annual capital–output ratio of 1.9 in 2012.[19] ψ is set to 0.227 so that the total fertility rate is 1.54.[20] σ and ε are jointly calibrated with other parameters. They are discussed later.

Two types of costs are associated with children: child-rearing time cost ϕ and educational cost $\bar{e}$. In the model, skilled worker is defined as a worker with an education level equal to or above high (secondary) school. The report from the National Statistical Office of Thailand suggested that the cost of raising a child until age 24 (net of the labor income earned by children) was approximately 1.156 million baht in 2004. To be consistent with our model, we use 0.867 million baht ($1.156 \times 18/24$) to represent the cost of having a child until graduation from high school. It is roughly 24.3% of the average earnings (30 years). Therefore, ϕ is set at 0.243. The educational cost is assumed to be proportional to the skilled wage rate, $\bar{e} = \phi_s w_s$. The proportion ϕ_s is chosen to be 0.089 such that the ratio of skilled workers to total workers is 17% (average of 2010–2012).[21] This calibration method implies that ϕ_s is net after the current government's educational subsidy for children in Thailand. Policy experiments on educational subsidy in Section 4.2 can be interpreted as subsidies on top of the current level.

The government collects consumption, capital income and labor income taxes with tax rates τ_C, τ_K and τ_L, respectively. They are set such that the ratios of total tax revenues collected from each tax tool to GDP match the data: 9%, 4%, and 2% for consumption, capital income, and labor income taxes, respectively.[22] Consumption tax revenue includes revenues from VAT, sales taxes on goods and service and import/export duties; capital income tax revenue is represented by revenues from cooperate taxes; and labor income tax revenue is approximated by revenues from taxes on individual earnings. Thus, $\tau_C = 12.1\%$, $\tau_K = 11.4\%$ and $\tau_L = 10.9\%$. With regard to the public medical care coverage ω of total

[19] Source: National Statistical Office, Thailand

[20] Source: World Population Prospects, United Nations Population Division.

[21] Source: National Statistical Office, Thailand

[22] Source: Revenue Department, Ministry of Finance of Thailand

medical, we calculate the average ratio of public health expenditures to total health expenditures based on WDI. We find that ω is approximately 85% in Thailand during 2007–2010.

We assume that skilled workers are not affected by institutional distortions, such as the minimum wage regulation. Given that skilled wage in the informal sector is much lower than that in the formal sector, we assume that the mobility constraint on skilled workers is binding in equilibrium (i.e., $\theta_s = \bar{\theta_s}$). Thus, the proportion of skilled workers in the formal sector among total skilled workers is given by:

$$\frac{L_s^f}{L_s} = \bar{\theta_s}. \tag{20}$$

This finding implies that $\bar{\theta_s}$ (the maximum probability of finding jobs in the formal sector during the lifetime for skilled workers) can be identified by the formal employment share of total skilled labor in the data. According to the 2011–2012 from the National Statistical Office of Thailand, we set $\bar{\theta_s}$ for skilled workers at 70%.

We assume that the institutional distortion is the major factor for the unskilled wage gap and the constraint for unskilled workers $\bar{\theta_u}$ is the same as $\bar{\theta_s}$ at 70% but not currently binding. The institutional distortion on the unskilled labor markets X_u is chosen to be 1.514 to match the wage gap of unskilled workers between the formal and informal sectors $w_u^f/w_u^x = 1.7$ (from HSES of Thailand and the authors' calculation).[23]

The rest of the parameters in the production side are TFPs of both sectors (A^f and A^x), three income shares in the formal sector (α_1, α_2, and α_3), two income shares in the informal sector (γ_1 and γ_2), and the labor efficiency of skilled workers in the informal sector (η). The TFP of the formal sector is normalized to be 10, and the TFP of the informal sector is set at 4.283 such that the relative output ratio (Y^x/Y^f) is 0.52 as estimated by the National Statistics Office of Thailand. The capital income share in the formal sector α_1 is set at 0.67 as the data in 2012. α_2 (and $\alpha_3 = 1-\alpha_1-\alpha_2$), γ_1 (and $\gamma_2 = 1-\gamma_1$) and two altruism parameters, ε and σ, are jointly calibrated such that the following targets from the data are matched:

- the skill premium in the formal sector is 2.4 ($w_s^f/w_u^f = 2.4$);
- the ratio of skilled workers to total workers (L_s/L) is 17%;
- the ratio of skilled parents' TFR to unskilled parents' TFR 0.5;

[23]Currently, only 30% unskilled workers belong in the formal sector. This setting allows the sizes of formal and informal sectors to change in response to economic/demographic/policy changes.

- the proportion of unskilled workers in the formal sector $L_u^f/L_u = 0.3$.[24]

As a result, $\alpha_3 = 0.182$ ($\alpha_2 = 0.148$) $\gamma_1 = 0.616$ ($\gamma_2 = 0.384$), $\sigma = 0.525$, and $\varepsilon = 0.51$. In addition, the labor efficiency in the informal sector η is set at 1.4 such that the skill premium in the informal sector $w_s^x/w_u^x = 1.4$. All targets and data moments are summarized in Table 4.

[24]The targets are based on HSES and aggregate data from the National Statistical Office of Thailand. The relative TFR of skilled to unskilled parents is adopted from the US data reported in Doepke (2004) We do not have direct data for Thailand. However, the relative TFR of urban (Bangkok) to rural (the south) parents is roughly 0.7. A large fraction of unskilled workers is still present in Bangkok although most of workers in rural areas are unskilled, 0.7 must be an upper bound for the skilled/unskilled TFR ratio. We think 0.5 is reasonable choice as a calibration target.

Table 3: Parameters

Parameters	Value	Source / Target
Survival rate and medical expenditure		
π^y	0.470	match life expectancy= 74.1
m	0.077	match $M/Y = 5.5\%$
Preference		
β	0.951	match $K/Y = 1.9$
σ	0.525	jointly calibrated
ε	0.510	jointly calibrated
ψ	0.227	match TFR= 1.54
Labor markets and productions		
X_u	1.514	match $w_u^f/w_u^x = 1.7$
$\bar{\theta}_s$	0.700	identified from data
$\bar{\theta}_u$	0.700	same as $\bar{\theta}_s$
A^f	10	normalization
A^x	4.283	match $Y^x/Y^f = 0.52$
α_1	0.670	identified from data
α_2	0.148	jointly calibrated
α_3	0.182	$1-\alpha_1-\alpha_2$
γ_1	0.616	jointly calibrated
γ_2	0.384	$1-\gamma_1$
η	1.400	match $w_s^x/w_u^x = 1.4$
Costs of children		
ϕ_s	0.089	match $L_s/L = 0.17$
ϕ	0.243	identified from data
Government		
τ_C	12.1%	match $T_C/Y = 9\%$
τ_L	10.9%	match $T_L/Y = 2\%$
τ_K	11.4%	match $T_K/Y = 4\%$
ω	85%	identified from data

Table 4: Calibration Targets for Benchmark Economy

Target moment	Model	Data
Life expectancy	74.1	74.1
Ratio of total medical exp. to output (M/Y)	0.055	0.055
Average TFR	1.540	1.54
Skilled/Unskilled TFR ratio	0.500	0.5
Capital–output ratio (K/Y)	1.900	1.9
Informal/Formal output ratio (Y^x/Y^f)	0.520	0.52
Formal employment share of unskilled labor (L_u^f/L_u)	0.300	0.3
Share of skilled labor among total (L_s/L)	0.170	0.17
Skill premium in the formal sector (w_s^f/w_u^f)	2.396	2.4
Formal/Informal wage gap for unskilled labor (w_u^f/w_u^x)	1.700	1.7
Skill premium in the informal sector (w_s^x/w_u^x)	1.400	1.4
Ratio of consumption tax revenue to output (T_C/Y)	0.090	0.09
Ratio of capital tax revenue to output (T_K/Y)	0.040	0.04
Ratio of labor tax revenue to output (T_L/Y)	0.020	0.02

3.2 Benchmark Economy

We summarize the main features of the benchmark economy below and in Table 5.

- **Low fertility**

  The average TFR is low as in the data (1.54), and it is mainly contributed by unskilled parents. The TFR of skilled parents is below one (0.8).

- **Large informal sector and low human capital**

  In addition, a large informal sector exists; the output from the informal sector is approximately half that produced in the formal sector. Moreover, 63.2% of workers work in the informal sector, whereas only 36.8% of workers are in the formal sector. Furthermore, the level of human capital, which is measured by the fraction of skilled workers out of total workers, is as low as 17%.

- **Informal sector is unskilled labor oriented and less productive**

  The majority (70%) of skilled workers are allocated in the formal sector, but only 30% of unskilled workers are employed in the formal sector. The wage gap between the formal and informal sectors for unskilled workers is 1.70 due to lower productivity in the informal sector and institutional distortions (e.g., the minimum wage regulation in the formal sector). Compared with the wage gap for unskilled workers, that for skilled workers is larger at 2.91 mainly because the informal sector is unskilled labor oriented and the value added by a skilled worker in the informal sector is low. By contrast, skilled labor is a necessary input factor in the formal sector. Given the existence of market frictions, the model captures the feature in the data that skilled workers tend to have low wages when they work in the informal sector. A related feature is that the skill premium (measure by skilled/unskilled wage ratio, w_s/w_u) is much larger in the formal sector despite a minimum wage requirement for unskilled labor.

- **Consumption tax is a major means of tax revenue**

  Consumption tax contributes 60% of the total tax revenue in the benchmark economy. The ratio of non-medical government expenditures to output is approximately 10.3%. The government also pays 85% of total medical expenditures and thus the ratio of public medical expenditures to output is 4.7%.

Table 5: Features of the Benchmark Economy

Description	Notation	Value
Life expectancy and fertility		
Life expectancy		74.1*
TFR of skilled	n_s	0.834
TFR of unskilled ($e = \bar{e}$)	$n_{u\|e=\bar{e}}$	0.804
TFR of unskilled ($e = 0$)	$n_{u\|e=0}$	1.832
Average (weighted) TFR		1.540*
Skilled/Unskilled TFR ratio		0.500*
Production		
Capital–output ratio	K/Y	1.900*
Informal/Formal output ratio	Y^x/Y^f	0.520*
Allocation of workers		
Formal employment share (total)	$(L_s^f + L_u^f)/L$	0.368
Formal employment share (skilled)	L_s^f/L_s	0.700*
Formal employment share (unskilled)	L_u^f/L_u	0.300*
Skilled worker share (total)	L_s/L	0.170*
Wage inequality		
Formal/Informal wage gap (skilled)	w_s^f/w_s^x	2.910
Formal/Informal wage gap (unskilled)	w_u^f/w_u^x	1.700*
Skill premium in the formal sector	w_s^f/w_u^f	2.396*
Skill premium in the informal sector	w_s^x/w_u^x	1.400*
Government		
Ratio of consumption tax revenue to output	T_C/Y	0.090*
Ratio of capital tax revenue to output	T_K/Y	0.040*
Ratio of labor tax revenue to output	T_L/Y	0.020*
Ratio of non-medical gov't exp. to output	G/Y	0.103
Ratio of public medical exp. to output	M_g/Y	0.047
Ratio of total medical exp. to output	M/Y	0.055*

Note: "*" denotes that the data moment is a calibration target.

4 Population Aging and Public Policy

On the basis of the benchmark economy, we first study the potential impacts of population aging. We also examine government financial tools, including consumption tax, capital income tax and labor income tax, for the extra costs due to population aging. Furthermore, two popular types of population policies are evaluated: a subsidy for general child-rearing cost and a subsidy for children's education cost.

4.1 Impacts of Aging and Feasible Taxation Arrangement

4.1.1 Aging

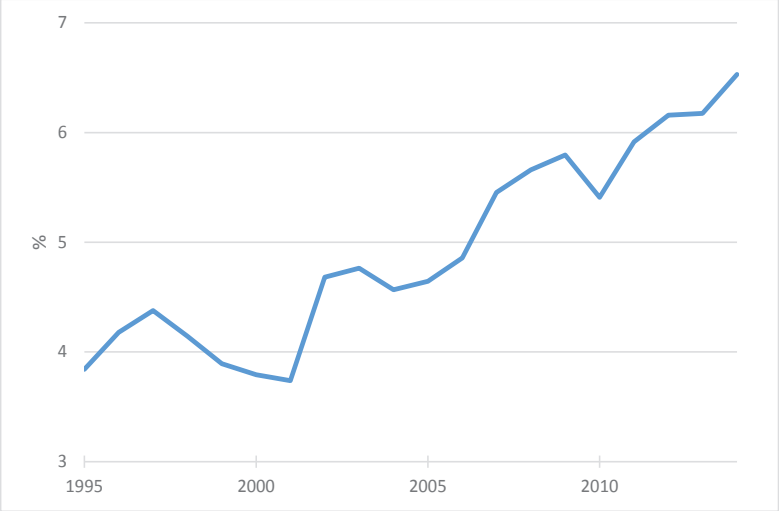
To study the impacts of aging, two main changes in the benchmark economy are considered: an increase in the life expectancy and the corresponding increase in the aggregate medical expenditures. All other model parameters remain unchanged. We assume the life expectancy will increase from the current 74 to 80 as forecasted in 2055 (WDI). As the population ages, medical expenditures increase accordingly because the elderly need more medical care. Figure 4 plots the ratio of total medical expenditure to GDP (M/Y) in Thailand during 1995–2014. On the basis of the time series data, we first use a simple linear regression to forecast the M/Y ratio in 2055, which is 12%.[25] The average life expectancy was 80 and the average M/Y ratio was 12.3% among OECD countries in 2014. The simple forecast is consistent with the aging phenomenon observed in OECD countries. Therefore, we assume that the ratio of aggregate medical expenditure to the output will increase from 5.5% in the benchmark to 12% when the life expectancy becomes 80 as our basic aging scenario.

The aging scenario is solved as a new steady state (which implies that the population age structure becomes stable when it reaches 2055 by assumption). The ratio of non-medical government expenditures to the output is assumed the same as that in the benchmark economy. We first consider that labor income tax is used to finance extra costs and ensure a balanced government budget in the aging economy. Alternative assumptions with capital income tax financing and consumption tax financing are investigated for comparison.

To ensure the economy transits to the new steady state, we compute the transition path starting from a steady state as in the benchmark, and at period t_0, the life expectancy and

[25] Thailand implemented an universal health insurance (UHI) system in 2001. After the UHI reform, the pattern of medical expenditure could differ from the pattern prior to the UHI reform. If we only use the data during 2002–2014 to forecast the M/Y ratio, it becomes 13%, which is slightly higher than the forecast based on a longer time series.

Figure 4: Ratio of Medical Expenditure to GDP in Thailand



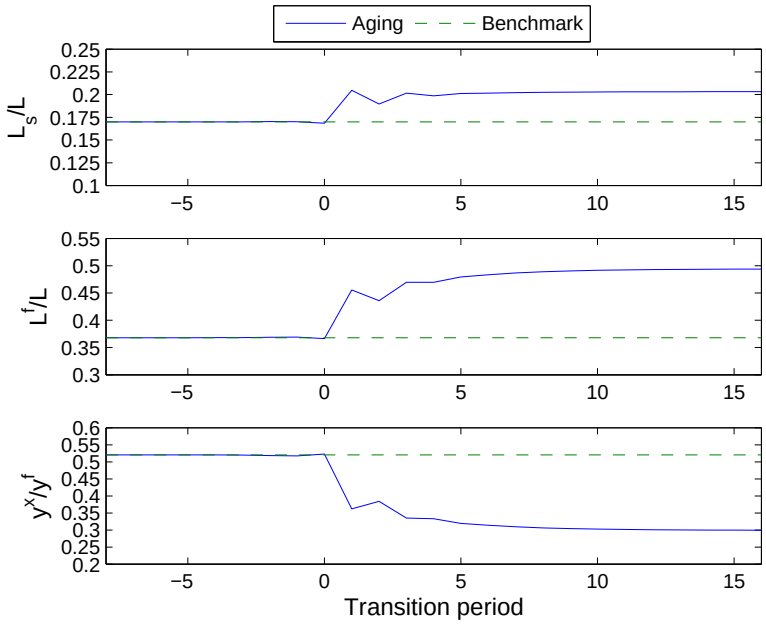
Source: National Statistical Office, Thailand

the aggregate medical expenditure increase to the 2055 levels. We require the government to balance its budget every period and assume that the extra fiscal burden caused by aging is financed by taxes. Other parameters remain unchanged. We keep track of the economy until it converges to a new steady state. With perfect foresight, individuals respond to the changes at t_0 in advance. Figure 5 plots the transition path for the skilled-worker share (L_s/L), the formal-worker share (L^f/L), and the relative output ratio of informal sector to the formal sector (Y^x/Y^f) if consumption tax is used to balance the government budget.

Our simulation result suggests that, unfortunately, both the labor income tax and capital income tax fail to sustain equilibrium in the aging society. Only the consumption tax is sustainable, but a significant increase in the tax rate is required. Table 6 summarizes the results. Labor and capital may switch to the informal sector to avoid high taxes; thus, the marginal tax revenue will be negative when the tax rate exceeds some critical point. As a result, no sustainable equilibrium is found. The consumption tax is the only feasible financing tool. Its tax rate increases significantly from 12% in the benchmark to 20.5%.

Nevertheless, aging is not entirely bad news for the developing economy. The main effects of population aging on the economy are summarized as follows: First, individuals need more savings for longer retirement and medical expenditures. As a result, the capital–output ratio increases from 1.9 in the benchmark to around 2.3. Second, the requirement of

Figure 5: Transition Path for Aging



more savings crowds out children. The average TFR declines from 1.54 to around 1.45. Third, the longer life expectancy and the requirement of more savings make education investment in children valuable. Thus, an increase in human capital stock is observed. The share of skilled workers to total workers increases from 17% in the benchmark to 20% in the aging economy. Fourth, the increases in both physical and human capital stocks enlarge the capacity of the formal sector. The labor employment in the formal sector increases from 36.8% to around 48.5% under the consumption tax financing scheme. The output ratio of the informal sector to the formal sector shrinks from 52% in the benchmark to 30% in the aging economy. In sum, the accumulations of physical and human capital and enlarged formal sector caused by population aging benefit economic growth.

An alternative scenario with a small increase in the medical cost, in which all the three tax financing schemes are feasible, is also discussed in Appendix E. In this case, the consumption tax is the best financing scheme because it results in less distortion of the factor allocation between the formal and informal sectors and is good for consumption smoothing over the life cycle in an aging economy.

Peñalosa and Turnovsky (2005) discussed optimal allocation between labor and capital

Table 6: Financing Population Aging

		Financing tools	
	Benchmark	Labor/Capital taxes	Cons. tax
Life expectancy	74.1	80.1	80.1
Medical exp/GDP	5.5%	12%	12%
Labor tax τ_L	10.9%	–	10.9%
Capital tax τ_K	11.4%	–	11.4%
Consumption tax τ_C	12.1%	–	20.5%
Average TFR	1.54	**No equilibrium**	1.451
Skilled-worker share	17.0%	–	20.3%
Formal-worker share	36.8%	–	49.4%
Capital–output ratio	1.900	–	2.256
Y^x/Y^f ratio	52.0%	–	29.9%
Skill premium (w_s^f/w_u^f)	2.396	–	2.832

taxes in a growth model with an informal sector and suggested that the capital tax rate should be at least as high as the labor tax rate. The main mechanism behind the result is the tax distortion on factor allocation between formal and informal sectors. Although optimal taxation is not the focus of this paper, we further find that tax distortion will lead to a failure of financing extra public expenditures caused by aging, and consumption tax is preferred in a developing economy with a large informal sector. The finding is consistent with the fact that the share of income taxes in total tax revenue is negatively correlated with the size of the informal sector (see Figure 7 in Besley and Persson, 2014).

4.2 Population Policy

On the basis of the above aging economy with consumption tax as the main financing tool (denoted as a baseline aging scenario), we evaluate two popular types of population policy. The first is a policy of reducing child-rearing cost through child allowance or tax return to encourage fertility, which is commonly observed in developed countries. For example, the Japanese government provides a monthly child allowance of 25,000 yen per child to each household. The second is a policy reform of providing subsidy for children's educational costs. For example, public schools with subsidized tuition fees, tuition waiver for low-income families, and government-sponsored student loans are common in developed

countries.

4.2.1 Subsidy on General Child-Rearing Cost

We first study the child-allowance type policy, which aims to encourage fertility. Table 7 presents the results with various subsidies (measured by percentage of total child-rearing cost per child). Except the subsidy policy, all the economic/demographic features are the same as those in the baseline economy. We still assume that the government will use consumption tax to finance the cost of the subsidy. Corresponding consumption tax rates for each subsidy are also reported in the table.

We find that this policy is costly and has a relatively small effect with a reasonable subsidy although it indeed improves the TFR and population age structure. For example, to increase the TFR to 2.1 (the fourth column of Table 7), this policy requires a significant amount of subsidy; consumption tax has to increase by 30 percentage points to 50% from 20% in the baseline (the first column), which is not financially and politically feasible. If the subsidy is not significantly large (the second column of Table 7), that is, the current child allowance in Japan, approximately 300 USD per child per year, then the effect would be negligible.

In the long run, the policy will have a negative effect on economic development. Both human capital (measured by skilled-labor share) and physical capital (represented by capital–output ratio) levels decrease under the child-allowance policy (see columns 2–6 in Table 7) because this type subsidy distorts the relative price between having skilled and unskilled children and the relative price between having children and savings. In particular, it encourages households with lower education (lower income) to have more children without providing higher education, but it is not effective in improving the fertility for households with higher education (high income).

Our finding is consistent with the recent empirical study by Kalwij (2010), which examined the effects of child allowance and other family benefits that aim to encourage fertility in 16 Western European countries. Kalwij found that those family programs had positive but insignificant effects on fertility.

The above analysis focuses on the long-term effects. Thus, to further understand the welfare implications of the policy reform across generations, we also conduct a transition analysis. We use the case with 15% child-rearing cost subsidy as an example for illustration. The model economy is simulated from an initial steady state as the baseline economy in Table 7. In period 0, the child allowance policy reform is implemented permanently, and the corresponding extra government expenditure is financed by consumption tax. Others

Table 7: Subsidy for Child-rearing Cost

	Baseline	Policy of child-rearing subsidy			
Subsidy	0%	5%	10%	15%	20%
TFR	1.5	1.6	1.9	2.1	2.5
Old–young ratio	92.3%	81.5%	71.5%	62.4%	54.2%
Consumption tax	20.5%	27.5%	36.9%	50.3%	70.0%
Capital–output ratio	2.256	2.144	2.037	1.938	1.846
Skilled-labor share	20.3%	18.5%	16.6%	14.8%	13.2%
Formal-labor share	49.4%	43.3%	37.6%	32.5%	28.0%
Y^x/Y^f ratio	29.9%	38.5%	49.1%	62.3%	78.1%

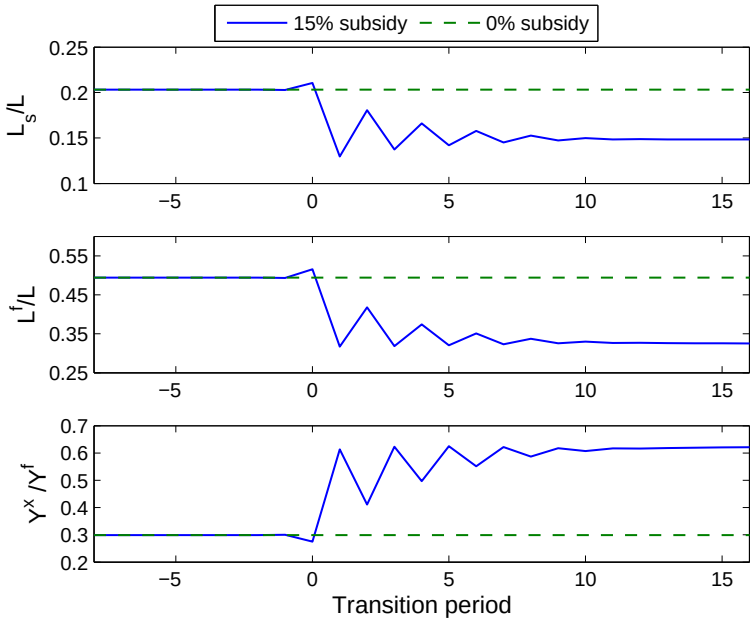
remain unchanged. We keep tracking the transition until the economy eventually converges to a new steady state as shown in the fourth column in Table 7. Figure 6 plots the patterns of the skilled-worker share, the formal-worker share, and the relative output ratio along with the transition path. Welfare is represented by the ex ante lifetime expected utility of young individuals when they start to be active in the model. Welfare changes are measured by the certainty consumption equivalent variation (CEV) of young individuals in each period compared with the same individuals in an economy without any policy change (i.e. the initial steady state). The patterns of CEV of each type of individuals in each period are shown in Figure 7.

We find that, when the policy reform is implemented, the generation in period 0 (a 30-year period) enjoys welfare improvement. However, the benefit will be offset by worse economic outcomes and will eventually hurt future generations in the long run.

Table 8 provides detailed information of some key variables in periods before and after the implementation of the child allowance. We can observe that in period 1, when the additional children born in period 0 without higher education grow up, most of them end up working in the informal sector, thereby enlarging the size of the informal sector, crowding out input factors in the formal sector, and reducing the aggregate productivity. The output per capita becomes lower. Thus, the tax rate has to increase to balance the government budget. Therefore, a tax hike and a significant decline in welfare are observed from period 1.

The negative impacts look large in our simulation result because we assume all other things remain unchanged and the period is 30 years. The skilled labor share continuously

Figure 6: Transition Path for a Reform of 15% Child-rearing Subsidy



declines for 30 years, which amounts to a large gap from the baseline economy without the policy change. If we assume a constant two-percent annual aggregate productivity growth, then the economy with the policy change will still grow although the growth rate will be significantly lower than the baseline economy without the policy. The child allowance policy will hurt the long-term economic development because human capital, which is crucial for growth in a modern economy, is generally under-established in developing countries.

Table 9 shows some indexes of human capital in selected developed and developing countries. The first column is the ratio of population with higher education (secondary and above) among the total population with age 25+ in 2010, which approximates the current stock of human capital. The second column presents the gross school enrollment rate for tertiary education, which measures the flow of human capital accumulation. In both columns, we observe significant gaps between developed and developing countries.

An additional factor that affects economic growth in developing countries is the informal sector. This issue is not a concern in developed countries but is important for developing economies because their informal sectors are large (above 50% of total employment) and is less skilled-labor intensive and productive than the formal sectors. A low skilled labor

Figure 7: Welfare Changes for a Reform of 15% Child-rearing Subsidy

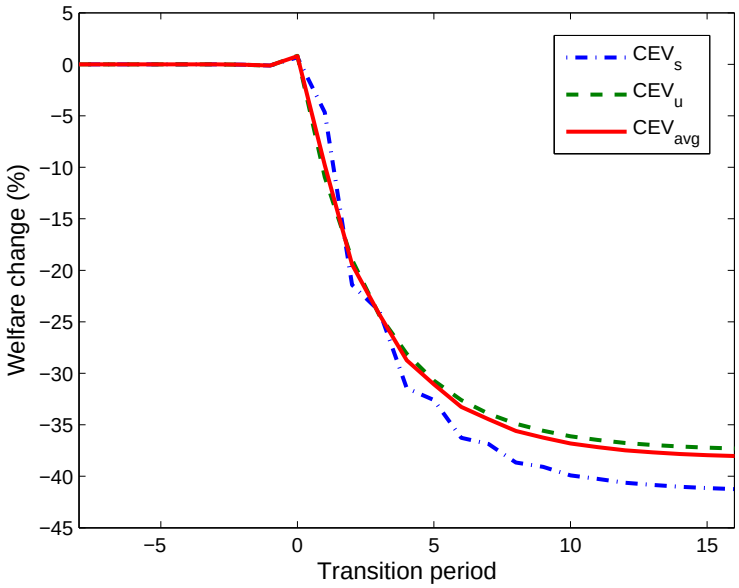


Table 8: Transition Path for a Reform of 15% Child-rearing Subsidy

Transition Period	-2	-1	0	1	2	3
Consumption tax τ_c	20.6%	20.6%	22.5%	31.1%	31.6%	39.2%
Average TFR	1.451	1.465	1.908	1.887	2.004	2.004
Skilled-worker share	20.3%	20.3%	21.1%	13.0%	18.1%	13.7%
Formal-worker share	49.4%	49.3%	51.6%	31.7%	41.8%	31.9%
Capital–output ratio	2.256	2.259	2.278	2.286	2.102	2.115
Y^x/Y^f ratio	29.9%	30.0%	27.5%	61.3%	41.1%	62.3%
Skill premium (w_s^f/w_u^f)	2.832	2.835	2.859	2.852	2.642	2.649
Δ welfare (skilled, CEV_s)	0.0%	-0.1%	0.7%	-4.7%	-21.4%	-24.0%
Δ welfare (unskilled, CEV_u)	0.0%	-0.1%	0.8%	-10.9%	-19.0%	-24.4%
Δ welfare (average, CEV)	0.0%	-0.1%	0.8%	-9.8%	-19.4%	-24.3%

Note: The shock of 15% child-rearing subsidy occurs at period 0 permanently. The extra cost due to the subsidy is financed by consumption tax. The welfare changes are compared with the baseline reported in Table 8.

Table 9: Human Capital Index

	Educational attainment	School enrollment
Country	Fraction of upper secondary and above among age 25+ (%), 2010	Tertiary (gross rate %) 2011–2013
U.S.	87.1	93.3
Japan	80.6	61.3
Germany	81.1	61.1
France	61.9	60.1
Malaysia	50.9	35.9
China	22.3	27.4
Thailand	27.3	51.9
Vietnam	25.7	24.9
Myanmar	NA	13.9

Source: World Bank.

share will shrink the formal sector and lead to a decline in the aggregate output. As a result, in the long run, this child allowance policy will reduce the efficiency of resource allocation and worsen the fiscal burden caused by population aging although its short-term effect is positive.

4.2.2 Subsidy for Children's Educational Cost

We then alternatively consider a policy that subsidizes children's educational cost, such as, tuition waiver for low-income families and government-sponsored student loans.

On the basis of the baseline economy, experiments with various additional subsidies (10% to 30%) of children's educational cost are conducted. We first study its long-term effect, and each experiment is solved as a new steady state. Other parameters are the same as in the baseline economy. The results are summarized in Table 10.

The subsidy for children's educational cost does not improve the population age structure. The old–young ratio (ratio of age 60+ to age 30–60) even increases slightly as the subsidy increases because education investment becomes relatively cheap. Therefore, more unskilled parents start to invest in education of their children and reduce the number of children. As a result, the share of skilled workers among total workers increases from 20%

Table 10: Subsidy for Children's Educational Cost

	Baseline	Policy with educational subsidy				
Subsidy	0%	10%	20%	25%	26%	30%
TFR	1.45	1.42	1.39	1.38	1.38	1.37
Old–young ratio	92.3%	94.2%	96.2%	97.2%	97.3%	97.5%
Consumption tax	20.5%	17.8%	15.1%	13.8%	13.8%	14.0%
Capital–output ratio	2.256	2.249	2.241	2.237	2.236	2.226
Skilled-worker share	20.3%	23.3%	26.8%	28.7%	29.1%	30.2%
Formal-worker share	49.4%	56.6%	64.9%	69.6%	70.0%	70.0%
Y^x/Y^f ratio	29.9%	22.8%	16.5%	13.6%	13.3%	13.3%

in the baseline, for example, to 26% in the experiment with 20% subsidy.

Although the population age structure is not improved, the high supply of skilled workers enlarges the formal sector and allows more input factors to flow into the formal sector, thereby improving the aggregate production efficiency. The fraction of formal workers increases up to 70%.[26] The informal output ratio reduces accordingly.

We find that the provision of education subsidy, rather than a pure child allowance, in the long run can help alleviate the extra tax burden caused by population aging because the larger formal sector increases the aggregate productivity and output/consumption, thereby enlarging the tax base and reducing the consumption tax rate.

However, the fiscal alleviation has a limit. We conduct an experiment by varying the extent of education subsidy to examine corresponding tax rate changes. Figure 8 shows a V-shape relationship between level of subsidy and consumption tax rate. The lowest tax rate is at 13.8% with a corresponding additional 26% education subsidy. Beyond this level of subsidy, the consumption tax rate starts to increase. We also examine the welfare, which is represented by young individuals' ex ante expected lifetime utility, under each subsidy policy. Figure 9 presents the relationship between level of education subsidy and change in welfare measured by CEV compared with the baseline economy. Patterns of CEV for skilled workers (CEV_s), unskilled workers (CEV_u), and the whole economy (social average, CEV_{avg}) are displayed, and we observe an inverse-V relationship that delivers the same

[26]The formal-worker share stops at 70% because we assume the existence of labor market friction for both skilled and unskilled workers. Average probabilities of finding jobs in the formal sector without policy distortion ($\bar{\theta}_s$ and $\bar{\theta}_u$, respectively) are both at 70%.

Figure 8: Tax Burden and Subsidy of Educational Cost

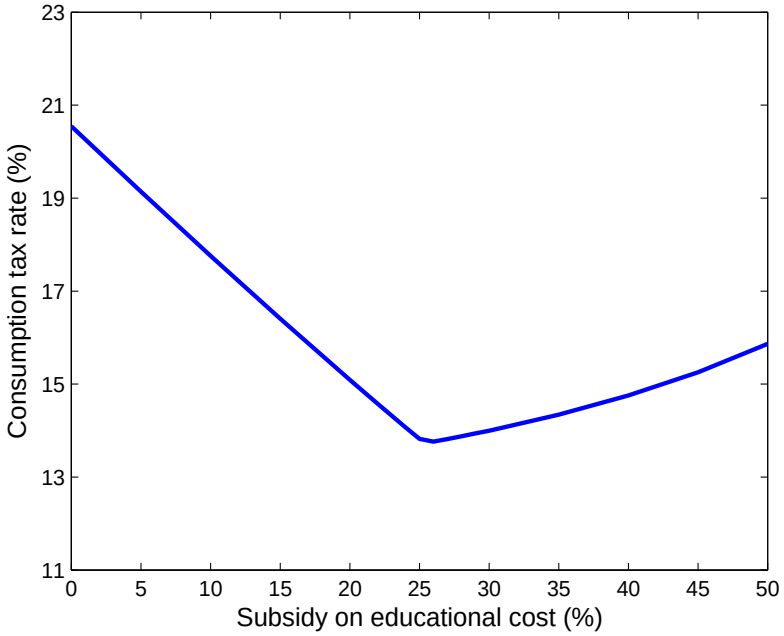
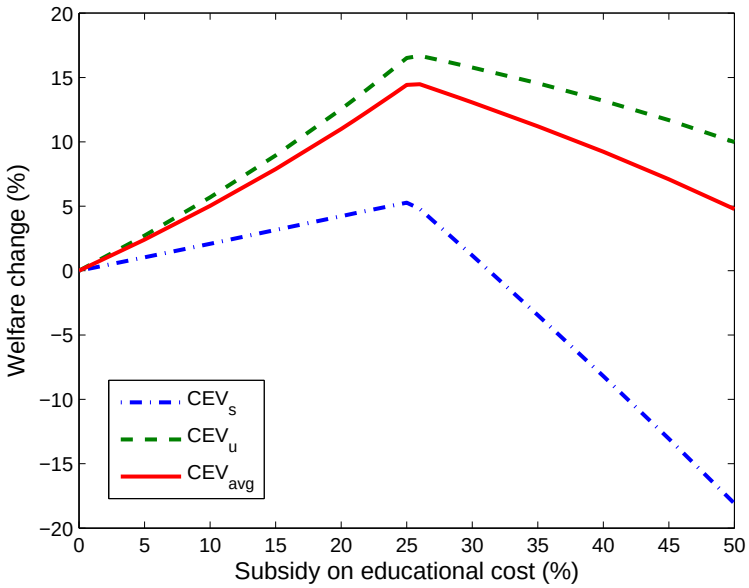


Figure 9: Welfare and Education Subsidy



implication for the optimal level of subsidy as shown in the tax rate patterns.

To study the welfare implication across generations, a transition analysis is conducted. We use an additional subsidy of 25% children's educational cost as an example. We simulate the economy from an initial steady state as in the baseline shown in Table 10. In period 0, an additional educational subsidy is implemented permanently. We still use consumption tax to ensure a balanced government budget. Others remain unchanged. We keep tracking the economy until it converges to a new steady state. Table 11 summarizes the transition path two periods before and three periods after the policy implication (i.e., period 0). Figure 10 plots the transition paths of the skilled-worker share (L_s/L), the formal-worker share (L^f/L), and the relative informal output ratio (Y^x/Y^f). Welfare changes by skill type (skilled, unskilled, and social average) and by generation born in each period are shown in Figure 11.

In contrast to our findings on the child-allowance type policy, our transition analysis shows that in first few decades after the policy is implemented, the skilled workers will suffer because of more competition, whereas the unskilled labor will benefit with the subsidy for children's educational cost and less competition in the labor market. Nevertheless, the

Table 11: Transition Path of an Education Policy Reform

Transition Period	-2	-1	0	1	2	3
Life expectancy	80.1	80.1	80.1	80.1	80.1	80.1
Medical exp/GDP	12%	12%	12%	12%	12%	12%
Consumption tax τ_c	20.6%	20.6%	22.2%	16.6%	16.5%	15.5%
Average TFR	1.454	1.477	1.430	1.431	1.416	1.406
Skilled-worker share	20.3%	20.3%	19.2%	31.2%	27.7%	28.7%
Formal-worker share	49.4%	49.3%	46.9%	70.0%	65.8%	68.2%
Capital–output ratio	2.256	2.258	2.262	2.108	2.170	2.177
Y^x/Y^f ratio	29.9%	30.0%	33.0%	13.6%	16.0%	14.5%
Skill premium (w_s^f/w_u^f)	2.832	2.834	2.837	2.584	2.738	2.747

Note: The shock of 25% education subsidy occurs at period 0 permanently. The extra cost due to education subsidy is financed by consumption tax. The welfare changes are compared with the baseline reported in Table 10.

Figure 10: Transition Path of an Education Policy Reform

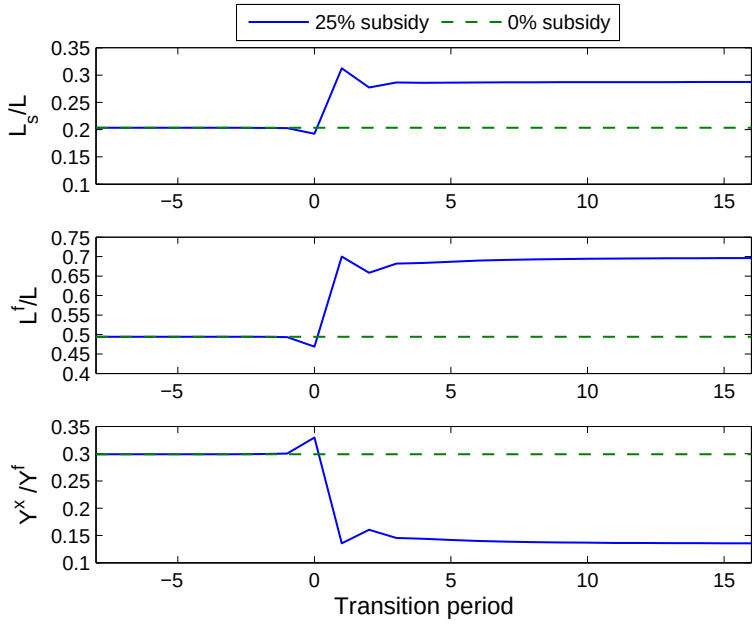
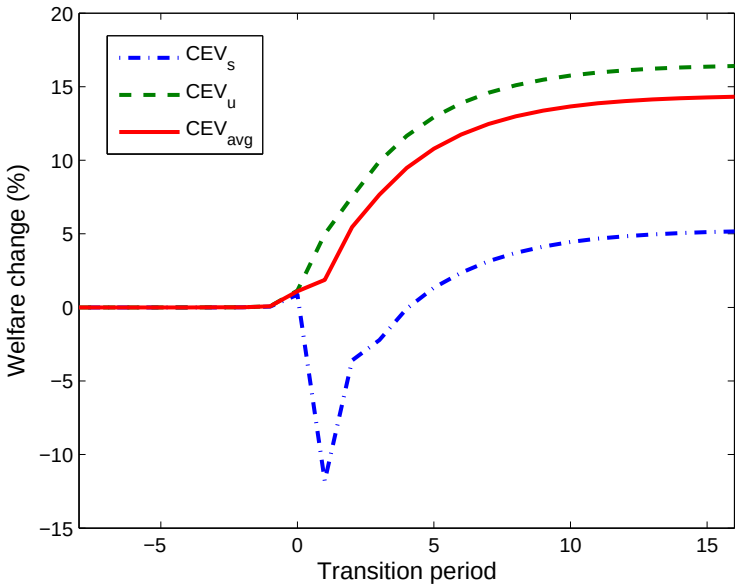


Figure 11: Welfare Changes by Generations of an Education Policy Reform



aggregate change in social welfare is always positive, thereby indicating some redistribution (to compensate the skilled labor) is possible to make everyone happy with the policy reform in the short run. In the long run, both the skilled and unskilled enjoy certain welfare improvements because of a better economic development (after period 5 in 11). This policy encourages educational investment in children and improves the level of human capital (skilled labor share) that enlarges the formal sector. Hence, the aggregate productivity increases (see the increasing patterns of L_s/L and L^f/L in Figure 10). As a result, the economy's aggregate output (per capita) increases and average tax burden decreases, thereby resulting in welfare gains. The welfare gains can be sustained in the long run because of the improved economic development, although the population age structure does not change significantly.

4.3 Role of the Informal Sector

This paper models an informal sector to capture the existence of large informal economies in developing countries. To provide a comparison and show the role of the informal sector, we remove the informal sector from the benchmark model and re-do the analysis, including

Table 12: Role of the Informal Sector

	With informal sector		No informal sector	
	Aging (baseline)	Edu. policy reform	Aging (baseline)	Edu. policy reform
Consumption tax τ_c	20.5%	13.8%	21.9%	21.4%
Average TFR	1.451	1.379	1.419	1.446
Skilled-worker share	20.3%	28.7%	22.9%	26.6%
Capital–output ratio	2.256	2.237	2.358	2.338
Change in output per capita	–	22.9%	–	2.1%
Skill premium	2.832	2.820	2.755	2.253
(change)	–	(-0.4%)	–	(-18.2%)
Δ welfare (skilled, CEV_s)	–	5.3%	–	-10.8%
Δ welfare (unskilled, CEV_u)	–	16.5%	–	8.3%
Δ welfare (average, CEV)	–	14.4%	–	4.3%

the baseline aging scenario and the education subsidy policy. Table 12 presents the result. The first column is the baseline aging scenario, as shown in the last column of Table 6, and the second column is the policy reform with an additional 25% education subsidy, as shown in Table 10. Columns three and four show the results of counterfactual experiments without the informal sector corresponding to those in the first two columns.

The policy implication is significantly different with the existence of a large informal sector. In our original analysis, the education policy reform will largely reduce the tax burden and improve welfare for all types of workers in the long run. By contrast, without the informal sector, the education policy reform does not reduce the tax burden significantly (from 21.9% to 21.4%) and causes a large welfare loss for skilled workers (roughly 18% of their lifetime consumption) in the long run.

The difference comes from the fact that the reallocation of resources from the informal sector to the formal sector improves the aggregate production efficiency and generates significant economic benefits. The formal sector is more skilled-labor intensive; thus, an increase in skilled labor supply enlarges the formal sector and induces resource reallocation, which that is not an advantage in an economy without the informal sector.

5 Conclusions

This paper explores the impacts of population aging and assesses related population policies with a focus on developing economies. We emphasize the features of low fertility and rapid aging in many middle-income and some low-income developing economies. Furthermore, a distinct feature in developing economies, namely, the existence of a large informal sector, which is unskilled labor intensive, is taken into account. We construct an overlapping-generations model to capture these features and perform a structural analysis.

Our quantitative results suggest that population aging (extended longevity) is not entirely detrimental to a developing economy although it imposes a heavier fiscal burden. It may benefit economic development; increased savings and education investment in children in an aging society are observed. Furthermore, increases in physical/human capital enlarge the formal sector and shrink the informal sector, thereby allowing resources to be allocated efficiently and improving the aggregate productivity. The negative relationship between human capital accumulation and the size of the informal sector is consistent with the empirical findings.

On the basis of the aging scenario, we first study a popular population policy among developed countries, which provides a subsidy for general child-rearing cost to encourage fertility, such as Child Allowance in Japan or Child Benefit in the UK. We find that this policy is costly, and the effect on fertility is small with a reasonable subsidy range. In the long run, however, the policy will have a negative effect on economic development. It encourages households with lower education (lower income) to have more children without providing higher education to their children, but it is not effective in improving the fertility for households with higher education (high income). Along with the transition of this policy reform, we find that the current generation (when the policy is implemented) enjoy the child allowance with a positive welfare gain, but the benefit will be offset by the worse economic outcomes, and future generations will be hurt.

We also study an alternative policy that subsidizes children's educational cost, such as tuition subsidy/waiver and government-sponsored student loans. Although the population age structure is not improved, the policy encourages educational investment, and the resultant increase in skilled workers enlarges the formal sector, thereby improving the aggregate production efficiency. It also helps alleviate the extra tax burden caused by population aging because of the expansion of tax base. Our transitional analysis indicates that some additional redistribution (to compensate skilled workers) is possible to improve everyone's welfare in the short run. In the long run, both skilled and unskilled workers enjoy welfare gains because of the improved economic development.

We also find that the existence of a large informal sector plays an important role. If the informal sector is not taken into account, then the above education policy reform will not reduce the tax burden and will instead cause a large welfare loss for the skilled workers in the long run. The difference comes from the effect of reallocation of resources between the informal and formal sectors.

Economic/market structures in developing countries are different from those in developed countries in many perspectives. Thus, a policy suggestion might be misleading if some related features of developing countries are not considered in the analysis. In this paper we show that given the large informal sector and low human capital development in developing countries, the policy suggestion deviates from those commonly taken in developed coun-tries. Other features, such as high rural/urban inequality and immature financial market, are worth careful considerations in related policy analyses that focus on developing economies.

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Appendix

A. Consumption and income tax revenues: a comparison between developed and developing countries

We present various types of tax revenues to GDP ratios during 2009–2014 in countries of three categories, namely, OECD, high income, and low and middle income, in Table 13. The first column is the ratio of total tax revenue to GDP, the second column is the ratio of income tax revenue to GDP, and the last column is the ratio of consumption tax revenue to GDP. Income tax revenue includes taxes on labor/capital income of individuals and on profits of firms. [27] Consumption tax includes taxes on goods, services, and international trade.[28] We observe that the ratios of consumption tax revenue to GDP (in the third column of Table 13) are similar across OECD, high-, middle- and low-income countries (in a small range of 7.6%–7.8%). However, the ratios of income tax revenue to GDP (in the second column) in high-income or OECD countries are 50% higher than those in low- and middle-income countries (i.e., developing countries) (6% vs. 4%).

Table 13: Tax revenue 2009–2014 (% of GDP)

Country group	Total tax	Income tax	Consumption tax
OECD	14.6	6.2	7.8
High income	14.4	6.2	7.6
Low and middle income	12.6	4.1	7.8

Source: World Development Indicators, World Bank, and authors' calculation. According to the classification of World Bank, high income: 2016 GNI per capita was $12,236 or more; low and middle income: 2016 GNI per capita was $12,235 or less.

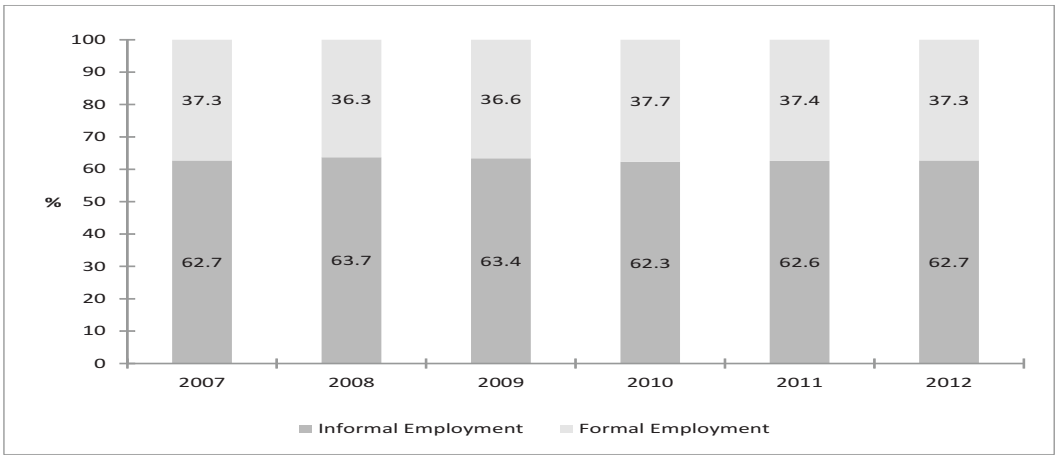
B. Informal employment in Thailand

The ratio of workers in the informal sector of Thailand is large and stable. Figure 12 plots the ratios of informal employment in Thailand for 2007–2012. The ratio fluctuated between 62%–64%.

[27] Based on the definition of World Bank, income tax includes taxes on income, profits, and capital gains are levied on the actual or presumptive net income of individuals, on the profits of corporations and enterprises, and on capital gains, whether realized or not, on land, securities, and other assets.

[28] Taxes on goods and services include general sales and turnover or VAT. Trade taxes include import duties, export duties, profits of export or import monopolies, exchange profits, and exchange taxes.

Figure 12: Ratio of Informal Employment (Thailand)



Source: National Statistical Office, Thailand

C: Features of labor market in developing economies

We use the data of HSES from Thailand to illustrate the labor market features in developing economies with a large informal sector. Skilled workers are those, whose education level is high school or above (i.e., schooling years $\leq$12). The main features are summarized as follows:

1. Approximately 70% of skilled workers work in the formal sector, while more than 70% of unskilled workers work in the informal sector.

2. Skilled workers usually stay in the informal sector less than one year. The panel data of HSES indicates that for skilled workers who are currently working in the informal sector, only approximately 10% of them will stay in the informal sector after one year. By contrast, the probability that unskilled workers will continue to stay in the informal sector after one year is higher than 70%.[29] This fact suggests that, for skilled workers, having a job in the informal sector is more like a temporary arrangement. They tend to switch to the formal sector quickly.

3. When a skilled worker is employed in the informal sector, her/his wage from the informal sector is very likely to be lower (with a 90% probability of having a wage

[29] See the employment transitions between formal and informal sectors in the appendix of Hsu, Huang, and Yupho (2015).

in the bottom 40% of total skilled workers). The pattern is not observed for unskilled workers.

4. The skill premium in the formal sector is around 2.4, while it is relatively smaller in the informal sector (approximately 1.4). A wage gap between formal and informal sectors also exists. For unskilled workers, the wage gap between the two sectors is approximately 1.7.

The facts above indicate that skilled workers in the informal sector are likely to be temporary, underpaid, and easy to be replaced with unskilled workers. Our model is designed to capture these features and described in Section 2.

D: Proof – Only one type of individuals can be indifferent on education decisions

A young adult's maximization problem is given by:

$$\max \quad \left\{ \frac{c_i^{y\,1-\sigma}}{1-\sigma} + \beta \pi_y \frac{c_i^{o'\,1-\sigma}}{1-\sigma} + \psi \left(\frac{E_i}{P_{ij}} \right)^{1-\varepsilon} V_j \right\}$$

subject to

$$\begin{aligned} (1+\tau_C)c_i^y &= [\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x] - E_i - \pi^y[a_i^{f'} + a_i^{x'}] \\ (1+\tau_C)c_i^{o'} &= [1+(1-\tau_K)r^{f'}]a_i^{f'} + (1+r^{x'})a_i^{x'} - (1-\omega)m' \end{aligned}$$

where $E_i = P_{ij} n_i(e_i)$, which is the total expenditure on children (a function of e_i).

A young adult is indifferent between investing and not investing in children's education if the following condition holds:

$$\psi \left(\frac{E_i}{P_{is}} \right)^{1-\varepsilon} V_s = \psi \left(\frac{E_i}{P_{iu}} \right)^{1-\varepsilon} V_u.$$

The above is rewritten to obtain the following equation:

$$\frac{V_s}{V_u} = \left(\frac{P_{is}}{P_{iu}} \right)^{1-\varepsilon} \tag{21}$$

where

$$\begin{aligned} P_{is} &= \phi[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x] + \bar{e} \\ P_{iu} &= \phi[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x]. \end{aligned}$$

On the right-hand side, the relative price for education (having a skilled child) is given by:

$$\frac{P_{ss}}{P_{su}} = \frac{\phi[\theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x] + \bar{e}}{\phi[\theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x]} = 1 + \frac{\bar{e}}{\phi[\theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x]};$$

The relative price for having an unskilled child is given by:

$$\frac{P_{us}}{P_{uu}} = \frac{\phi[\theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x] + \bar{e}}{\phi[\theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x]} = 1 + \frac{\bar{e}}{\phi[\theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x]}.$$

The condition $\frac{P_{ss}}{P_{su}} < \frac{P_{us}}{P_{uu}}$ holds if and only if

$$\theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x > \theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x. \tag{22}$$

Note that,

$$\begin{aligned} & \theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x \\ > \quad & \theta_s(1-\tau_L)w_u^f + (1-\theta_s)w_u^x \\ > \quad & \theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x. \end{aligned}$$

With the assumptions that $w_s^f > w_u^f$, $(1-\tau_L)w_u^f > w_u^x$, and $w_s^x > w_u^x$, the last inequality holds if $\theta_s > \theta_u$. Therefore, if $\theta_s > \theta_u$, then Equation (22) holds. A skilled child is relatively cheaper for skilled parents than for unskilled parents, $\frac{P_{ss}}{P_{su}} < \frac{P_{us}}{P_{uu}}$. Only one type of parents will be indifferent between investing and not investing in children's education.

E: Alternative aging scenario – Lower cost

Table 14 provides the simulated results for an alternative scenario: the life expectancy goes up to 80.1, and the M/Y ratio slightly increases to 6.3% such that each tax financing tool is feasible. Using labor income tax as the financing tool will reduce the return of education because the majority of skilled workers is allocated in the formal sector. Therefore, compared with other financing tools, the share of skilled workers to total workers does not increase considerably (to 18.4%) when population aging is financed by the labor income tax. Financing by capital income tax does not distort labor allocation directly, but it reduces the capital return in the formal sector. This condition would indirectly decrease the wage rates in the formal sector because of changes in capital–labor ratio. Financing by consumption tax results in the highest level of human capital stock because it does not distort the labor allocation between the two sectors.

Table 14 also reposts changes in welfare, measured by CEV. Compared with the case of the labor income tax financing scheme, the other two tax tools are better because labor income tax is collected only from young adults who are working in the formal sector and because it also distorts labor allocation. By contrast, capital income tax is collected from old adults whose assets are invested in the formal sector. The distortion on labor allocation for young adults is indirect and small. Thus, welfare is slightly improved. Consumption tax is collected from all adults and no distortion exists in the labor market. Thus, the welfare improvement obtained by this scheme is the greatest.

Table 14: Financing Population Aging – Scenario 1

		Financing tools		
	Benchmark	Labor tax	Capital tax	Cons. tax
Life expectancy	74.1	80.1	80.1	80.1
Medical exp/GDP	5.5%	6.3%	6.3%	6.3%
Labor tax τ_L	10.9%	13.1%	10.9%	10.9%
Capital tax τ_K	11.4%	11.4%	12.6%	11.4%
Consumption tax τ_C	12.1%	12.1%	12.1%	12.2%
Average TFR	1.540	1.500	1.490	1.466
Skilled-worker share	17.0%	18.4%	19.1%	20.1%
Formal-worker share	36.8%	42.5%	44.2%	48.5%
Capital–output ratio	1.900	2.216	2.229	2.233
Y^x/Y^f ratio	52.0%	39.1%	37.3%	31.1%
Skill premium (w_s^f/w_u^f)	2.396	2.630	2.650	2.804
Δ welfare (skilled, CEV_s)	–	Baseline	2.9%	6.9%
Δ welfare (unskilled, CEV_u)	–	Baseline	3.1%	4.2%
Δ welfare (average, CEV)	–	Baseline	3.0%	4.6%