Financing Aging in Developing Economies: Feasible Taxation and Population Policies

Tanyasorn Ekapirak [*] BOT
Minchung Hsu[†] GRIPS
Pei-Ju Liao[‡] IEAS

Job Market Paper

Abstract

This paper develops a two-sector general equilibrium overlapping generations model with endogenous fertility and education choices to explore the feasible taxation arrangement and population policies in a developing economy with the trend of population aging. The features of low fertility, rapid population aging and the existence of a large informal sector in developing countries are captured in the framework. To provide a representative quantitative analysis, Thailand is taken as an example. We find that only consumption tax is feasible to finance the extra expenditure caused by population aging in the future. Furthermore, policies aiming at increasing fertility indeed can improve the age structure but lower the stock of human capital and physical capital. Eventually, it does not alleviate the heavy tax burden caused by population aging. In contrast, policies that subsidizing on children's education investment provide incentives to accumulate human capital, enlarge the formal sector and alleviate the tax burden. In terms of welfare improvement, education subsidy could be a possible solution in an aging economy.

[*]Bank of Thailand, Thailand.
[†]National Graduate Institute for Policy Studies (GRIPS), Japan.
[‡]Institute of Economics, Academia Sinica, Taiwan.

1 Introduction

Population aging is a global trend. The higher old-age dependence ratio forces the government to impose a higher tax rate in order to finance the extra expenditure caused by population aging. In addition, the sharp decline in fertility and the existence of a large informal sector in developing countries worsen the problem. To explore this issue, this paper develops a two-sector general-equilibrium overlapping generations model. Our framework incorporates endogenous fertility, education choice and labor allocation between formal and informal sectors to capture the main features of lower fertility, rapid population aging and a large informal sector in developing countries.

Based on the data in Japan, Taiwan, Thailand and the US during 2003-2007, Hsu, Huang and Yupho (2015) point out that the elderly significantly need more health care than young people. The annual medical expenditure of an old adult (age 64 and above) is two to six times more than that of a young individual. Thus, it is unavoidable for a country with population aging to face a significant increase in aggregate medical expenditure and the financing problem of the public health care program.

The problem could be worse if a country had a sharp decline in fertility. As reported in Lee et al. (2014), the average total fertility rate (TFR) in middle-income developing countries were already below the replacement rate during 2005-2010. Table 1 provides the average TFR for selected countries. They were classified into three income groups.[1] As shown in the table, the TFRs of some low-income countries were even lower. For example, Vietnam's TFR was 1.89, which was lower than that of the US. Figure 1 plots the time series data of TFRs in developing countries. The US is used as a reference. The figure shows that the TFRs in these developing countries rapidly declined from around 6 to around 2 within fifty 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. The faster speed worsens the problem of population aging.

In addition, different from developed countries, developing countries often have large informal sectors. This further constraints the government's ability on tax collection. Figure 2 presents the ratio of informal employment to total employment in non-agriculture sectors for selected developing countries. The ratio of informal employment was higher than 70% in several countries, such as India, Indonesia, Paraguay and Philippines. Turkey, whose income level was the highest among the middle income countries, was a representative as

[1]The income group classification is based on the criteria of World Bank in 2014. 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.

Table 1: Total Fertility Rate during 2005-10

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

Source: Lee et al. (2014) and United Nations.

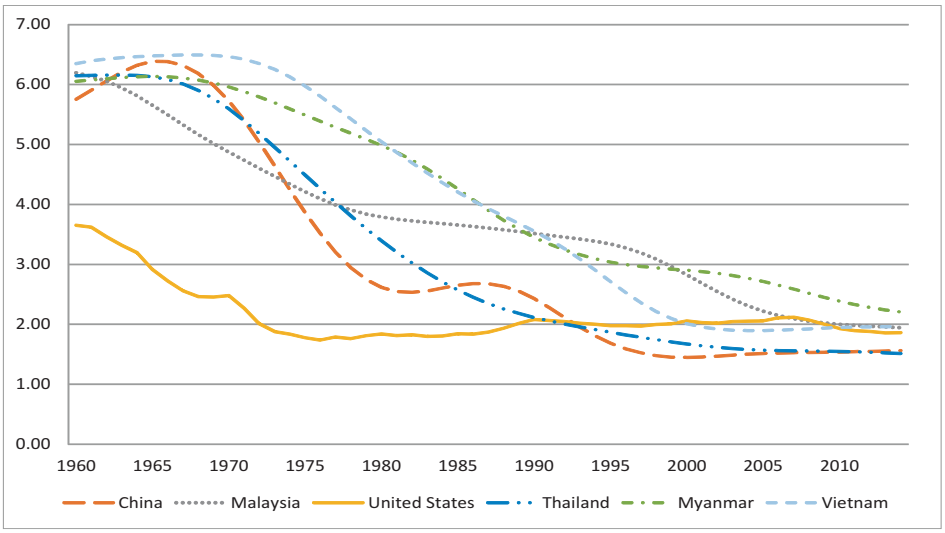
the lower bound, at 30%. The ratio could be even higher (generally higher than 50%) if the agricultural sector was included. The existence of a large informal sector makes the problem of population aging more terrible.

To study the issue of population aging in developing countries, we develop a two-sector general equilibrium overlapping generations model with endogenous fertility and education choices. Individuals also allocate labor between the formal and informal sectors. The life-cycle is characterized by three stages: childhood, young adulthood and old adulthood. In the model, only young adults make decisions. Human capital is modeled in a discrete way that children will become skilled workers if parents invest on children' education. To capture the main spirit of the existence of a large informal sector in developing countries, we assume there are labor mobility constraints and institutional distortions in the labor market. The assumptions allow us to have both voluntary and nonvoluntary informal workers in the equilibrium.

Then, quantitative analyses are provided. Our strategy is that the theoretical framework is calibrated to be a benchmark economy. Based on the benchmark economy, we first discuss the feasible taxation and the impacts on the economy when population aging occurs in a developing country. The arrangement of taxation among consumption tax, labor income tax and capital income tax are particularly discussed in response to the conventional issues in the public finance and macroeconomic literature. Second, countries with lower TFR used to spend efforts on encouraging fertility. Therefore, using the aging economy as a baseline, two alternative population policies, encouraging fertility or education, are studied.

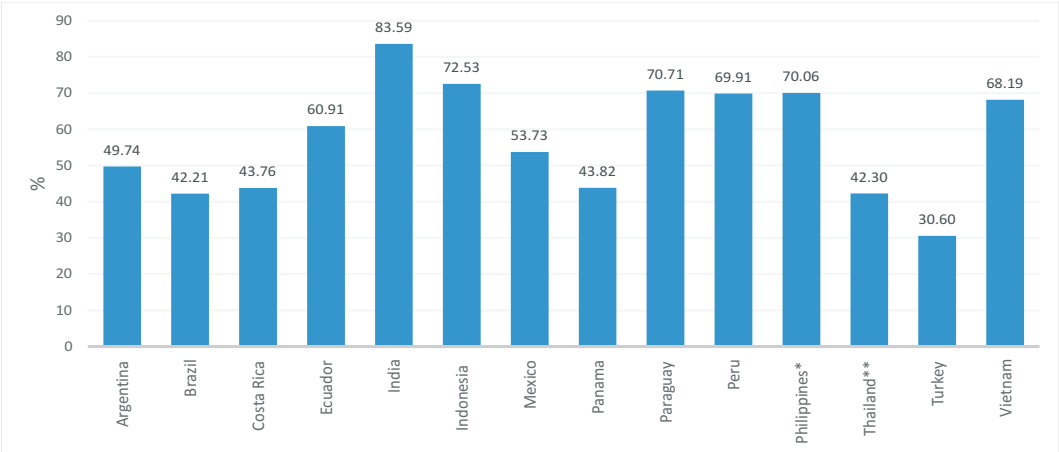
In the calibration, Thailand in the 2000s is selected as a representative because: (1) Compared with developed countries, Thailand has experienced a dramatic demographic

Figure 1: Total Fertility Rate 1960-2010



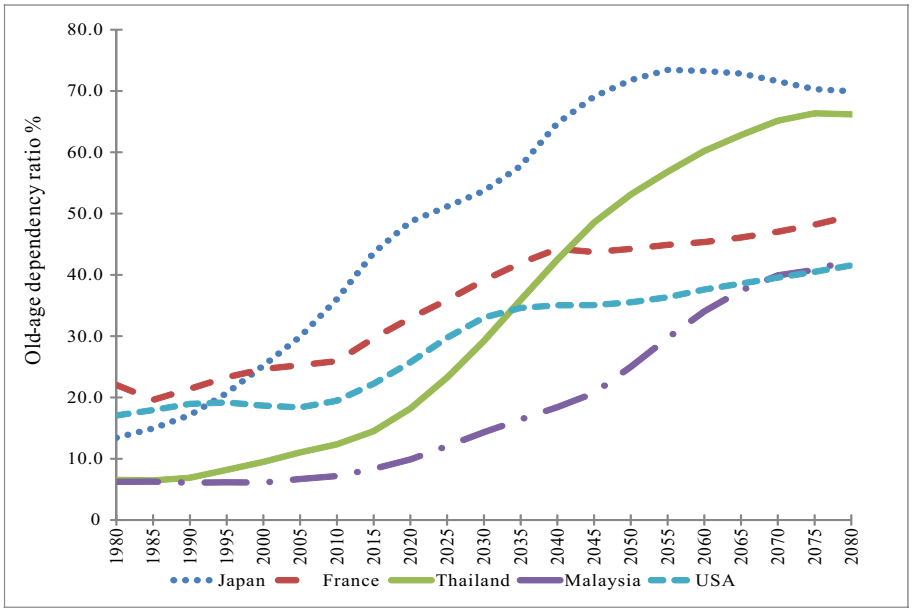
Source: WDI, World Bank.

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



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

Figure 3: Old-age Dependency Ratio

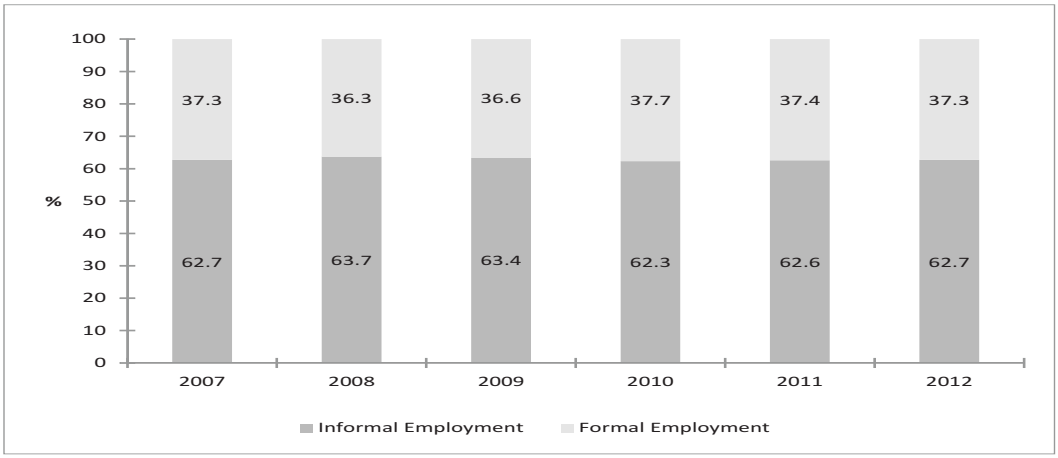


Source: United Nations.

transition. As Figure 3 shows, its old-age dependency ratio was below 10% in the 1980s but is expected to have a rapid increase to over 60% in the next few decades. The old-age dependency ratio is expected to increase to the level that is close to Japan, higher than France and the US. (2) The ratio of workers in the informal sector of Thailand is relatively large and stable. Figure 4 plots the ratios of informal employment in Thailand for 2007-2012. The share fluctuated between 62-64%. (3) Thailand has developed an universal health insurance system. This enable us to study the effects of increases in aggregate medical expenditure due to population aging on the economy.

Using the calibrated results as the benchmark economy, the impacts of population aging is explored. For the scenario of population aging, two effects are considered here. First, life expectancy increases from 74.1 in the benchmark economy to 80.1 as projected to Thailand of 2055. Besides, due to population aging, the ratio of total medical expenditure to GDP goes up from 5.5% of current Thailand to a forecasted value, 12%. The results suggest that in a developing economy with a large informal sector, like Thailand, only consumption tax is feasible when population aging occurs. This is because labor and capital can switch to the informal sector if the corresponding tax rate is high. In this scenario, the consumption

Figure 4: Ratio of Informal Employment (Thailand)



Source: TBA

tax rate has to increase from 12% to 20.5%.

In a scenario with a mild increase in the ratio of total medical expenditure to GDP (from 5.5% to 6.3%), all tax tools are available. In terms of welfare improvement, we find that consumption tax is the best tax tool in an aging economy. The literature discusses the redistribution effects of using consumption tax in replace of income taxes. In this paper, the redistribution effects exist between the young and the old generations when using consumption tax as a financing tool. This is preferred in an aging economy that has a high old-age dependency ratio.[2]

Based on the scenario with population aging and financing with consumption tax, population policies are explored. Because many countries with lower TFRs used to formulate a policy to encourage fertility, we first study the effects of a child-rearing subsidy on an aging economy. Although it indeed improves the old-age dependency ratio, the policy makes everyone worse off. This is because the policy distorts the relative price between skilled and unskilled children; thereby discouraging education investment. The accumulation of physical capital is also crowded out by the higher fertility. Therefore, the formal sector becomes smaller. The policy eventually does not help to alleviate the tax burden caused by population aging.

Alternatively, a policy on subsidizing children's education improves the level of human

[2]Correia (2010) shows that consumption tax also has a preferred redistribution effect over income groups.

capital stock. Because skilled workers tend to work in the formal sector, the policy also enlarges the formal sector. This helps to alleviate the tax burden and results in a welfare improvement. In terms of tax rate and welfare improvement, the policy experiment suggests that a 26% subsidy on children's education cost is the optimal.

Is population aging a problem in developing countries? We find that individuals will save more in response to a longer life. This leads to the accumulation of physical capital. Besides, a longer life makes education investment more attractive. Human capital is also accumulated. Using consumption tax as the financing tool, increases in physical and human capital enlarge the formal sector. This also help to release the tax burden. Furthermore, if appropriate population policies are implemented, such as education subsidy, a lower tax rate with welfare improvement is possible. Therefore, the population aging in developing countries might not be so pessimistic.

The theoretical framework in this paper builds on the strand of the literature that studies quantity-quality tradeoff of children, demographic change and economic growth. It is pioneered by Becker (1960) that introduces endogenous fertility to the theoretical model. Following up studies link fertility, demographic change and economic growth based on the mechanism of quantity-quality tradeoff, such as Becker, Murphy and Tamura (1990), Galor and Weil (1996), 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. In contrast, our paper focuses on developing countries that are in a later stage of development with a low fertility. We extend the models in Doepke (2004) and Liao (2011) to incorporate the informal sector and fiscal policies on taxation arrangement.

Regarding to population policies, Lee et al. (2014) is a study close to this paper. Given current population structures and fiscal conditions, they use a static model to investigate optimal fertility rates in 40 economies. They find that to improve living standards and fiscal burdens, the fertility rates can be lower in some countries even though their current fertility rates are already below the replacement rate, such as Brazil and Thailand. They assume that fertility is exogenously determined. Our paper develops a richer framework that allowing endogenous fertility choice and taking demographic dynamics into account. Therefore, our framework enable us to assess alternative population policies and examine the effects on fertility, human capital accumulation, long-run economic performance and welfare changes.

This paper also sheds light on understanding the implication of informal employment on optimal taxation and fiscal polices. However, most studies target developed countries.

Only a few studies in the literature consider informal employment. For example, Penalosaa and Turnovsky (2005) study optimal taxation on labor and capital incomes in a standard growth model with the existence of the informal sector. Jung and Tran (2012) discuss the potential effects of the extension of social security to informal workers in developing countries to reduce the poverty problem for the elderly. As a complement to the literature with informal employment, we further explore the implications of aging and population policies in developing countries by allowing endogenous fertility and education choices.

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 calibration for the current Thailand. In Section 4, we provides quantitative analysis and 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 about children. They make decisions on the number of children, education investment on children, their own labor supply and savings. Old adults are assumed to be retired. They consume their own savings and pay medical expenditures. Human capital is modeled in a discrete way that children will become skilled labor if parents invest on education; otherwise, children will be unskilled labor. Labor and capital allocations between formal and informal sectors are recognized. Capital is freely mobile between the two sectors. In the labor market of developing countries, there exists a large wage gap between the two sectors and the informal employment share is relatively large. Thus, we consider frictions on the labor market to prevent completely free movement between formal and informal sectors. In the equilibrium, both voluntary and non-voluntary informal employments exist.

2.1 Features of the Labor Market in Developing Countries

To model the labor market in developing countries with a large informal sector, we take Thailand as an example. Skilled workers are defined as those whose education level is high school or above (schooling years >12). The main features of Thailand's labor employment

are summarized as follows.[3]

1. About 70% of skilled workers are working in the formal sector, while more than 70% of unskilled workers are in the informal sector.

2. Skilled workers usually stay in the informal sector less than one year. The panel data of Household Social-Economic Survey (HSES) indicates that, for those skilled workers who are currently working in the informal sector, only about 10% of them will stay in the informal sector after one year. In contrast, the probability of unskilled workers to stay in the informal sector after one year is higher than 70%.[4] The fact suggests that, for skilled workers, having an job in informal sector is more like a temporary arrangement. They tend to switch back to formal sectors quickly.

3. When a skilled worker switches to the informal sector, his wage from the informal sector is very likely to be lower (with a probability of 90% to have a wage 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 (about 1.4). The wage gap between formal and informal sectors also exists. For unskilled workers, the wage gap between the two sectors is about 1.7.

Based on the facts observed above, we construct labor market frictions and distortions in our model in order to capture the skill premiums and wage gaps between formal and informal sectors.

2.2 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. Denote n to be the average fertility per young adult. N^c is then given by:

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

[3] Data are from Household Social-Economic Survey (HSES), Thai National Statistics Office.

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

By assumption, all children can survive to the young adulthood for sure. Thus, the population of young adult next period is $N^{y\prime} = N^c$. Furthermore, we assume that young adults survive to the old adulthood with the probability π^y. Therefore, the old population next period becomes $N^{o\prime} = \pi^y N^y$.

2.3 Education Investment and Human Capital Accumulation

In the framework, human capital is assumed to be discrete: skilled (s) and unskilled (u). Parents make decisions on children education level. Education investment costs e. If parents decide to do investment on children's education on top of the fundamental level, their children will become skilled workers. In contrast, children who do not receive higher education will become unskilled workers in the young adulthood. N_s^y is employed to denote the population of skilled young adults and N_u^y is the population of unskilled young adults. The population identity implies that $N^y = N_s^y + N_u^y$. According to the setting, human capital accumulation is represented by the increase in the proportion of skilled young adults to total young adults (N_s^y/N^y).

2.4 Government

The government taxes on consumption, labor income and capital income with the rate τ_C, τ_L and τ_K, respectively. The total tax revenue is the sum of consumption tax T_C, labor income tax T_L and capital income tax T_K. By assumption, the government cannot monitor the labor income and the capital income in the informal sector. Thus, tax revenues of labor income and capital income are only collected from the formal sector.

The government runs a public medical care program for all old adults as a social welfare system. It covers a fraction ω of total medical expenditure M. Then, the public medical expenditure M_g is given by:

$$M_g = \omega M.$$

The government is required to maintain a balanced budget in each period. The budget constraint for the government is given by:

$$M_g + G = T_C + T_L + T_K, \tag{1}$$

where G is other government expenditures.

2.5 Production and Labor Market

There exists one final goods but two production sectors: formal and informal sectors. We use superscript f to denote variables in the formal sector and superscript x for the informal sector. In both sectors, there are perfectly competitive firms using physical capital (K), skilled workers (L_s) and unskilled workers (L_u) as inputs to produce the final goods. The two sectors employ a standard constant return to scale production technology. The production functions are summarized as follows:

$$Y^f = A^f (K^f)^{\alpha_1} (L_s^f)^{\alpha_2} (L_u^f)^{\alpha_3}; \tag{2}$$

$$Y^x = A^x (K^x)^{\gamma_1} (\eta L_s^x + L_u^x)^{\gamma_2}, \tag{3}$$

where Y^f and Y^x are output in the formal and informal sector, 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. γ_1 and γ_2 are income shares of physical capital and total labor in the informal sector. The total output Y of the economy is then given by:

$$Y = Y^f + Y^x. \tag{4}$$

According to the features of labor market described in Section 2.1, the wage of skilled workers in the informal sector tends to be lower. For skilled workers, having a job in the informal sector is more like a temporary arrangement. Therefore, we assume skilled and unskilled workers are substitutable in the informal sector. The labor efficiency η is included to capture the existence of skill premium in the informal sector.

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

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

$$w_u^f = \alpha_3 A^f (K^f)^{\alpha_1} (L_s^f)^{\alpha_2} (L_u^f)^{\alpha_3 - 1}; \tag{6}$$

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

$$w_u^x = \gamma_2 A^x (K^x)^{\gamma_1} (\eta L_s^x + L_u^x)^{\gamma_2 - 1}. \tag{8}$$

However, as we describe in Section 2.1, there exists a wage gap between formal and informal sectors. It could be due to the institutional distortions on the labor market. For example, the minimum wage regulation and the requirement on employer-sponsored insurance coverage for employee in the formal sector. To capture the main spirit, we assume there are distortions on wage in the labor market and the distortions mainly affect unskilled workers.

Therefore, the wage gap of unskilled workers is created by the distortion X_u such that the wage gap of unskilled workers between formal and informal sectors is given by:

$$\frac{(1-\tau_L)w_u^f}{w_u^x} = X_u. \tag{9}$$

2.6 Individual's Problem

A young adult with skill level $i = \{s,u\}$ cares about his current consumption c_i^y, his consumption at old age $c_i^{o\prime}$ and how his children will be in the next period. Therefore, a young adult allocates his disposable income on his current consumption, asset holdings in formal and informal sectors ($a_i^{f\prime}$ and $a_i^{x\prime}$) and total education investment on his children.

Each young adult is assumed to be endowed with one unit of time. Raising a child costs a fraction ϕ of a young adult's time. Then, he can supply the rest of time to the labor market. Assume that he allocates the fraction θ_i of his rest time to the formal sector. The time he works in the informal sector is $1-\theta_i$ of his rest time. Therefore, a young adult's income consists of labor income from both sectors.

When a young adult survives to the old adulthood, he consumes his own savings and capital income from both sectors. At old age, he has to pay the proportion of medical expenditure m' that is not covered by public medical care program.

To summarize, a young adult chooses current consumption, savings, the number of children n_{ij}, education investment and the proportion of labor supply in the formal sector to maximize his lifetime utility. j represents children's skill level, $j = \{s,u\}$. The maximization problem can be expressed as follows:

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

subject to

$$(1+\tau_C)c_i^y + \pi^y(a_i^{f\prime} + a_i^{x\prime}) + e_i n_{ij} = (1-\phi n_{ij})[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x]; \tag{11}$$

$$(1+\tau_C)c_i^{o\prime} = [1+(1-\tau_K)r^{f\prime}]a_i^{f\prime} + [1+r^{x\prime}]a_i^{x\prime} - (1-\omega)m'; \tag{12}$$

$$j = s, \text{ if } e_i = \bar{e};\ j = u, \text{ if } e_i = 0;$$

$$0 \le \theta_i \le \bar{\theta_i};$$

where $r^{f\prime}$ and $r^{x\prime}$ are capital returns in the formal and the informal sectors, respectively. We assume there is a perfect annuity market in each sector. A young adult, who holds $\pi^y a_i^{f\prime}$ annuity (as savings) in the formal sector, will receive $(1+(1-\tau_K)r^{f\prime})a_i^{f\prime}$ next period if he survives. Similarly, the asset holdings $\pi^y a_i^{x\prime}$ in the informal sector will deliver a payment of

$(1+r^{x\prime})a_i^{x\prime}$ next period if he survives. Furthermore, education cost is discrete, $e_i = \{0, \bar{e}\}$. If parents pay the cost $\bar{e}$, the child will become skilled worker next period. Finally, to capture the features of non-voluntary informal workers, we assume there exists a labor mobility constraint $\bar{\theta_i}$ to represent the employment capacity of sector i. When the labor mobility constraint is not binding, a young adult can freely allocate his working time between formal and informal sectors. Otherwise, he will be forced to work as a non-voluntary worker in one sector.

2.7 Equilibrium Features

2.7.1 Individual Optimal Decision Rules

- Savings ($a_i^{f\prime}$ and $a_i^{x\prime}$):
  Asset holdings can be used in both formal and informal sectors. Intuitively, an individual will hold the asset that gains a higher rate of return. The optimal asset holdings are determined by the following equations:

$$u_{c_i^y} = \beta(1+(1-\tau_K)r^{f\prime})u_{c_i^{o\prime}}, \qquad \text{if } (1-\tau_K)r^{f\prime} \geq r^{x\prime}; \tag{13}$$

$$u_{c_i^y} = \beta(1+r^{x\prime})u_{c_i^{o\prime}}, \qquad \text{if } r^{x\prime} \geq (1-\tau_K)r^{f\prime}; \tag{14}$$

  where $u_{c_i^y}$ and $u_{c_i^{o\prime}}$ are marginal utility of consumption at young adulthood and at old adulthood, respectively. Because there is no distortions and mobility constraints in the capital market, in equilibrium after-tax capital gains from the two sectors must be the same, $(1-\tau_K)r^{f\prime} = r^{x\prime}$. Thus, an individual is indifferent between the two assets. To be simple, we use r to denote the after-tax rate of return in equilibrium:

$$r = (1-\tau_K)r^f = r^x. \tag{15}$$

- Labor allocation (θ_i):
  Intuitively, an individual will supply labor to a sector with a higher return. The marginal return of one additional labor supply in the informal sector is w_i^x. The after-tax marginal return of labor is $(1-\tau_L)w_i^f$ in the formal sector. Therefore, in equilibrium, $(1-\tau_L)w_i^f = w_i^x$ and $0 < \theta < 1$ if there is no mobility constraint or the constraint is not binding in the labor market. If the constraint is binding, $\theta_i = \bar{\theta_i}$.

  As we observed in the data, when a skilled worker works in the informal sector, his wage is very likely to be lower. This implies that the mobility constraint on skilled workers must be binding. Otherwise, in equilibrium, $(1-\tau_L)w_s^f = w_s^x$, which

contradicts to the data feature. Therefore, in the quantitative analysis that we provide in this paper, we require the mobility constraint on skilled workers is binding, $\theta_s = \bar{\theta_s}$. Besides, there are distortions $X_u > 1$ on the unskilled labor market such that the wage gap between formal and informal sector for unskilled workers exists in equilibrium, as shown in equation (9).

- Fertility (n_{ij}):
  The first order condition with respect to n_{ij} implies the following equation:

$$\psi(1-\varepsilon)(n_{ij})^{-\varepsilon}V_j' = (\frac{u_{c^y}}{1+\tau_C})\{\phi[\theta_i(1-\tau_L)w_i^f + (1-\theta_i)w_i^x] + e_i\}. \quad (16)$$

  The left-hand side of equation (16) is the marginal benefit of having an additional child. On the right-hand side is the marginal cost of having an additional child. A young adult chooses the number of children until the marginal benefit is equal to the marginal cost.

- Education investment on children (e_i):
  In one family, children are indifferent except education investment. Thus, children in the same family should be all skilled or all unskilled. Skilled and unskilled children will not live in the same family. Besides, in our quantitative analysis, we focus on an equilibrium that both skilled and unskilled workers exist in the economy. It can be shown that the only feasible equilibrium is that skilled parents always invest on children's education, while some unskilled parents make education investment and others do not. Thus, in equilibrium, only unskilled parents are indifferent between investing and not investing on children's education. It is impossible for both types of parents to satisfy the indifference condition. The details are provided in Appendix A.

2.7.2 Markets Clearing Conditions

- Market clearing condition for skilled workers:
  The mobility constraint on skilled workers is binding. Thus, the proportion of skilled workers working in the formal sector is given by:

$$\frac{L_s^f}{L_s} = \bar{\theta_s}. \quad (17)$$

- Market clearing condition for unskilled workers:
  By assumption, there exists a distortion X_u on the unskilled labor market to create the wage gap between formal and informal sectors. Substituting marginal products of

labor to the definition of distortion in equation (9) and using the facts that $L_s^f = \bar{\theta}_s L_s$, $L_s^x = (1-\bar{\theta}_s)L_s$, $L_u^f = \theta_u L_u$ and $L_u^x = (1-\theta_u)L_u$, the proportion of unskilled workers working in the formal sector is then given by:

$$\theta_u = \frac{\eta(1-\bar{\theta}_s)l_s + l_u}{(1+B)l_u}, \tag{18}$$

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 $l_u = \frac{L_u}{N^y}$.

- Market clearing condition for physical capital:
  Because there is no mobility constraint on capital market, capital market clearing implies a no-arbitrage condition: $(1-\tau_K)r^f = r^x$. Therefore, the optimal capital allocation between the two sectors is given by:

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

3 Calibration and the Benchmark Economy

As mentioned in the introduction, Thailand has a relatively low fertility but a large share of informal employment. Therefore, Thailand is selected as a representative economy for our quantitative analysis. The model described in Section 2 is calibrated to match data from Thailand during 2000-2012. Then the calibrated economy is used as a benchmark economy. Based on the benchmark economy, quantitative analysis and policy experiments are performed in the next section.

3.1 Parameters

The model economy is calibrated as a steady state. The model period is 30 years. Table 2 summarizes the parameters for calibration. According to the estimate in World Development Indicators (WDI), the life expectancy at birth for Thailand during 2010-2012 is 74.1. In our model, children survive to the young adulthood for sure. Therefore, the survival rate for young adults π^y is 0.47 such that the life expectancy at birth is matched. Medical expenditure per old adult m is set at 0.0767 to match the ratio of total medical expenditure to output 5.5%, which is reported by WDI for Thailand during 2007-2010.

There are four preference parameters: β, σ, ε and ψ. The annual discount factor is 0.951 to match capital-output ratio 1.9 in 2012. ψ is set to be 0.227 so that the total fertility rate 1.54 is matched. σ and ε are jointly calibrated. They are discussed later.

There are two costs associated with children: child-rearing time cost ϕ and education cost ϕ_s. In the calibration, 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 about 1.156 million Thai baht in 2004. To be consistent with our model, we use 0.867 million baht ($1.156 \times 18/24$) to represent the cost until graduation from high school. It is about 24.3% of the average earnings (30 years) in 2004. Therefore, ϕ is set at 0.243. ϕ_s is chosen to be 0.089 to match the ratio of skilled workers to total workers 17% (average of 2010-12).

The government collects three taxes: τ_C, τ_K and τ_L. They are set so as to match the ratios of total revenues collected from consumption tax to GDP, capital income tax to GDP and labor income tax to GDP are 9%, 4% and 2%, respectively. Here, consumption tax refers to VAT, duties and sales taxes; capital income tax is cooperate tax; labor income tax is individual income tax. Thus, $\tau_C = 12.1\%$, $\tau_K = 11.4\%$ and $\tau_L = 10.9\%$. The government runs a public medical care program for all old adults as a social welfare system. It covers the fraction ω of total medical expenditure. According to the report of WDI, the average ratio of public health expenditure to total health expenditure is about 85% in Thailand during 2007-2010. Thus, we set $\omega = 85\%$.

There are two parameters for distortions and capacity constraint in the labor market. The distortions on unskilled labor market X_u is chosen to be 1.514 in order to match the wage gap of unskilled workers between the formal and informal sectors $w_u^f/w_u^x = 1.7$. The capacity constraint on skilled workers $\bar{\theta_s}$ is 0.7 from data.

The rest parameters in the production side are two TFP (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 in the informal sector (η). The TFP in the formal sector is normalized to be 10. Then, the TFP in the informal sector is set at 4.283 such that the relative output ratio (Y^x/Y^f) is 0.52. The income share of physical capital in the formal sector α_1 is set at 0.67. With the skill premium and the ratio of skilled workers in the formal sector, we can compute α_3. We know that the skill premium in the formal sector is 2.4. Furthermore, the ratio of skilled workers to total workers (L_s/L) is 17%. We believe that the fraction of skilled workers in the formal sector, $L_s^f/(L_s^f + L_u^f)$, should be higher than that in the informal sector. If the fraction is 0.2, the income share of unskilled labor in the formal sector should be equal to 0.20. If the fraction is 0.25, α_3 is 0.183. If the fraction is 0.3, α_3 is 0.1627. Here we set $\alpha_3 = 0.182$ to obtain a better calibrated results. Therefore, $\alpha_2 = 0.148$. The labor efficiency in the informal sector η is set at 1.4 to match $w_s^x/w_u^x = 1.4$. The last

two parameters are γ_1 and γ_2 in the informal sector. In the calibration, γ_1, σ and ε are jointly calibrated to match the ratio of skilled parents' TFR to unskilled parents' TFR 0.5, the proportion of unskilled workers working in the formal sector $L_u^f/L_u = 0.3$ and the skill premium in the formal sector $w_s^f/w_u^f = 2.4$. Thus, $\gamma_1 = 0.616$, $\sigma = 0.525$ and $\varepsilon = 0.51$. Finally, γ_2 is 0.384. All targets and data moments are summarized in Table 3.[5]

3.2 Benchmark Economy

The benchmark economy is calibrated to the data from Thailand during 2000-2012. Table 4 provides the macroeconomic features of the benchmark economy. In the benchmark economy, the total fertility rate is mainly contributed by unskilled parents with unskilled children. Other parents prefer less than one child. In addition, the relative TFR implies that the number of children that skilled parents want is only a half of the amount that unskilled parents choose.

On the production side, the output from the informal sector is about a half of that produced in the formal sector. Besides, about 63.2% of workers work in the informal sector, while only 36.8% of workers in the formal sector. The result is close to the ratio of the informal employment presented in Figure 4. Our benchmark economy captures the main features that there exists a large informal sector in developing countries. Furthermore, the level of human capital accumulation, the fraction of skilled workers as a percentage of total workers, is 17% in the benchmark economy. Since we assume that the labor mobility constraint on skilled workers is binding, only 70% of skilled workers work in the formal sector.

Compared with unskilled workers, the wage gap between the formal and informal sectors for skilled workers is relatively large, about 2.91. The wage gap for unskilled workers is 1.70. This captures the feature in the data that skilled workers tend to obtain a lower wage when they work in the informal sector. In addition, the skill premium in the formal sector (2.396) is also larger than that in the informal sector (1.400). These results imply that skilled workers working in the informal sector more like to be non-voluntary. Once they have a chance, skilled workers will switch back to the formal sector.

Other government expenditure is solved so that the government maintains balanced budget every period. In the benchmark economy, the ratio of other government expenditure to output is about 10.3%. In the next section, we will keep this ratio and assume it is unchanged when the experiments are solved. Finally, based on WDI data, the ratio of total medical expenditure to output is 5.5%. The public medical care program for old adults

[5]Data sources will be added later.

Table 2: 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	computed from data
$\bar{\theta}_u$	0.700	preset
A^f	10	normalization
A^x	4.283	match $Y^x/Y^f = 0.52$
α_1	0.670	computed from data
α_2	0.148	computed by $1-\alpha_1-\alpha_3$
α_3	0.182	computed from data
γ_1	0.616	jointly calibrated
γ_2	0.384	computed by $1-\gamma_1$
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	computed 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%	computed from data

Table 3: 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
Relative TFR (skilled/unskilled)	0.500	0.5
Capital-output ratio (K/Y)	1.900	1.9
Relative output (Y^x/Y^f)	0.520	0.52
Share of unskilled in the formal sector $(\theta_u = L_u^f/L_u)$	0.300	0.3
Share of skilled labor to total labor (L_s/L)	0.170	0.17
Skill premium in the formal sector (w_s^f/w_u^f)	2.396	2.4
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 to output (T_C/Y)	0.090	0.09
Ratio of capital tax to output (T_K/Y)	0.040	0.04
Ratio of labor tax to output (T_L/Y)	0.020	0.02

covers 85% of total medical expenditure. Thus, the ratio of public medical expenditure to output is roughly equal to 4.7%.

Table 4: Calibrated Results for the Benchmark Economy

Description	Notation	Value
Life Expectancy and fertility		
Life expectancy		74.1*
Fertility of type *ss*	n_{ss}	0.834
Fertility of type *us*	n_{us}	0.804
Fertility of type *uu*	n_{uu}	1.832
Average (weighted) TFR		1.540*
Relative TFR (skilled/unskilled)		0.500*
Production		
Capital-output ratio	K/Y	1.900*
Relative output	Y^x/Y^f	0.520*
Allocation of workers		
Share of workers in the formal sector	$(L_s^f + L_u^f)/L$	0.368
Share of skilled workers in the formal sector	L_s^f/L_s	0.700**
Share of unskilled workers in the formal sector	L_u^f/L_u	0.300*
Share of skilled workers to total workers	L_s/L	0.170*
Relative wages		
Wage gap for skilled workers	w_s^f/w_s^x	2.910
Wage gap for unskilled workers	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 to output	T_C/Y	0.090*
Ratio of capital tax to output	T_K/Y	0.040*
Ratio of labor tax to output	T_L/Y	0.020*
Ratio of other Gov't exp to output	G/Y	0.103
Medical expenditure		
Ratio of public medical exp to output	M_g/Y	0.047
Ratio of total medical exp to output	M/Y	0.055*

Note: "*" represents the moment is our calibration target. "**" denotes the moment is preset.

4 Policy Experiments

Based on the benchmark economy, we start with the scenario of population aging. Three financial tools, consumption tax, capital income tax and labor income tax, are considered to finance the increase in medical expenditure due to population aging. Then, based on the results of population aging, two population policies are discussed: a subsidy on child-rearing cost and a subsidy on education cost.

4.1 Impacts of Population Aging and Feasible Taxation Arrangement

To study the impacts of aging, we mainly consider changing two parameters together in the benchmark economy: increases in life expectancy and the ratio of total medical expenditure to GDP (M/Y). Other parameters remain unchanged. Two scenarios are discussed. First, the life expectancy increases from 74.1 to 80.1, as forecasted by WDI in 2055 and the ratio of total medical expenditure to GDP mildly increases from 5.5% to 6.3%.[6] Second, the life expectancy goes up to 80.1 with a rapid increase in the ratio of total medical expenditures to GDP, from 5.5% to a forecasted value 12%. Figure 5 plots the ratio of total medical expenditure to GDP in Thailand during 1995-2014. Based on the time series data, the ratio is forecasted by a simple linear regression. Then the forecasted value is 12%.[7]

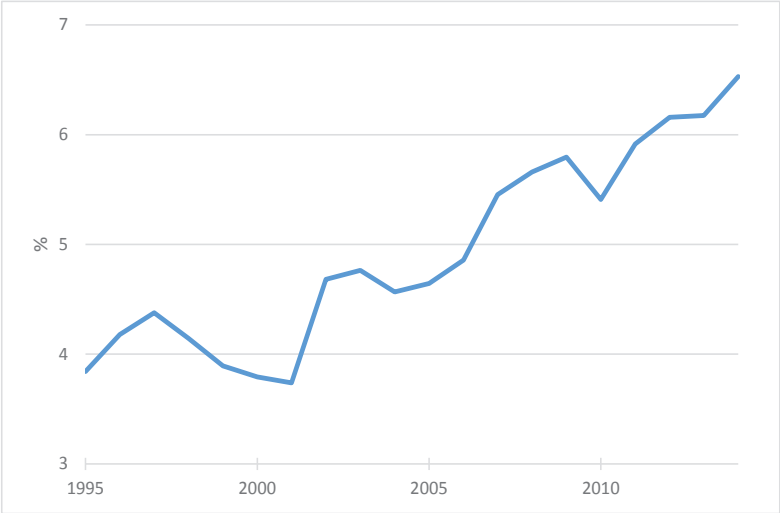
Each scenario is solved as a new steady state. Using the ratio of other government expenditure to output in the benchmark economy, we first use labor income tax as the financing tool to ensure balanced budget in the aging economy. Alternative tax tools, capital income tax and consumption tax, are also investigated for comparison.

Table 5 provides the simulated results for the first scenario: the life expectancy goes up to 80.1 and the M/Y ratio increases to 6.3%. The main effects of population aging are summarized as follows. First, population aging implies that people live longer and face higher medical expenditure. Therefore, individuals require more savings for their retirement life. As a result, the capital-output ratio goes up from 1.9 in the benchmark economy to around 2.2 in all cases. Second, increased savings crowd out children. The average TFR

[6] When the life expectancy reached 80 in Japan of 1995, the ratio of total medical expenditure to GDP was 6.9%. However, if we consider 6.9% for the experiments, there is no equilibrium because the tax rate cannot sustain (financed by labor income tax and capital income tax). Therefore, we consider 6.3% in the first scenario.

[7] Thailand implemented an universal health insurance (UHI) system in 2001. When the UHI system is implemented, the pattern of medical expenditure could be different. To consider this, we also use the data during 2002-2014 to forecast the ratio. The forecasted ratio of total medical expenditure to GDP becomes 13%. Since the average life expectancy of OECD countries was 80 and the average M/Y ratio in OECD countries was 12.3% in 2014, we choose 12% to be the second scenario.

Figure 5: Ratio of Medical Expenditure to GDP in Thailand



Source: The Thai National Statistical office

declines from 1.54 to around 1.47-1.50. Third, longer life and the higher requirement of savings make the education investment in children more 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 18.4%-20.1%. 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 slightly increase (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 would indirectly decrease the wage rates in the formal sector because of changes in capital-labor ratio. Financing by consumption tax results in a highest level of human capital stock since it does not distort the labor allocation between the two sectors. 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 42.5% under the labor tax financing scheme. It goes up to around 48.5% under the consumption tax financing scheme. Finally, the capacity of the formal sector increases, so the informal sector shrinks. The output ratio between informal and formal sectors becomes smaller, from 52% in the benchmark to 31% when using consumption tax as the financing tool.

Table 5 also provides changes in welfare, measured by consumption equivalent variation (CEV). Compared with the case that financing by labor income tax, using the other two tax tools are both better off. This is because labor income tax is only collected from young adults who are working in the formal sector. This also distort on labor allocation. In 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 smaller. Thus, welfare is slight improved. Since consumption tax is collected from all adults and there is no distortion on the labor market, the welfare improvement is the largest one.

Although we start with scenario 1, it is not likely to be the situation that Thailand will face in 2055 because Thailand's total medical expenditure to GDP ratio has gone up rapidly and reached over 6% since 2012. Scenario 2 is exactly what happened in OECD countries and will be more likely to occur in Thailand. Because the ratio of total medical expenditure to GDP goes up a lot, a significant increase in tax revenue is required in this scenario. Table 6 summarizes the results. Unfortunately, both labor income tax and capital income tax fail to sustain an equilibrium. Because labor and capital may switch to the informal sector to avoid high taxes, the marginal tax revenue by increasing one unit of tax rate will be negative when it reaches some critical point. As a result, no equilibrium is found. In scenario 2, consumption tax is the only feasible financing tool. It increase from 12% in the benchmark economy to 20.5%. Other impacts of population aging on the economy in scenario 2 are similar to that in scenario 1.

4.2 Population Policies – Improving Labor Quantity or Quality?

Based on the second scenario that using the consumption tax as the financing tool, we further explore if additional population policies are able to improve the welfare in an aging society. Two population policies are considered. First, we aim at an increase in TFR to represent an improvement on population quantity. Alternatives, education subsidy is discussed to provide an experiment on improving the quality of population.

4.2.1 Improving Labor Quantity

We first study a subsidy on the child-rearing cost to encourage fertility. The results are presented in Table 7. The baseline is the scenario with population aging and using consumption tax as a financing tool, which is reported in Table 6. In the baseline, life expectancy is 80.1 and the ratio of total medical expenditure to GDP is 12%. The TFR in the baseline is 1.54. Based on the baseline, we conduct experiments with the assumption that the TFR increases

Table 5: 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%

Table 6: Financing Population Aging: Scenario 2

		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

to a higher level, from 1.6 to 2.5. The government provides subsidies on child-rearing cost to encourage fertility to the target level. Others remain unchanged and are fixed at the baseline level.

The results suggest that the encouragement to TFR with an subsidy on child-rearing cost indeed increases the amount of labor force and improves the age structure. The old-age dependency ratio sharply declines as the TFR goes up. However, the policy lows the level of human capital stock in the economy. It is because, first, the subsidy on child-rearing cost makes education investment relatively more expensive. Second, an subsidy on child-rearing cost mainly encourages the fertility of unskilled parents having unskilled children. Therefore, the share of skilled workers to total workers declines from 20.3% to 13.2%. Furthermore, the increase in fertility also crowds out the accumulation of physical capital. The capital-output ratio declines from 2.256 to 1.846 as TFR increases. The share of workers working in the informal sector goes up accordingly. Therefore, the relative output (informal to formal) increases to 78%.

In a summary, under the policy of aiming at TFR, although the amount of labor force and age structure are improved, the policy eventually hurts the economy. Because the subsidy requires more tax revenue, the government has to raise the consumption tax to a higher level. Then education and physical investment are both crowded out. The formal sector is shrinking and the government collects fewer tax revenues from the formal sector. Thus, the policy does not help to alleviate the tax burden caused by population aging. Everyone in the economy is worse off with the implementation of the policy.

4.2.2 Improving Labor Quality

The alternative policy is the government provides subsidies on education cost of children. Based on the baseline, experiments with 10% to 30% subsidy of education cost are conducted. Others are fixed at the baseline level. The results are summarized in Table 8.

In contrast to the subsidy on child-rearing cost, the subsidy on education cost does not improve the age structure of the economy. The old-age dependency ratio increases as the subsidy on education cost increases. However, due to the educational subsidy, education investment becomes relatively cheaper. More unskilled parents start to invest education on their children. Therefore, the share of skilled workers to total workers goes up from 20.3% in the baseline to 30.2% in the experiment with 30% subsidy. Furthermore, parents adjust the number of children they want in response to the educational subsidy (quantity-quality trade-off), so the crowding out effect on physical capital is not large. Capital-output ratio slightly declines from 2.256 to 2.226. With more physical capital and skilled workers, the

Table 7: Improving Labor Quantity (TFR) – Subsidy on Child-rearing Cost

	Baseline	Policy of child-rearing subsidy			
TFR	1.5	1.6	1.9	2.1	2.5
Old-age dependency 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-worker share	20.3%	18.5%	16.6%	14.8%	13.2%
Formal-worker 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%
Δ welfare (skilled, CEV_s)	–	-15.1%	-28.9%	-41.5%	-53.0%
Δ welfare (unskilled, CEV_u)	–	-13.5%	-25.9%	-37.5%	-48.4%
Δ welfare (average, CEV)	–	-13.8%	-26.5%	-38.3%	-49.3%

Table 8: Improving Labor Quality – Subsidy on Education Cost

	Baseline	Policy of education subsidy				
Subsidy	0%	10%	20%	25%	26%	30%
Old-age dependency ratio	92.33%	94.24%	96.21%	97.19%	97.29%	97.46%
Consumption tax	20.55%	17.76%	15.09%	13.82%	13.76%	14.00%
Capital-output ratio	2.256	2.249	2.241	2.237	2.236	2.226
Skilled-worker share	20.32%	23.29%	26.76%	28.72%	29.05%	30.22%
Formal-worker share	49.42%	56.56%	64.93%	69.64%	70.00%	70.00%
Y_x/Y_f ratio	29.92%	22.81%	16.46%	13.56%	13.34%	13.31%
Δ welfare (skilled, CEV_s)	–	2.09%	4.23%	5.28%	4.79%	1.17%
Δ welfare (unskilled, CEV_u)	–	5.69%	12.55%	16.51%	16.68%	15.78%
Δ welfare (average, CEV)	–	5.02%	11.00%	14.43%	14.48%	13.07%

Figure 6: Tax Burden and Policy of Education Subsidy

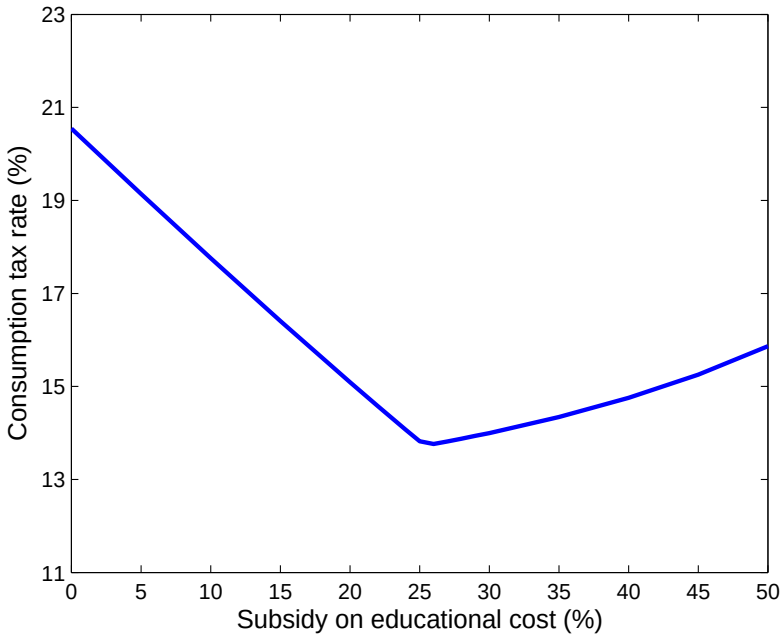
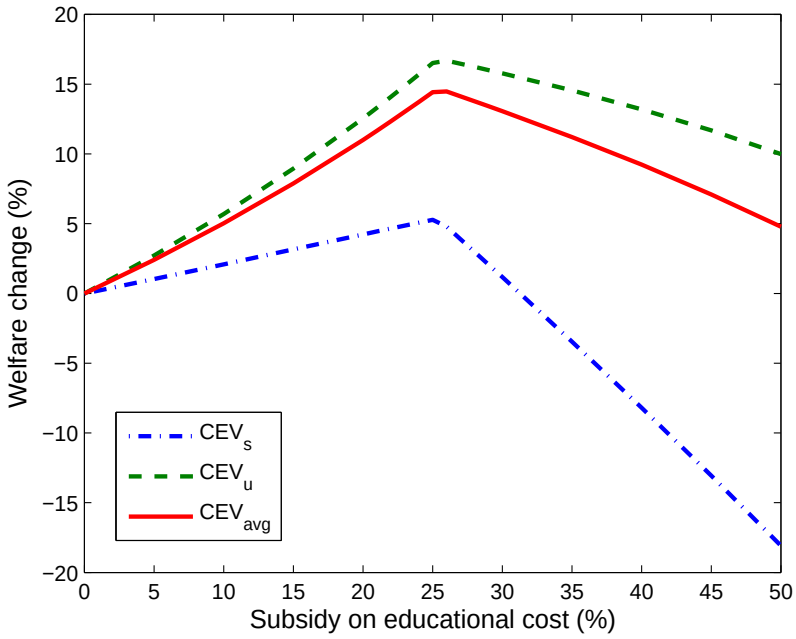


Figure 7: Welfare Changes and Policy of Education Subsidy



labor employment in the formal sector goes up, from 49.4% to 70%.[8] The relative output (informal to formal) is getting lower.

Because of the subsidy on education cost, the scale of the formal sector becomes larger. It becomes easier for the government to collect tax revenues from the formal sector. Therefore, even in the experiment with the subsidy of 30%, the consumption tax rate (14%) is still lower than the baseline (20.6%). To conclude, we find that the policy of education subsidy can help to alleviate the tax burden caused by population aging.

The subsidy itself requires an additional tax revenue to be collected. We find that there exists a critical level. Beyond the critical level, it might not be worth to provide a higher level of subsidy. Figure 6 shows a V-shape relationship between level of education subsidy and the consumption tax rate. The lowest tax rate is about 13.8% with an education subsidy of 26%. Beyond the level of 26% subsidy, the consumption tax rate goes up again. In terms of welfare changes, Figure 7 presents the relationships between the level of education subsidy and welfare changes for skilled workers (CEV_s), unskilled workers (CEV_u) and the whole economy (social average, CEV_{avg}). The figure suggests that the welfare improvement of the social average is the largest at the 26% subsidy. The trade off determines that the optimal subsidy on education could be at the 26% subsidy in our experiments.

5 Conclusion

This paper explores the feasible taxation arrangement and population policies in a developing economy with a trend of population aging. The facts of low fertility and rapid population aging in many middle income developing economies are taken into consideration. Furthermore, a distinct feature in developing economies is included: the existence of a large informal sector. A three-period overlapping generations model is constructed to capture the above features.

The quantitative analysis suggests that labor income tax and capital income tax are not feasible to finance the extra cost caused by population aging in developing countries in the future. This is mainly because of the existence of the large informal sector. Factor inputs may switch from the formal to the informal sector if tax burden is high. Consumption tax is the only feasible financing tool. We also find that population aging makes education investment more attractive and thus leads to a higher level of human capital stock. The capacity of the formal sector also increases.

Two alternative population policies are also provided. The findings show that the policy

[8]The formal-worker share stops at 70% because we set both $\bar{\theta}_s$ and $\bar{\theta}_u$ at 70%.

aiming to increase fertility by subsidizing on child-rearing cost indeed improves the age structure of the aging economy. However, the policy distorts the relative price of skilled and unskilled children. Asset holdings are also crowded out by the higher fertility. Eventually, the policy hurts the formal sector and does not help to alleviate the tax burden. In contrast, the policy that subsidizing on education investment improves the level of human capital stock and enlarge the formal sector. It may alleviate the tax burden. In terms of welfare, we find that there exists welfare improvement when the policy that subsidizing on education investment is adopted. The numerical experiments also suggest that a 26% subsidy could be an optimal subsidy rate.

Population aging in developing countries might not be so pessimistic. Population aging results in a high old-age dependency ratio and a heavy tax burden. However, it also leads to higher savings and makes education investment more valuable. As shown in this paper, with appropriate population policies, the tax burden can be alleviate and welfare improvement is possible.

References

Becker, G. S. (1960). An Economic Analysis of Fertility. in Demographic and Economic Change in Developed Countries, NBER Conference Volume, New Jersey: Princeton University Press.

Becker, G. S., Murphy, K.M., & Tamura, R. (1990). Human Capital, Fertility, and Economic Growth. *Journal of Political Economy*, *98*(5), 12-37.

Correia, I. (2010). Consumption Taxes and Redistribution. *American Economic Review*, *100*(4), 1673-1694.

Doepke, M. (2004). Accounting for Fertility Decline during the Transition to Growth. *Journal of Economic Growth*, *9*(3), 347-83.

Doepke, M. & Zilibotti, F. (2005). The Macroeconomics of Child Labor Regulation. *American Economic Review*, *95*(5), 1492-1527.

Galor, O. & Weil, D. N. (1996). The Gender Gap, Fertility, and Growth. *American Economic Review*, *86*(3), 374-87.

Hsu, M., Huang, X. and Yupho, S. (2015). The Development of Universal Health Insurance Coverage in Thailand: Challenges of Population Aging and Informal Economy. *Social Science & Medicine*, *145*, 227-236.

Jung, J. & Tran, C. (2012). The Extension of Social Security Coverage in Developing Countries. *Journal of Development Economics*, *22*(2), 439-458.

Lee, R., A. Mason & members of the NTA Network. (2014). Is Low Fertility Really a Problem? Population Aging, Dependency, and Consumption. *Science*, *346*, 229-234.

Liao, P. (2011), Does Demographic Change Matter for Growth?. *European Economic Review*, *55*(5), 659-677.

Penalosaa & Turnovsky. (2005). Second-Best Optimal Taxation of Capital and Labor in a Developing Economy. *Journal of Public Economics*, *89*, 1045-1074.

United Nations, Department of Economic and Social Affairs, Population Division. (2013). *World Population Ageing 2013*. ST/ESA/SER.A/348.

Appendix A: Proof for The Indifference Condition

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 $E_i = P_{ij}n_{ij}$.

A young adult is indifferent between having skilled or unskilled children if the following condition holds:

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

Rewrite to obtain the following equation:

$$\frac{V_s}{V_u} = \left(\frac{P_{is}}{P_{iu}} \right)^{1-\varepsilon} \tag{20}$$

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 a skilled young adult 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 an unskilled young adult 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

$$\theta_s(1-\tau_L)w_s^f + (1-\theta_s)w_s^x > \theta_u(1-\tau_L)w_u^f + (1-\theta_u)w_u^x. \tag{21}$$

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 $\theta_s > \theta_u$, equation (21) 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 having skilled or unskilled children.