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Human Capital Accumulation under Social Restrictions and Government Interventions in Developing Economies

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The process of composing and revising my doctoral dissertation is significant and rewarding for me. I have got enormous instructions and supports from different people.

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Contents

1 Introduction

1.1 Background

Human capital is the key element for economic growth. To accumulate human capital, people will need to invest resources in education or training. When deciding how many resources to invest in human capital, individuals need to consider the cost and the benefit of that investment.

Unlike in developed economies, people in developing economies often face many restrictions and interventions, which will not appear in countries like the United States. Those imperfections matter because they will change some underlying assumptions from the very beginning.

For instance, family planning and the "one-child policy" restricted China's fertility rate and family size for several decades. Since the higher education expansion and education marketization from 1998, China's graduates have increased greatly. Simultaneously, college graduates' unemployment and underpaying problems become increasingly serious (Wu & Zheng, 2008).

Higher education, a way of accumulating human capital and signaling individuals' ability, is also a way to show higher social status (Veblen, 1899). There are always some family members to perform that honored task. When the fertility rate is low enough, a high proportion of the whole population will be involved in the education arms race, resulting in a distortion in education signaling and causing education inflation.

Another major difference between developed and developing economies is that access to saving is not always guaranteed in some places due to some social circumstances. People in some least developing countries are unable to save. For example, the fruit vendors from Chennai borrow about 1,000 rupees ($45.75) each morning at the rate of 4.69 percent per day, and although they have good opportunity to save enough money to get rid of that debt, they never try to do so (Banerjee et al., 2011).

According to Banerjee et al.'s theory and research (2011), the difficulty of saving is caused by social restrictions. There are three main reasons: first, individuals who have been living in poverty for a long time have suffered too much stress and have to restraint continuously, which make it very difficult for them to control themselves when they have some excess money; second, when they have some excess money, the circumstance around them will drive the money away from them quickly: for example, when their friends get married, or guests come, they will be forced to spend that excess money, and those things happen very often; third, as banks do not want to deal with small amount of money and the deposit fees are usually very high for the poor, individuals prefer to put the money at home, which make money even more vulnerable against the above self-control problem and social circumstance problem. We can see that the "unable to save" problem in those poor economies involves many things and cannot be solved quickly. We believe it is appropriate to assume that people cannot save in those economies for those reasons.

Under the assumption of no saving, our analysis will be very different when we borrow financial tools from developed economies and bring them to those no saving economy. One issue is the insurances' effect on human capital accumulation in those economies.

This dissertation investigates how a specific kind of insurance will boost economic growth by enhancing human capital accumulation: Income protection insurance (IPI). Nowadays, IPI is typically implemented as an industry-specific employment benefit. As an insurance policy, IPI is available principally in many countries such as Australia and the United Kingdom, paying benefits to policyholders who are incapacitated and unable to work due to illness or accident. In Australia, for example, such insurance packages are often bundled together with other benefits in the Superannuation contributions, which is a compulsory system of placing a minimum percentage of ones' income into a fund to support their financial needs in retirement. However, when we want to bring IPI into the developing world, we may modify it.

First, microfinance institutions (MFIs) often provide insurance (Banerjee et al., 2011), so it cannot be compulsory. Also, IPI in developed industrial countries is part of the social welfare system, which may favor those with worse health at the cost of those healthy ones. However, MFIs do not have that power and have to charge the premium actuarially fairly. If we bring IPI into those poor developing countries, although the name is the same, it will become a very different thing to the developed world's counterpart. For those reasons, we assume individuals in our model can choose whether to enroll and the specific level of coverage.

One may ask that if the poor are unable to save money, why would they be able to invest in IPI, which also needs to sacrifice current consumption. Banerjee et al. (2011) have given the example of "building the house brick by brick," that is, the poor crystalize their money in house building whenever they have a little excess money, but the houses will remain unfinished for many years. At least, the example showed that if there is some way to crystalize excess money, the poor will try. If they invest their money in IPI little by little, it will be a much safer and smarter way of financing excess money.

Based on the above situations, the government in those no-saving economies can intervene in people's IPI purchases and make some difference. The intertwining of social restrictions and government intervention is also an interesting topic in our research.

1.2 Research Purposes

In this dissertation, we would like to show how human capital investment will occur in developing economies, where many social restrictions and government interventions play a role. The existing literature that touches that field is relatively scarce because economists generally make the analysis based on many assumptions in free economies, such as free individual choice in raising children and easy access to saving.

We want to study human capital accumulation and motivations with the above restrictions and disadvantages, making the research's main contribution.

Specifically, as for the effect of the fertility rate control on the higher education arms race, we can find the logical link between a low fertility rate and a distortion in the higher education signaling problem. We want to show how government interventions in one area will affect a seemingly unrelated field. In developing economies with strong government control, those interventions are usually a big problem for a healthy economic environment.

For the discussion on IPI in no saving economies, our aim is not to explain the existing situation but to provide some theoretical prediction for governments' and international organizations’ future policies. What will happen if we bring in a specific kind of insurance IPI to some least developed economies? How will that influence human capital accumulation and economic growth? Can government intervention improve the positive effect of IPI on economic growth? We find that the role of government intervention is not always bad in those economies. Appropriate government control can solve the dilemma of individual optimal and long-run economic growth.

In a word, our research aims to provide a subjective and overall impression on some specific social restrictions and government control and provide some basic ideas and inspirations for future research on that field.

1.3 Literature review

Human capital is the key to economic growth. It contributes to endogenous economic growth by offsetting the diminishing returns to physical capital (Lucas, 1988). This feature of human capital attracts the interest of many theorists. The investment of human capital requires many resources, such as innate ability (Zilcha, 2003), money (Arawatari & Ono, 2009), and time (Yakita, 2003).

This dissertation discusses the accumulation in two respects: higher education and basic education and training. The logic behind those kinds of education is different. Higher education requires individuals to have high ability, or the productivity improvement may not cover the education cost. Basic education and training do not require individuals to have a high ability. It is usually optimal for some least developed economies to increase investment in human capital accumulation.

As for the decision to receive higher education, there is always a difference between the individual profitable and socially optimal. For individuals, receiving higher education is profitable if the wage improvement can cover the education cost and provide them with net income improvement. However, only those who can get higher productivity improvement than education costs should receive higher education for society. The asymmetrical information problem generates the difference between productivity and wage improvement.

Asymmetrical information is a major problem in labor markets (Grorud & Pontier, 2001; Zeng & Shen, 2003). Many researchers have tried to find methods to deal with that problem, and investing in education is usually regarded as a useful method (Arrow, 1973; Vuksanović & Aleksić, 2017). The reason is obvious. Individuals with higher ability usually need lower costs in receiving education, making their education investment more profitable (Spence, 1978, 2002). However, as it is not easy to evaluate each individual's productivity, although high ability ones can acquire high productivity improvement after higher education, they usually receive similar wages with low ability ones with the same education level. As a result, higher education is not a perfect filter.

If the imperfection due to asymmetrical information in productivity is more or less tolerable, another issue can make that imperfection much more serious. That is the education arms race for honor. People receive higher education not only for higher income but also for the honor. If we regard "honor" as a relatively high social status, the honor game should be a zero-sum game. As Veblen (1899) pointed out in his masterpiece *The Theory of the Leisure Class*, higher education is a way to demonstrate one's social status. In East Asian countries with deep Confucian tradition such as China and South Korea, receiving better education has always been a great honor (Marginson, 2011; Shin, 2012; Tu & Du, 1996). People's decisions are often affected by others' decisions. One example is the famous "neighborhood effect," a reference is made to interdependencies between individual decisions and others' decisions and characteristics within a common neighborhood (Brock & Durlauf, 2002). Even though receiving higher education is not a good idea in the economy, individuals may choose to enter college for the honor. We call that pursuit for honor "education arms race." As a filter to select the most suitable individuals to receive higher education, the higher education system will be distorted greatly due to that effect.

Now, we have clarified how the education arms race between individuals can distort the education signaling system. In reality, competition does not always occur among individual persons. When we consider families as agents, things become different. Parents usually compare with each other and gain some utility if they are better off than others in some respects, such as their children's education level. However, that does not need to involve all members. As Veblen pointed out, some family members can do this for the whole family. For example, housewives usually need to perform "Vicarious Leisure" and "Vicarious Consumption" for the family (Veblen, 1899).

The relationship between fertility rate and individual human capital has long been a hot topic. Qian (2009) argues that increasing the fertility rate in rural China leads to increased enrollment rates for the first-born child. Here, however, we focus on the "choosing" process. When the family resource is limited, parents will choose one child that satisfies some standards and gives them more resources than others. In this dissertation, if a family has several children, it can choose the most brilliant one to perform "Vicarious Education" to honor the whole family.

When family size increases, more and more children are free from that honor competition and can receive education according to their ability, which is good for families and society. Nevertheless, for those one-child families, they cannot choose. As a result, with lower fertility rates, especially under the one-child policy, more low-ability guys enter the college and lower average ability and average productivity in college students, leading to lower wages for college graduates.

Until now, we have discussed higher education in college. Whether productivity improvement is larger than the education loss depends on each individual's ability. Excess investment in education means distortion in education signaling problem and social welfare loss. There is an optimal level of higher education for society, and too many graduates is not a good thing (Ordine & Rose, 2017). Nevertheless, unlike higher education, basic education and training do not require high ability and have a very obvious improvement in people's productivity, especially in the least developing countries. In most situations, the problem is underinvestment in labor force training. Finding ways to enhance that education and training is essential for poverty reduction in those countries, such as insurance tools.

Insurance as a way of reducing poverty has been a hot topic for a long time. The 2019 Economics Nobel Prize winner, Banerjee, and Duflo (2011), in their famous book *Poor economics:*

A radical rethinking of the way to fight global poverty, use a whole chapter to discuss the risk and insurance of the poor.

Individuals will face uncertainty in the future, influencing their income (Levhari & Weiss, 1974; Fuster, 1999). For example, even if they invest in human capital, there is a risk that they will fall ill in the future and lose their working ability (Lu & Yanagihara, 2013). As a result, they cannot realize their human capital. That is a possible disincentive for human capital accumulation.

Whether insurance can enhance human capital investment has been discussed by many researchers, such as Ostaszewski (2003). Also, researchers want to find the optimal insurance level for economic growth (Brown & Kaufold, 1988).

IPI has attracted researchers' interests (Pitt, 2007), but research on IPI's human capital effect is relatively scarce. As IPI benefits are directly relevant to individuals' gross earnings, it will certainly play an important role in human capital accumulation. Individuals will take the premium and benefits into consideration when they make their investment in education or training. However, there exist two opposite effects at the same time: "guarantee effect" and "crowding-out effect." On the one hand, IPI can guarantee some proportion of future income despite illness and accidents, which will make individuals more willing to invest in education and training, that is, the "guarantee effect."

On the other hand, IPI needs to collect the premium, which comes from the individuals' current income. If too much money is used to pay the IPI premium, less money will be left for human capital accumulation, that is, the "crowding-out effect." Although the choice and impact of life insurance, which is directly related to death and survival, have attracted so much attention (Yaari, 1965; Pliska & Ye, 2007), as far as I know, very few researchers have investigated the mixed effects of IPI on human capital, which should make it a major contribution of this paper. The paper intends to provide some basic insight and policy implications for insurance to reduce poverty and enhance long-run economic growth in poor developing countries such as India and Kenya.

Lu & Yanagihara (2013) have invested how life insurance will influence the human capital accumulation and economic growth when there is no saving. However, their research did not consider individuals' choice of insurance coverage. In their model, individuals must buy full-covered life insurance.

That full coverage assumption can be relaxed. Previous research has found that well-informed, expected utility-maximizing, risk-averse individuals might choose not to buy some kinds of insurance or choose lower coverage by trading-off the costs of benefits (Pauly, 1990). Also, this trading-off will apply to IPI. In some poor developing countries, where people cannot save due to self-control problems and social circumstances, even if they have access to money and accessibilities to a bank account (Banerjee et al., 2011), we can see individuals with different health perspectives have very different attitudes towards IPI.

Based on Yanagihara and Lu's research (2013), we extend our model, allowing individuals to choose IPI coverage freely. We want to investigate how the freedom to choose will influence the result.

Through that extension, we find some individuals with good health perspectives will not buy IPI at all. The human capital boosting effect will only appear on individuals with relatively bad health perspectives.

No matter for individuals or the whole economy, the optimal level of insurance is a hot topic. For instance, Brown and Kaufold (1988) investigated the optimal unemployment insurance level to increase human capital investment. In their model, coverage is a critical index of insurance level to achieve higher human capital investment. Now, in our model, there are two kinds of optimal IPI coverage: the coverage that is optimal for growth, which we call "growth-optimal," and the coverage which is optimal for individuals, which we call "freely-chosen." Developing countries often suffer from absent or under-developed IPI markets, which may restrict IPI coverage below the optimal level, let alone the full coverage.

The dilemma of individually optimal and socially optimal levels for any good or service has always been an interesting issue. Previous studies mainly attribute that dilemma to two main sources: The market's defects, including asymmetric information, and human beings' limitation.

As for the former, we have discussed enough in our research about high education's imperfection as a signaling tool. As for the latter, Diamond (1965) showed that in an economy with infinitely long life, despite the absence of all the usual sources of inefficiency, the competitive solution can be inefficient. In our analysis, except for limited lifetime, risk aversion, which is often regarded as human nature, is the primary reason for that dilemma: individuals prefer to be safer than having what the "growth-optimal" coverage can guarantee them. As a result, the government must set benefit limitations to increase the economic growth rate.

Combining and comparing "freely-chosen" and "growth-optimal" IPI cases should make a significant innovation and contribution. Our research aims to provide some fundamental insights and policy references for governments, insurance companies, and international organizations to reduce poverty through insurance tools in the least developed countries.

1.4 Limitations and future research direction

There are some limitations to this research. First, our discussion overs only some specific issues of that field. More general research and theoretical models are needed to extend our research. Second, most of our research focused on theoretical models. Future data and econometric research are needed to verify our theoretical conclusions.

In the future, there are three research directions. First, we want to extend our theoretical model to include more social restrictions and government intervention topics. Second, we want to generalize our model to explain more general situations. Third, we want to add some econometric elements to our research to determine some model parameters and make our model more accurate and quantified.

1.5 The structure of the dissertation

The structure of the rest thesis is as follows.

Chapter 2 focused on the impact of the fertility rate control on the education arms race, especially the Chinese one-child policy. We built a simple model to show how the numbers of children in each family affect education arms races' intensity. We find that the most significant change occurs when the children number in each family is reduced from two to one.

Chapter 3 studied the effect of IPI on human capital accumulation in an economy without saving. We got several concluding remarks. For individuals with different health perspectives, the IPI will have different impacts. Only individuals with relatively bad health perspectives will buy IPI. Only for individuals with extremely bad health perspectives IPI will increase their human capital accumulation.

Chapter 4 showed the possibility that the government can use the IPI as a human capital enhancing tool through some limitations. We find a significant difference between IPI coverage that can achieve the highest economic growth and IPI coverage preferred by individuals. By setting a limitation on IPI coverage, the government can use IPI to boost economic growth.

Finally, in chapter 5, we got some general conclusions. In developing worlds, people suffer many restrictions and interventions. Although, in most cases, those restrictions and interventions mean efficiency and social welfare loss, in certain situations, they may increase economic growth.

2 The education arms race, fertility rate, and education inflation

2.1 Introduction

Since the higher education expansion and education marketization from 1998, China's graduates have increased greatly. Moreover, correspondingly, graduates' unemployment and underpaying problem become increasingly serious (Wu & Zheng, 2008). In other words, if we deem the college degree as a currency, there is significant "education inflation" in China's labor force market.

We built a model to explain why parents continue to send their children to universities despite college graduates' low wages. The analysis showed that as the fertility rates drop, the intensity of the education arms race increases. As a theoretical model, it can also explain similar situations in other economies with decreasing fertility rates.

The structure of the rest of the chapter is as follows. First, section 2.2 presented the basic model without the education arms race. The education arms race was added in section 2.3. Then, we considered the effects of the fertility rate on the education arms race in section 2.4. Finally, in section 2.5, we got several concluding remarks.

2.2 The basic model

Before we move on to models with education arms race and fertility rate, we need a basic model based on which we can make further analysis.

Consider a continuum of individuals of mass one characterized by heterogeneous ability θ. Ability is distributed according to uniform distribution $F(\theta)$, whose density function is $f(\theta)$ over an interval $[\underline{\theta}, \bar{\theta}]$, where $1 \leq \underline{\theta} < \bar{\theta}$.[1] And the critical ability level where individuals are indifferent in whether receiving higher education or not is θ^*.The probability density function is given by:

[1] The basic idea of this distribution comes from Ordine and Rose's model (2017), I simplify it further by assuming it is a uniform distribution.

$$f(\theta) = \frac{1}{\bar{\theta}-\underline{\theta}} \ , \theta \in [\underline{\theta}, \bar{\theta}]. \quad (2.1)$$

The final productivity is influenced by education level and individual ability, g represents graduate education, and u means the individuals are not graduates:

$$\mathrm{y(E, \theta)} = \begin{cases} \theta, & if\ E = g \\ 1, & if\ E = u \end{cases} . \quad (2.2)$$

As a developing country, China's education and labor market have asymmetry information problems. Firms cannot know individuals' exact productivity and judge a worker's potential ability and productivity according to their education level. Graduates get wage according to firms' expectation on their productivity, which is also the average productivity of all individuals with the same education level:

$$\mathrm{w}(u, \theta) = \mathrm{y(u, \theta)} = 1; \mathrm{w(g, \theta)} = \mathbb{E}[\mathrm{y(g, \theta)}] = \frac{\theta^* + \overline{\theta}}{2}, \quad (2.3)$$

as a result, productivity improvement and wage improvement are not the same things for an individual:

$$\mathrm{y(g, \theta) - y(u, \theta) = \theta - 1}, \quad (2.4)$$

$$\mathrm{w(g, \theta) - w(u, \theta)} = \frac{\theta^* + \overline{\theta}}{2} - 1. \quad (2.5)$$

Spence (1978, 2002) pointed out that education cost should be inversely proportional to an individual's ability as an efficient signaling tool. So, we assume

$$c(\theta) = \frac{\mu}{\theta}. \tag{2.6}$$

We assume there is a socially optimal point of whether higher education is socially optimal, θ^o:

$$\theta^o - 1 = \frac{\mu}{\theta^o}. \tag{2.7}$$

An individual will choose to get higher education when

$$w(\theta, g) - w(\theta, u) > \frac{\mu}{\theta}. \tag{2.8}$$

We know

$$w(\theta, g) = \frac{\bar{\theta}+\theta^*}{2}, w(\theta, u) = 1. \tag{2.9}$$

That means an individual will choose to get a higher education if

$$\frac{\bar{\theta}+\theta^*}{2} - 1 \geq \frac{\mu}{\theta}. \tag{2.10}$$

As shown in Figure 2.2, in the individual critical point θ^*, the individual will be indifferent in receiving higher education because the wage increment equals the education cost.

$$\frac{\bar{\theta}+\theta^*}{2} - 1 = \frac{\mu}{\theta^*}. \tag{2.11}$$

Figure 2.2 presents us with the fraction of graduates in the population as $G = \frac{\bar{\theta}-\theta^*}{\bar{\theta}-\underline{\theta}}$ and the social surplus of higher education SSC=$S_B - S_A$. In the following analysis in section 2.3, a decrease in critical ability θ^* will lead to an increase in G and S_A. As S_B remains constant, social surplus SSC will decrease.

2.3 The model with the education arms race

As we have mentioned, higher education is a symbol of social status (Veblen, 1899). Higher education usually provides individuals and their families more respect from others. However, in this comparison game, the utility is determined by individuals' relative position in a hierarchy. Because when one is respected, someone else will be looked down on. Under the one-child policy, each family has only one child, and all children must take the responsibility of "Bring honor to the family." We begin our analysis from the one-child policy because it is the simplest case.

We assume the degree of respect for an individual is proportional to his height in the hierarchy. Here we adopt this assumption for simplicity. His disutility due to lower education is proportional to the proportion of people having a higher education level than him. We assume there are only two layers in the hierarchy: graduates and undergraduates. In Figure 2.3, on the left, there are very few graduates and many undergraduates. On the right, there are many graduates and a few undergraduates.

Next, we can find why this game is a zero-sum one. We use r to measure the degree of respect to education, which is how much importance people attach to higher education in society. If we assume the proportion of graduates is a, the undergraduates' proportion will be $(1-a)$. For a graduate, he can get a utility of $(1-a)r$. Then the total utility of graduates will be $(1-a)ra$. Similarly, an undergraduate will get a disutility -ar; the total negative utility will be $-ar(1-a)$. We can find $(1-a)ra - ar(1-a) = 0$. No matter what a is, it is always a zero-sum game.

If we consider the utility and disutility due to comparison, we have the total utility function:

$$U(E,\theta) = w(E,\theta) + R(E), \tag{2.12}$$

$$R(E) = \begin{cases} (1-a)r, if\ graduated \\ -ar,\ \ if\ undergraduated \end{cases}. \tag{2.13}$$

When an individual wants to decide whether or not receiving higher education, he just needs to compare the utility improvement and education cost:

$$U(g,\theta) - U(u,\theta) > c(\theta), \tag{2.14}$$

$$\frac{\bar{\theta}+\theta^*}{2} - 1 + r > \frac{\mu}{\theta}, \tag{2.15}$$

So, the honor of high education is just like a fixed volume of bonus. When an individual finds receiving higher education can give him higher utility improvement than the cost of education, he will choose to receive higher education. Changes before and after the education arms race are shown in the following Table 2.1 and Figure 2.4.

Table 2.1 Changes due to education arms race

	Critical ability	Wage for graduates	Total graduates' number	Social surplus changes due to high education
Before	θ^{*o}	w_o	$\frac{\bar{\theta}-\theta^{*o}}{\bar{\theta}-\underline{\theta}}$	$S_B - S_A$
After	θ^{*1}	w_a	$\frac{\bar{\theta}-\theta^{*1}}{\bar{\theta}-\underline{\theta}}$	$S_B - S_{A'}$
Change	Decrease	Decrease	Increase	Decrease

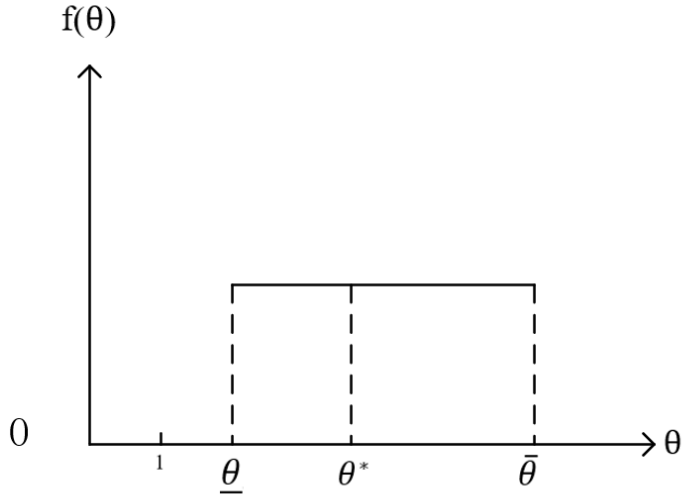


Figure 2.1 The distribution of individuals' ability and individuals' choice

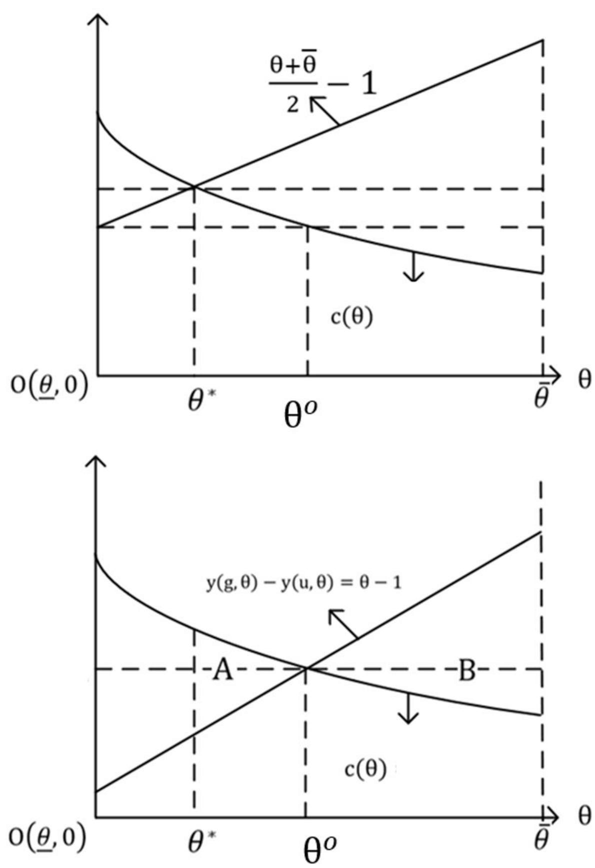


Figure 2.2 The individuals' choices and social surplus

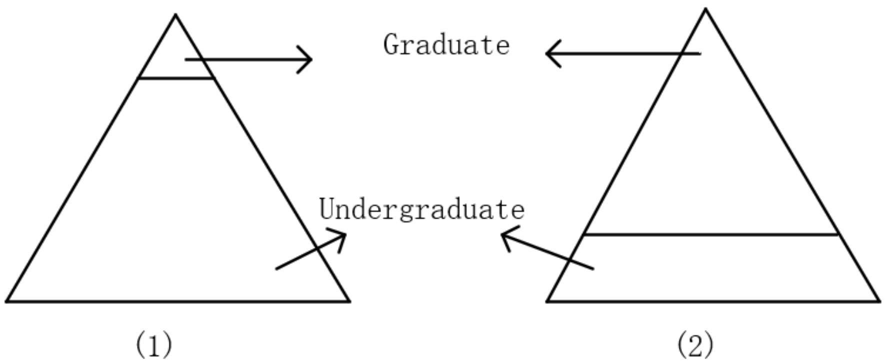


Figure 2.3 Two different education hierarchies

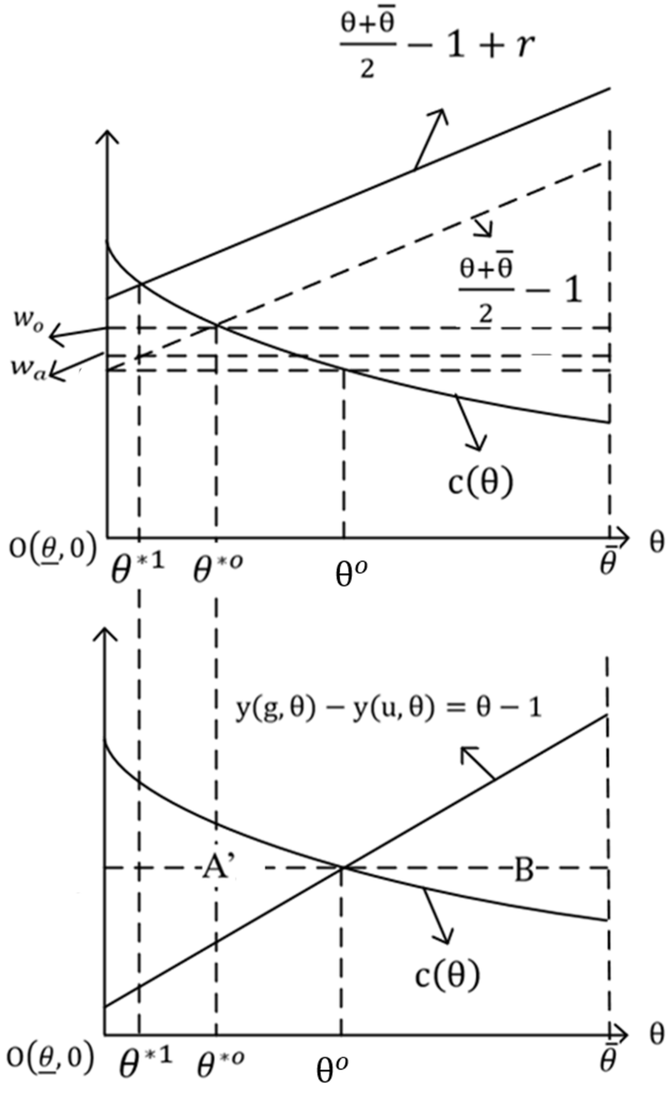


Figure 2.4 The education arms race and social welfare loss

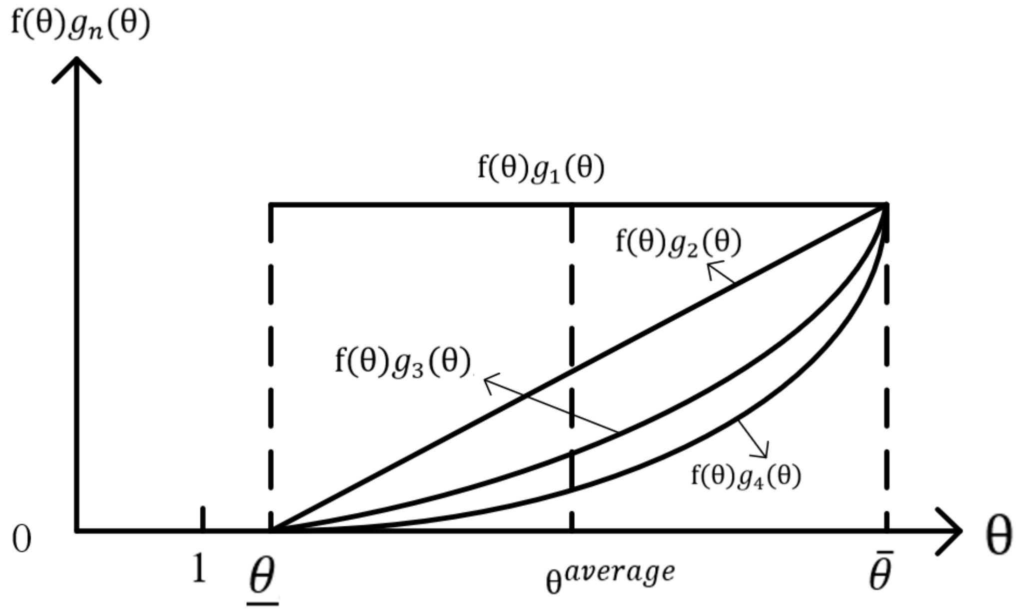


Figure 2.5 The participants in an education arms race if each family has n children

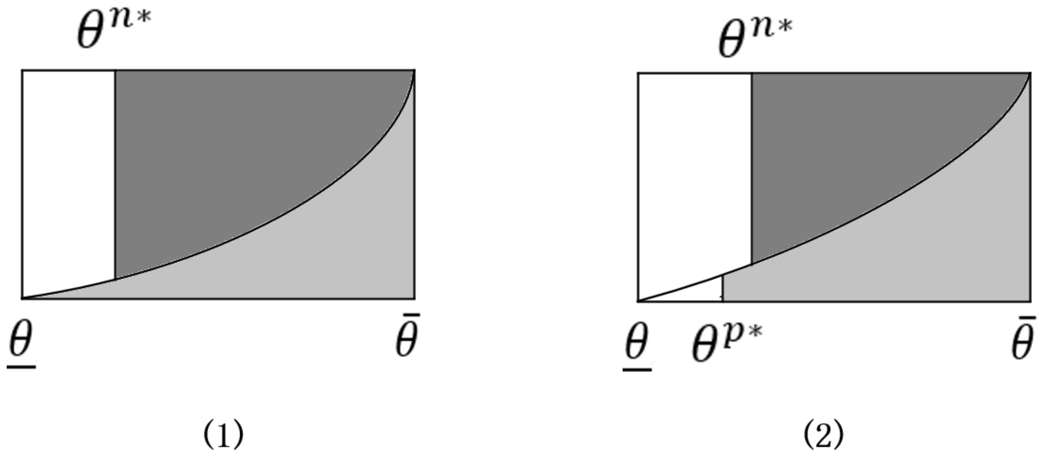


Figure 2.6 Two different cases with different r

2.4 Vicarious education and the education arms race

If we loosen the one-child policy and allow each family to have more children, things will differ. We assume that the child with the highest education level determines a family's education level. In that situation, a family with more children will not need to support all the children's education arms race. The more practical way is to support the most brilliant child if the pride and economic return can compensate for the education costs. At the same time, let other children choose their education status based on economic return and costs. We can call that situation "vicarious education," which is derived from Veblen's two famous conceptions: "vicarious leisure" and "vicarious consumption" (Veblen, 1899). "Vicarious" here means representative. In other words, some family members can participate in some activities as representatives of their families. So, the utility of those participants in the education arms race will be affected by his family's position in the education hierarchy determined by his education level.[2]

Now let us consider if one family has more than one child. Then what will happen? As assumed above, families will only compare their children's highest education level. So, families can choose to support the smartest to receive education and enjoy the pride and economic outcome.

If each family has two children, then for an individual with ability θ, the probability that he is the smarter one is $\frac{\theta-\underline{\theta}}{\bar{\theta}-\underline{\theta}}$.[3] If each family has three children, then that possibility should be $(\frac{\theta-\underline{\theta}}{\bar{\theta}-\underline{\theta}})^2$.[4] For the same reason, in an n-children family, the possibility that he is smartest should be $(\frac{\theta-\underline{\theta}}{\bar{\theta}-\underline{\theta}})^{n-1}$. We define that possibility as $g_n(\theta)$. Obviously, $g_1(\theta) = 1$, because one-child families do not have other choices.

We can use $f(\theta)g_n(\theta)$ to represent the possibility that an individual has θ ability and is the smartest one in his family. We can see the differences between the different n in Figure 2.5. We

[2] Notice here we refer to the family's position in the hierarchy, not the individuals' position. This ensures the zero-sum game. If we assume the proportion of "graduate families" is a, the "undergraduate families' proportion" will be (1-a). Similarly, we can get (1-a)ra-ar(1-a)=0.

[3] We can also see it as the possibility that the other child is not as smart as him.

[4] That means the other two are not as smart as him.

can find from $f(\theta)g_1(\theta)$ to $f(\theta)g_2(\theta)$, $f(\theta)g_3(\theta)$, and $f(\theta)g_4(\theta)$, the lower area will be smaller and smaller. What is more, the lower area's left part decreases faster, which means fewer low-ability individuals will participate in the education arms race. When n is large enough, the low-ability individuals in the education arms race will be so few that the situation is almost the same as the situation without the education arms race.

For the convenience of further discussion, we need to clarify some terms. "Participants" means participants in the education arms race. "Non-participants" means individuals that are not in the education arms race. SSC means social surplus change due to higher education. We define θ^{n*} as the critical ability in non-participants, θ^{p*} as the critical ability in participants, G^p as the graduates' number in participants, G^n as the graduates' number in non-participants, $G = G^p + G^n$ as total graduates' number.[5]

As Figure 2.6 shows, when the degree of credentialism r is different, the outcome can be different. The light-grey area represents graduates in participants. The deep-grey area represents graduates in non-participants. When r is large, all the participants in the arms race will receive higher education. When r is not so large, not all participants will receive higher education. We need to discuss them separately.

When all participants receive higher education, we have

$$\theta^{p*} = \underline{\theta}, \tag{2.16}$$

$$G^p = \frac{1}{n}, \tag{2.17}$$

$$G^n = \int_{\theta^{n*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} [1 - \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1}] d\theta, \tag{2.18}$$

$$w(g, \theta) = \frac{\int_{\theta^{p*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1} \theta d\theta + \int_{\theta^{n*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} [1 - \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1}] \theta d\theta}{G^n + G^p}, \tag{2.19}$$

[5] As all individuals are assumed to be mass 1, G is also the proportion of graduates in all individuals.

$$\frac{\mu}{\theta^{n*}} = \mathrm{w}(\mathrm{g}, \theta) - 1, \tag{2.20}$$

then from (2.18), (2.19), and (2.20), we can get θ^{n*}, G^n and $\mathrm{w}(\mathrm{g}, \theta)$.

When r is not so large, and not all participants receive higher education,

$$G^p = \int_{\theta^{p*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1} d\theta. \tag{2.21}$$

And we know, for the critical participant,

$$\frac{\mu}{\theta^{p*}} = \mathrm{w}(\mathrm{g}, \theta) - 1 + r. \tag{2.22}$$

From (2.18), (2.19), (2.20), (2.21), and (2.22), we can get $\theta^{p*}, G^p, \theta^{n*}, G^n$ and $\mathrm{w}(\mathrm{g}, \theta)$.

Finally, we can find the social surplus change due to higher education:

$$\mathrm{SSC}=\int_{\theta^{n*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} \left[1 - \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1}\right] \left(\theta - 1 - \frac{\mu}{\theta}\right) d\theta$$
$$+ \int_{\theta^{p*}}^{\overline{\theta}} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\frac{\theta-\underline{\theta}}{\overline{\theta}-\underline{\theta}}\right)^{n-1} (\theta - 1 - \frac{\mu}{\theta}) d\theta. \tag{2.23}$$

It will be difficult for us to compare directly, so we just need to set $\underline{\theta} = 2, \overline{\theta} = 6$.[6]Then we can get $\mu = 12, c(\theta) = \frac{12}{\theta}$. Table 2.2 is the results. We choose $\mathrm{r} = 2$ and $\mathrm{r} = 4$ to establish the two cases in Figure 2.6. In this model, $\mathrm{r} = 4$ is high enough because it forces all participants to

[6] The value of $\underline{\theta}$ means that, if the worker with lowest ability receive higher education, how many times of undergraduate productivity they can provide. Of course, this ratio is only a rough estimation. It varies from country to country and changes all the time. As we have assumed $\underline{\theta} > 1$ and a too large $\underline{\theta}$ will seem unrealistic, here we set that ratio as 2. This means, for example, in China, if an undergraduate worker with the lowest ability create 2000 RMB value per month, he will create 4000 RMB value per month if he receives higher education. $\bar{\theta}$ can be interpreted similarly. According to our assumptions, if we set $\underline{\theta}$ and $\bar{\theta}$, then $\mu, c(\theta)$ are also fixed.

receive higher education, which is an extreme case in the real world. Moreover, the no education arms race (NAR or r=0) is the benchmark. It represents the lowest level of education inflation and the highest social surplus. Here n is the fertility rate or the number of children in each family. We just set n value as 1,2,3,4 because those fertilities are common, and n=4 is high enough to explain our problem. PP means they participate in proportion or the fraction of children who participate in the education arms race. Other variables have already been explained.

Table 2.2 Calibration Results ($\underline{\theta} = 2, \overline{\theta} = 6, \mu = 12, c(\theta) = \frac{12}{\theta}$)

	n	PP	θ^{p*}	θ^{n*}	w(g, θ)	G^p	G^n	G	SSC
r	NAR	0	n/a	3.292	4.646	n/a	0.677	0.677	0.668
4	1	1	2	n/a	4	1	n/a	1	−0.296
	2	1/2	2	3.386	4.544	0.5	0.214	0.714	0.563
	3	1/3	2	3.309	4.626	0.333	0.351	0.684	0.649
	4	1/4	2	3.296	4.641	0.25	0.429	0.679	0.664
2	1	1	2.325	n/a	4.163	0.919	n/a	0.919	0.061
	2	1/2	2.164	3.384	4.546	0.499	0.214	0.713	0.566
	3	1/3	2.133	3.309	4.627	0.333	0.351	0.684	0.649
	4	1/4	2.127	3.296	4.641	0.250	0.429	0.679	0.664

We can find many interesting things in Table 2.2.

First, the education arms race reduces social welfare by enhancing the excessive education arms race. Table 2.2 shows that under the education arms race, no matter what value n and r is, we can find the SSC smaller than the NAR benchmark. So, although it is a zero-sum game by itself, the education arms race costs real social resources and reduces social welfare. We can find the graduate proportion g will be larger than the benchmark group. That means those low-ability individuals, who would not receive higher education otherwise, are forced to receive it by the education arms race.

Second, the impact of the education arms race is greatly related to the fertility rate. We can see that very clearly if we notice the case when $n = 4$. We can find when n=4, no matter r=2 or r=4, g values are the same (0.679), and SSC values are the same (0.664). Moreover, they are close to the benchmark value (G=0.677; SSC=0.668). Under a sufficiently high fertility rate, the education arms race for honor will only distort the NAR case's outcome a little. In other words, under a high fertility rate, the education arms race is not a serious problem. However, the real situation is just the opposite, especially under China's one-child policy; the distortion reaches its maximum level. We can find when n=1, G will be very large (When r=4, G=1; When r=2, G=0.919), and SSC will be very small (When r=4, SSC=-0.296; When r=2, SSC=0.061).

Third, the fertility rate has a "diminishing return." That is, when we increase the fertility rate from a very low level (n=1), the distortion effect reduce dramatically (When r=4, $G_{n=2} - G_{n=1} = 0.714 - 1 = -0.286; SSC_{n=2} - SSC_{n=1} = 0.563 - (-0.296) = 0.859$;When r=2, $G_{n=2} - G_{n=1} = 0.713 - 0.919 = -0.206; SSC_{n=2} - SSC_{n=1} = 0.566 - 0.061 = 0.505$). But if the fertility rate is already high (n=3) and the distortion is already sufficiently low, increasing the fertility rate will not make much difference anymore (When r=4, $G_{n=4} - G_{n=3} = 0.679 - 0.684 = -0.005; SSC_{n=4} - SSC_{n=3} = 0.664 - 0.649 = 0.015$;When r=2, $G_{n=4} - G_{n=3} = 0.679 - 0.684 = -0.005; SSC_{n=4} - SSC_{n=3} = 0.015$). In a word, most distortion under the one-child policy can be overcome by just one additional kid.

2.5 Concluding remarks

We got some concluding remarks from our analysis and get some impression of how government interventions in one field can cause problems in a seemingly unrelated field.

First, the education arms race can cause social welfare loss. As people receive education to get a higher position in the zero-sum honor game, more and more low ability individuals are forced to receive expensive higher education. As productivity improvement is not enough to cover the cost, it caused social welfare loss.

Second, the intensity of the education arms race is determined by the number of children in each family. With more children as alternatives, families can choose the most intelligent child to participate in the education arms race while leaving others alone.

Third, the most significant difference occurs when each family is forced to have only one child. Even if we allow each family to have two children, most distortions caused by the education arms race disappears. As a form of government intervention, China’s “one-child policy” causes a high education inflation problem, which means social welfare loss.

3 Individual health perspective, income protection insurance coverage, and human capital growth

3.1 Introduction

As we have mentioned above, higher education in college requires individuals to have enough ability. Not all individuals can get higher productivity improvement than education cost. Now let us forget that kind of education and turn our eyes to the least developed world, such as the countryside in India and Kenya.

In those economies, things are much simpler: basic education and training can improve individuals' productivity. As that knowledge is so basic and simple, mastering it does not require high personal ability. As long as workers are willing to invest their income in some education and training, their future income will significantly increase.

When individuals receive education and training to invest in human capital, they face a trade-off between current consumption and future consumption. Moreover, uncertainties, especially health risks, may cause the failure of the realization of human capital. That is a disincentive for human capital accumulation. For that reason, as an important way of dealing with risks, insurance can have significant effects on human capital accumulation.

In our dissertation, we would like to discuss the human capital effect of a specific kind of insurance: IPI. whether that effect is positive or negative depends on the two opposite effects: "guarantee effect" and "crowding-out effect." The former is positive, while the latter is negative.

The rest of this chapter is organized as follows. Section 3.2 presented the basic model. Section 3.3 showed the impact of IPI. Section 3.4 got some concluding remarks.

3.2 The model

The model is a discrete-time overlapping one. The initial period is period 0. All individuals live and work for two periods: youth period and old period and denoted by 1 and 2. Individuals who spend their youth in period t are called generation t. In the beginning, there is an initial old generation, each of whom with human capital, $h_{2,0}$. Here, the first subscript represents the generation's period, and the second refers to the current period.

Proportional human capital inheritance is an assumption that has been applied by many researchers (Yakita, 2003; Lu & Yanagihara, 2013; Viaene & Zilcha's 2002). Here, we borrow the idea of proportional human capital inheritance from that research. Children's generations' human capital in their youth is proportional to their parents' generations' human capital in old periods. Also, for simplicity, we push Viaene and Zilcha's (2002) assumption of average parents' human capital further by assuming that children's generations' human capital in the first period, $h_{1,t}$, is proportional to their parents' generations' average human capital in the old period, $\bar{h}_{2,t}$.

$$h_{1,t} = \chi \bar{h}_{2,t}, \chi > 0\,. \tag{3.1}$$

We assume that individuals in the economy will consume in the current period and invest in human capital education in the future. There are no other ways of storage. It may seem unrealistic at first sight, but as Banerjee et al. (2011) pointed out, "Unable to save" is the real situation in many poor developing economies.

We assume they get their income equal to their human capital. So, we can get the following budget constraint[7]:

$$c_{1,t} + e_{1,t} = h_{1,t}. \tag{3.2}$$

Following Krebs (2003) and Grossmann (2008), the human capital in generation t in their old period, $h_{2,t+1}$, is proportionally influenced by the amount of education investment:

$$h_{2,t+1} = \theta e_{1,t}, \tag{3.3}$$

[7] If individuals can save, the individuals who have negative net return will save their money in the bank and the conclusions will need some modification. But as we have mentioned, "no saving" is just the reality in those poor countries.

where $\theta > 1$ measures the efficiency of education.

We assume individuals are risk-averse, and the utility function is has a constant relative risk aversion (CRRA), that is, isoelastic function for utility, here; we assume the relative risk aversion is 1/2 for the simplicity of calculation, and any risk aversion that is between 0 and 1 will not change the main results[8].

$$\mathrm{u}\left(c_{1,t}, c_{2,t+1}\right) = 2\sqrt{c_{1,t}} + 2\frac{\sqrt{c_{2,t+1}}}{1+\beta}, \tag{3.4}$$

where $\beta > 0$ is the discount rate.

In the old period, individuals may fall ill or not, and the illness can be light and heavy, depending on individuals. For example, if individuals have a probability of π to fall ill, and the illness can cause a fraction of ϕ of income loss, then his consumption in the old period will be:

$$c_{2,t+1} = \begin{cases} h_{2,t+1}, & if\ healthy \\ (1-\phi)h_{2,t+1}, & if\ unhealthy \end{cases}, \tag{3.5}$$

and his expected utility function should be

$$E\left[u\left(c_{1t}, c_{2,t+1}\right)\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}E\left[\sqrt{c_{2,t+1}}\right], \tag{3.6}$$

$$E\left[u\left(c_{1t}, c_{2,t+1}\right)\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right] + \frac{2}{1+\beta}\left[\pi\sqrt{(1-\phi)h_{2,t+1}}\right]. \tag{3.7}$$

According to (3.3) and (3.4), we get the simplified budget constraint:

8 The isoelastic function for utility has the form: $u(c) = \begin{cases} \frac{c^{1-\eta}-1}{1-\eta}, \eta \geq 0, \eta \neq 1 \\ ln(c), \eta = 1 \end{cases}$, in our case, we take $\eta = 1/2$.

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} = h_{1,t}. \tag{3.8}$$

Maximizing (3.7) subject to (3.8), we get those individuals optimal education investment and human capital in the old period without IPI:

$$e_{1,t} = \frac{h_{1,t}}{\frac{(1+\beta)^2}{\left[(1-\pi)+\pi\sqrt{1-\phi}\right]^2}+\theta}; h_{2,t+1} = \frac{h_{1,t}}{\frac{(1+\beta)^2}{\left[(1-\pi)+\pi\sqrt{1-\phi}\right]^2\theta^2}+\frac{1}{\theta}}. \tag{3.9}$$

Their human capital growth from his previous generation will be:

$$G^O = \frac{h_{2,t+1}}{\bar{h}_{2,t}} = \frac{\chi}{\frac{(1+\beta)^2}{\left[(1-\pi)+\pi\sqrt{1-\phi}\right]^2\theta^2}+\frac{1}{\theta}}. \tag{3.10}$$

3.3 The impact of IPI on human capital growth

Now, if there is an IPI which allows individuals to choose coverage freely, then individuals will choose the optimal coverage δ to maximize their expected utility.

We assume individuals need to pay $x_{1,t}$ to the insurance company to cover some risks. Here, $\pi h_{2,t+1}\phi$ is his expected loss in the future, but they choose to cover a δ fraction of the full risk. So, we have

$$\delta\pi h_{2,t+1}\phi = x_{1,t}. \tag{3.11}$$

Here, to guarantee the equation in (3.11), we assume the IPI companies are perfectly competitive. We ignore their functioning costs to simplify our analysis because our main focus of this paper is the effects of IPI on human capital. In the real world, it is a common practice that IPI companies charge different premiums according to individual health perspectives and keep an eye on individuals' behavior. There are several exclusions to exclude self-abasement moral hazard. Here we assume both the IPI companies and individuals have perfect information and rational expectations, so the reverse selection and moral hazard are ruled out.

If they fall ill in the future, they can get compensation $X_{2,t+1}$ based on the chosen coverage:

$$X_{2,t+1} = \delta h_{2,t+1}\phi. \tag{3.12}$$

His budget constraint is:

$$c_{1,t} + e_{1,t} + x_{1,t} = h_{1,t}. \tag{3.13}$$

So, his second-period consumption when they are unhealthy will be:

$$c_{2,t+1}^{u} = (1-\phi)h_{2,t+1} + X_{2,t+1} = (1-\phi+\delta\phi)h_{2,t+1}. \tag{3.14}$$

His expected utility function will be

$$E\left[u\left(c_{1,t}, h_{2,t+1}, \delta\right), \pi\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right] + \frac{2}{1+\beta}\left[\pi\sqrt{(1-\phi+\delta\phi)h_{2,t+1}}\right]. \tag{3.15}$$

According to (3.4) (3.11) and (3.13), we can get the simplified budget constraint:

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} + \delta\pi\phi h_{2,t+1} = h_{1,t}. \tag{3.16}$$

Proposition 3.1: Individuals choose not to buy IPI when $\mathrm{T} = (1-\pi)\sqrt{1-\phi} + \pi(1-\phi) - \frac{1}{\theta} > 0$.

The proof is shown in Appendix A.

We can also regard $\mathrm{T} = 0$ as the zero-insurance boundary (ZIB). Any combination of (ϕ, π) below ZIB means the individual will not buy IPI.

ZIB also has another form:

$$\pi = \frac{\frac{1}{\theta} - \sqrt{1-\phi}}{1-\phi-\sqrt{1-\phi}}. \tag{3.17}$$

Next, we investigate whether we can get the corner solution at $\delta^{EN} = 1$. According to Appendix A, when there are interior solutions:

$$\delta - 1 = \frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi)}{(1-\pi)^2\phi} - 1 = \frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2}{(1-\pi)^2\phi}. \tag{3.18}$$

To find whether $\delta - 1 < 0$, we just need to find the value of the following equation:

$$\frac{1}{\theta} - \pi(1-\phi) - (1-\pi) = \frac{1}{\theta} - 1 + \pi\phi = \frac{1-\theta(1-\pi\phi)}{\theta}. \tag{3.19}$$

Notice that $\theta(1-\pi\phi) - 1$ is the net expected return from investing in education; for some people, it is positive. However, we cannot deny that for some people else, it can be negative.

Proposition 3.2: If individuals can get a positive expected net return from investing in education, that is, $\theta(1-\pi\phi) - 1 > 0$, then they will not cover all his risks when buying IPI. If they cannot get a positive expected net return from education, that is $\theta(1-\pi\phi)-1 \leq 0$, they will choose to cover all his risks. The full covered IPI boundary (FIB) is $\theta(1-\pi\phi)-1=0$, or

$$\pi = \frac{1-\frac{1}{\theta}}{\phi}. \tag{3.20}$$

The proof is shown in the above analysis.

Figure 3.1 shows how the ZIB and FIB divide the area $\pi \in (0,1), \phi \in (0,1)$ when $\theta = 1.5, 2, 3\ and\ 4$. The curve on the left is ZIB, and the curve on the right is FIB.

If the equation holds when $\delta^{EN} = \frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2\phi} \in (0,1)$, then there is the interior solution of δ. We want to determine whether IPI will increase his investment in education and human capital or decrease them.

Proposition 3.3: If individuals can choose their IPI coverage freely when they choose to buy IPI to cover part of the risks, their individual human capital growth rates in the second period will be lower than the case without IPI.

Proof: See Appendix B.

When individuals choose full coverage, we have the expected utility function and simplified budget constraint:

$$E(c_{1,t}, h_{2,t+1}) = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\sqrt{h_{2,t+1}}, \tag{3.21}$$

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} + \pi\phi h_{2,t+1} = h_{1,t}. \tag{3.22}$$

The Lagrangian equation will be:

$$L = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\sqrt{h_{2,t+1}} + \lambda[c_{1,t} + \frac{h_{2,t+1}}{\theta} + \pi\phi h_{2,t+1} - h_{1,t}].$$

Finally, we get the human capital in the second period and the personal growth rate

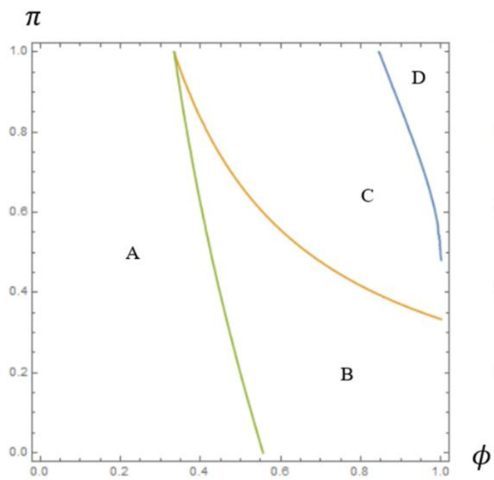
$$h_{2,t+1} = \frac{h_{1,t}}{(1+\beta)^2\left[\frac{1}{\theta}+\pi\phi\right]^2+\frac{1}{\theta}+\pi\phi}; G^F = \frac{h_{2,t+1}}{h_{1,t}} = \frac{\chi}{(1+\beta)^2\left[\frac{1}{\theta}+\pi\phi\right]^2+\frac{1}{\theta}+\pi\phi}. \quad (3.23)$$

To compare G^F with G^O, we define:

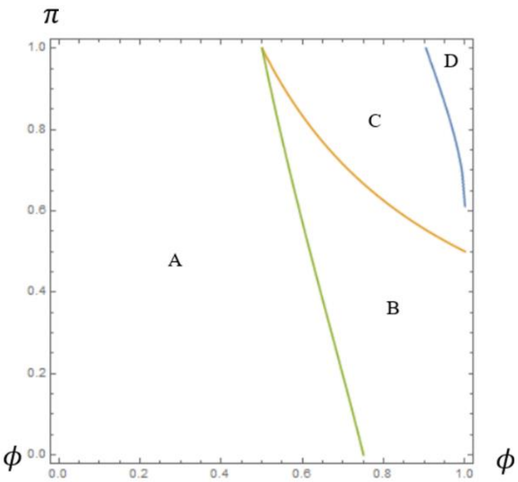
$$S = \frac{\chi}{G^F} - \frac{\chi}{G^O} = (1+\beta)^2\left(\frac{1}{\theta}+\pi\phi\right)^2 - \frac{(1+\beta)^2}{\left((1-\pi)+\pi\sqrt{1-\phi}\right)^2\theta^2} + \pi\phi. \quad (3.24)$$

The sign of S is ambiguous. For example, when $\pi = \phi = 0.8$, $\theta = 2$, $\beta = 0.2$, $\frac{1-\frac{1}{\theta}}{\phi} = \frac{1-\frac{1}{2}}{0.8} = 0.625 < \pi = 0.8$, so this individual is in the area above FIB and will choose full coverage. We get $S = 1.3524 > 0$, $G^F < G^O$. On the contrary, when $\pi \to 1^-, \phi \to 1^-$, $-\frac{(1+\beta)^2}{\left[(1-\pi)+\pi\sqrt{1-\phi}\right]^2\theta^2} \to -\infty, S < 0$, $G^F > G^O$.

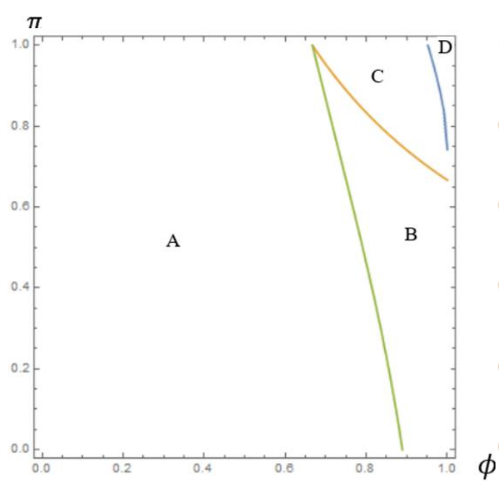
By the latter extreme example, we know that full IPI will surely increase human capital accumulation when individuals have an extremely bad health perspective.



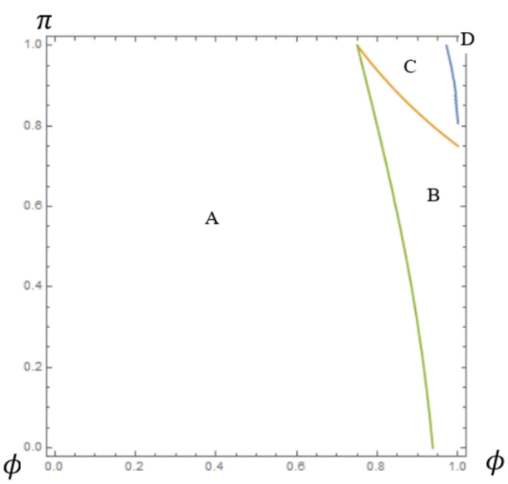
(a) $\theta = 1.5$



(b) $\theta = 2$



(c) $\theta = 3$



(d) $\theta = 4$

Figure 3.1 The relative positions of ZIB, FIB, and HEB

Proposition 3.4: For those individuals with extreme bad health perspectives, in other words, when $\pi \to 1^-, \phi \to 1^-$, they will always choose a full IPI covering all the risks, and IPI can increase their human capital accumulation in their second life periods.

The proof is shown in the above analysis.

The boundary where the IPI begins to enhance human capital accumulation, or human capital enhancing boundary (HEB) is influenced not only by π, ϕ, θ but also β. Moreover, the HEB is surely located beyond FIB. Figure 3.1 shows the relative location of ZIB, FIB, and HEB when $\beta = 0.2$ and $\theta = 1.5, 2, 3,$ and 4. The three curves from left to right are ZIB, FIB, and HEB. The three curves divide the whole area into four small areas: A, B, C, and D.

We notice that as θ increases, the ZIB, FIB and, HEB all move rightward when θ is extremely high; for example, when $\theta = 4$, all the three lines will crowd in a small area on the right, and most people will not want to invest in IPI. That means that as people can get higher returns from education, they will not want to sacrifice current insurance resources. Rather they would like to invest those resources in human capital accumulation.

If we know the distribution density function of individual health perspectives $f(\phi, \pi)$, we can get the total growth rate with and without IPI:

$$\mathrm{G}^{IT} = \iint_A G^O f(\phi,\pi) d\phi d\pi + \iint_B G^{EN} f(\phi,\pi) d\phi d\pi + \iint_C G^F f(\phi,\pi) d\phi d\pi + \iint_D G^F f(\phi,\pi) d\phi d\pi.$$

$$G^{OT} = \iint_{\substack{\pi\in(0,1)\\ \phi\in(0,1)}} G^O f(\phi,\pi) d\phi d\pi. \tag{3.25}$$

The total impact of IPI can be seen by comparing G^{IT} and G^{OT}.

For the whole economy, whether IPI is good or bad for economic growth depends on the whole population's distribution on life perspectives. For example, if most individuals in an economy located in areas A, B, C, or D, IPI's impact will be clear, shown in Figure 3.2 and Table 3.1. In our model, the economy does not have physical capital. As a result, even if individuals have free access to saving, those savings cannot be transferred to long-run economic growth.

Table 3.1 The preferred coverages and the impact of insurance on human capital in different areas

	A	B	C	D
Coverage	None	Partial	Full	Full
Impact	None	Negative	Negative	Positive

If the individuals are scattered in all four areas, things will become a bit complex. For example, if more individuals' perspectives are polarized: either very good or very bad, then individuals in area A or D, especially D, will have a higher weight in the whole economy, and the IPI will be more likely to enhance human capital growth, or at least not deter it, $G^{IT} > G^{OT}$. On the contrary, if more individuals have normal or moderate health perspectives: neither very good nor very bad, then individuals in area B and C will have a higher weight, and the IPI will be more likely to decrease human capital growth, $G^{IT} < G^{OT}$.

3.4 The robustness check

If individuals have free access to saving, they will have another option to finance the second-period consumption in their life. Depending on their health perspectives, we have the following results:

In area A, Individuals will neither save nor buy IPI (income protection insurance). In area B, Individuals will buy IPI but will not save. In other words, adding saving into the model will not change individuals' choices in those areas. Individuals will save but will not buy IPI or invest in human capital accumulation in area C and area D. In a word, allowing individuals in those countries to save will decrease human capital growth and economic growth because capital will not contribute to our model's economic growth.

3.5 Concluding remarks

Through our analysis, we can find the impact of IPI on human capital accumulation is related to individuals' health perspectives.

First, for individuals with relatively good health perspectives, IPI is not necessary. As a result, they will not buy IPI at all, and IPI affects their human capital choice.

Second, for individuals with moderate health perspectives, IPI can decrease their human capital investment. As a result, economic growth will be lower.

Third, for individuals with extremely bad health perspectives, IPI will increase their human capital investment. The economic growth will be larger than the case without IPI.

4 Human capital accumulation, income protection insurance, and poverty reduction in the least developed countries

4.1 Introduction

Until the last chapter, we have discussed IPI's impact on human capital and economic growth with the "no-saving" social restriction. Next, we can discuss the case where government interventions are also taken into consideration. Specifically, in our analysis, we allow the government to set some limitations on IPI coverage to achieve better economic growth.

The rest of this chapter is organized as follows. Section 4.2 presented the basic model, similar to the last chapter. Section 4.3 compared the freely-chosen IPI and growth-optimal IPI. Section 4.4 showed a numerical example. Section 4.5 got some concluding remarks.

4.2 The basic model

We build a discrete-time overlapping-generation model. The economy starts in period 0. All individuals live for two periods: young and old, denoted by 1 and 2, respectively. Those who spend their young period in period t are called generation t. In period 0, there are the initial old, each of whom has human capital, $h_{2,0}$. Here, the first subscript represents the period of the individuals' lives, and the second represents the period of the economy.

Imagine a developing economy where people get all their income based on their human capital. The healthcare system is underdeveloped, which means people who fall ill will lose working ability and income. Children learn their skills by watching their parents do their work. Adults improve their skills by spending money on their education and training.

Following Lu and Yanagihara (2013) and Liu (2020), we assume that the parents' human capital can be inherited by their children entirely. In the young period, generation t work with the human capital $h_{1,t}$, which is equal to the human capital of their parents, generation $t-1$, in the old period, $h_{2,t}$. Thus, the following holds:

$$h_{1,t} = h_{2,t}. \tag{4.1}$$

Based on this level of human capital, they get an income, which is assumed to be equal to their human capital. Individuals allocate their income to consumption in the young period, $c_{1,t}$And investment in human capital, $e_{1,t}$. Therefore, the budget constraint in the young period becomes:

$$c_{1,t} + e_{1,t} = h_{1,t}. \tag{4.2}$$

Here, we assume individuals finance their consumption in the old period only by investing in human capital. This assumption implies that there are no other storage tools. This assumption reflects the economic circumstances in some developing economies where people find it is difficult to save money.

The seemingly unrealistic assumption of no saving is based on Banerjee and Duflo's (2011) theory and research. People in the least developed economies cannot save for many reasons. First, they must endure continuous and intense financial stress in their everyday lives, making them more vulnerable when faced with short-run temptation. Second, their social networks tend to prevent them from saving. For example, they are forced to spend excess money on such things as weddings. Third, those economies' banking system is underdeveloped and unfriendly, making them prefer to put aside money at home. Funds held outside of the banking system are more vulnerable to a lack of self-control and adverse social circumstances.

We assume skills in their young period will be entirely outdated in the future. Thus, without further investment in human capital, people will have no skills in their old adult period. As with Krebs (2003) and Grossmann (2008), the human capital of generation t in their old period, $h_{2,t+1}$, is proportionally determined by the amount of education investment as:

$$h_{2,t+1} = \theta e_{1,t}, \tag{4.3}$$

where $\theta > 1$ is a parameter measuring education efficiency.

If there is no uncertainty in health, income will equal human capital in the old period. An individual will consume all his income so that the budget constraint in the old period will be:

$$c_{2,t+1} = h_{2,t+1}, \tag{4.4}$$

where $c_{2,t+1}$ refers to the consumption in the old period. The utility of generation t consists of consumption in two periods. Concretely, it is given by:

$$u\left(c_{1t}, c_{2,t+1}\right) = 2\sqrt{c_{1,t}} + 2\frac{\sqrt{c_{2,t+1}}}{1+\beta}, \tag{4.5}$$

where $\beta > 0$ is the discount rate.

To see the effect of IPI's introduction on human capital accumulation and economic growth more clearly, we begin our analysis from the baseline situation with no IPI.

Consider that individuals face uncertainty in their old period. If they are healthy, they can get a return from their human capital. On the contrary, if they become unhealthy, they will lose their ability to work and not return from their human capital. Therefore, a sick old individual will have no income. The consumption in the old period depends on their health status:

$$c_{2,t+1} = \begin{cases} h_{2,t+1}, if\ healthy \\ 0, if\ unhealthy \end{cases}. \tag{4.6}$$

Denoting the probability of being unhealthy as $\pi \in [0,1]$, the expected utility function will be:

$$E\left[u\left(c_{1t}, h_{2,t+1}\right)\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right]. \tag{4.7}$$

From (4.3) and (4.4), we can rewrite the budget constraint in the young period as:

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} = h_{1,t}. \tag{4.8}$$

Under given $h_{1,t}, \pi$ and θ, maximizing (4.7) subject to (4.8), we can obtain the utility-maximizing human capital level of the old period (which is equivalent to the one of the young period of the next period), and the growth rate of human capital:

$$h_{1,t+1} = h_{2,t+1} = h_{1,t}\left(\frac{1}{\frac{1}{\theta}+\frac{1}{\theta^2}\left(\frac{1+\beta}{1-\pi}\right)^2}\right), \tag{4.9}$$

$$G^O = \frac{h_{1,t+1}}{h_{1,t}} = \frac{h_{2,t+1}}{h_{1,t}} = \frac{1}{\frac{1}{\theta}+\frac{1}{\theta^2}\left(\frac{1+\beta}{1-\pi}\right)^2}. \tag{4.10}$$

Lemma 4.1： **Poverty trap conditions**. When $\frac{1}{\theta}+\frac{1}{\theta^2}\left(\frac{1+\beta}{1-\pi}\right)^2 > 1$, we get $G^O < 1$, the original economy will be in a poverty trap. Specifically, when $\beta > (1-\pi)\sqrt{\theta^2-\theta} - 1$, or we can say $\pi > 1 - \frac{1+\beta}{\sqrt{\theta^2-\theta}}$, or we can say $\theta < \frac{1}{2} + \sqrt{\left(\frac{1+\beta}{1-\pi}\right)^2 + \frac{1}{4}}$The economy will be trapped in poverty.

We can find if θ is small enough, or if β and π are big enough, G^O will be small enough. In other words, lower education efficiency, a higher subjective discount rate, or higher health risk can keep the economy in the poverty trap.

4.3 Freely-chosen IPI and growth-optimal IPI

Nowadays, in developed industrial countries, IPI is typically implemented as an industry-specific employment benefit, often bundled together with other benefits. When we bring IPI into impoverished economies, there are many things that we need to note. For instance, insurance in those regions is often provided by microfinance institutions (MFIs) instead of the government, so it cannot be compulsory. It should not be a tool to transfer incomes among people.

Readers may wonder how individuals can invest in IPI if they cannot save. Banerjee and Duflo (2011) showed that the poor could crystallize their income in some form, such as "building a house brick by brick." That shows that if we allow the poor to pay the premium by the month or by the week, IPI can be a feasible risk-management tool.

As we mainly discuss IPI's role in poverty reduction, it may be necessary to assume that the economy can escape the poverty trap and rule out the situation where poverty is destined.

Assumption 4.1: Individuals can get positive expected net returns from investing in education; i.e., $\theta(1-\pi)-1>0$.

Notice that $\delta^{EN}<1$ should hold, or $\theta(1-\pi)>1$, which means positive expected net returns from education. That is a necessary but not sufficient condition for an economy to escape the poverty trap. When $\theta(1-\pi)\leq 1$, even if individuals choose to invest all their income in the young period to education, there will be no such thing as "growth." So, for convenience, we should clarify that in our following analysis, that is also the case.

When individuals can choose their coverage δ freely, in the young period, they need to pay the premium $x_{1,t}$ according to the expected potential loss. We assume the interest rate is 0. So, according to the zero-profit condition, the premium should be:

$$\delta\pi h_{2,t+1}=x_{1,t}. \tag{4.11}$$

Then we have their budget constraint and expected utility function:

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} + \delta\pi h_{2,t+1} = h_{1,t}. \tag{4.12}$$

$$E\left[u\left(c_{1t}, h_{2,t+1}, \delta\right)\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right] + \frac{2}{1+\beta}\left[\pi\sqrt{\delta h_{2,t+1}}\right]. \tag{4.13}$$

If we maximize (4.13) subject to (4.12), we can have the following result:

$$\delta^{EN} = \frac{1}{\theta^2(1-\pi)^2}; h_{2,t+1}^{EN} = \frac{h_{1,t}}{\frac{(1+\beta)^2+\theta(1-\pi)^2+\pi}{\theta^2(1-\pi)^2}}; G^{EN} = \frac{1}{\frac{(1+\beta)^2+\theta(1-\pi)^2+\pi}{\theta^2(1-\pi)^2}}. \tag{4.14}$$

So, is the freely-chosen IPI helpful for long-time poverty reduction? To find that, we just need to compare G^{EN} and G^{O}.

Proposition 4.1: When individuals choose IPI coverage freely, the economic growth rate will be lower than the case without IPI.

Proof:

$$\frac{1}{G^{EN}} - \frac{1}{G^{O}} = \frac{(1+\beta)^2 + \theta(1-\pi)^2 + \pi}{\theta^2(1-\pi)^2} - \frac{1}{\theta} + \frac{1}{\theta^2}\left(\frac{1+\beta}{1-\pi}\right)^2 = \frac{\pi}{\theta^2(1-\pi)^2} > 0.$$

So, $G^{EN} < G^{O}$.■

The above analysis shows that abundant insurance services may not be a good thing for long-run poverty reduction because individuals may invest too much in insurance. Less money will be left for human capital accumulation.

In the least developed economies, such as those of India and Kenya, for example, the above case may be impossible because, in fact, those least developed economies usually do not have access to such an abundant insurance service. Usually, the problem is that people in those economies have little or no insurance in the face of risks (Banerjee & Duflo, 2011).

So, our next question is, if we increase the IPI insurance supply from little or none, will that increase, at least at some stage, economic growth? To investigate that, we need to change the coverage to an exogenous variable.

The expected utility function and budget constraint will be the same as before, except δ now is an exogenous variable:

$$c_{1,t} + \frac{h_{2,t+1}}{\theta} + \delta\pi h_{2,t+1} = h_{1,t}, \tag{4.15}$$

$$E\left[u\left(c_{1t}, h_{2,t+1}\right)\right] = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right] + \frac{2}{1+\beta}\left[\pi\sqrt{\delta h_{2,t+1}}\right], \tag{4.16}$$

Maximizing (16) subject to (15), we finally have:

$$h_{2,t+1}^{EX} = \frac{h_{1,t}}{\frac{(1+\beta)^2\left(\frac{1}{\theta}+\delta\pi\right)^2}{\left(1-\pi+\pi\sqrt{\delta}\right)^2}+\left(\frac{1}{\theta}+\delta\pi\right)}; G^{EX} = \frac{h_{1,t+1}}{h_{1,t}} = \frac{h_{2,t+1}^{PF}}{h_{1,t}} = \frac{1}{\frac{(1+\beta)^2\left(\frac{1}{\theta}+\delta\pi\right)^2}{\left(1-\pi+\pi\sqrt{\delta}\right)^2}+\left(\frac{1}{\theta}+\delta\pi\right)}, \tag{4.17}$$

Now we can see G^{EX} is influenced by the coverage δ. So, we need to find out whether there is a growth-optimal coverage $\delta = \delta^*$, which can maximize G^{EX}.

Proposition 4.2: There is a single IPI coverage $\delta^* \in [0,1]$ that corresponds to the maximum growth rate G_{MAX}^{EX}. The growth-optimal IPI can increase economic growth, that is, $G_{MAX}^{EX} > G^O$, and the growth-optimal coverage is smaller than freely-chosen coverage: $\delta^* < \delta^{EN}$.

Proof: See Appendix C.

The intuitive explanation is: IPI can guarantee the future return of human capital, but it takes money to implement. Before the growth-optimal coverage δ^*, as δ increases, the "guarantee effect" dominates; people will be willing to invest more in human capital because they can get at least some proportion of the future income. However, when δ exceeds δ^*, the "crowding-out effect" will dominate, people will have less money left to invest in education or training.

We should note that economic growth is not a concern for most individuals. When there is a chance to mitigate risk, individuals would want to take full advantage of the IPI to ensure the perfect combination of the two-period consumption to gain the highest utility. So, individuals would want to be safer than the growth-optimal coverage would allow them. By choosing higher coverage, too much money is spent on IPI, and less will left for education, the "crowding-out effect" will dominate the "guarantee effect." As a result, education investment with freely-chosen IPI would be lower than the original situation without IPI.

If we have the value of $\beta, \pi,$ and θ, we can get the value of δ^* in the implicit function F=0.

Proposition 4.3: The freely-chosen coverage δ^{EN} will decrease with education efficiency θ and increase with the unhealthy probability π. The freely-chosen coverage is independent of the discount rate. The growth-optimal coverage proportion of IPI is higher with a higher discount rate β, and it will be lower with a higher education efficiency θ.

Proof: See Appendix D.

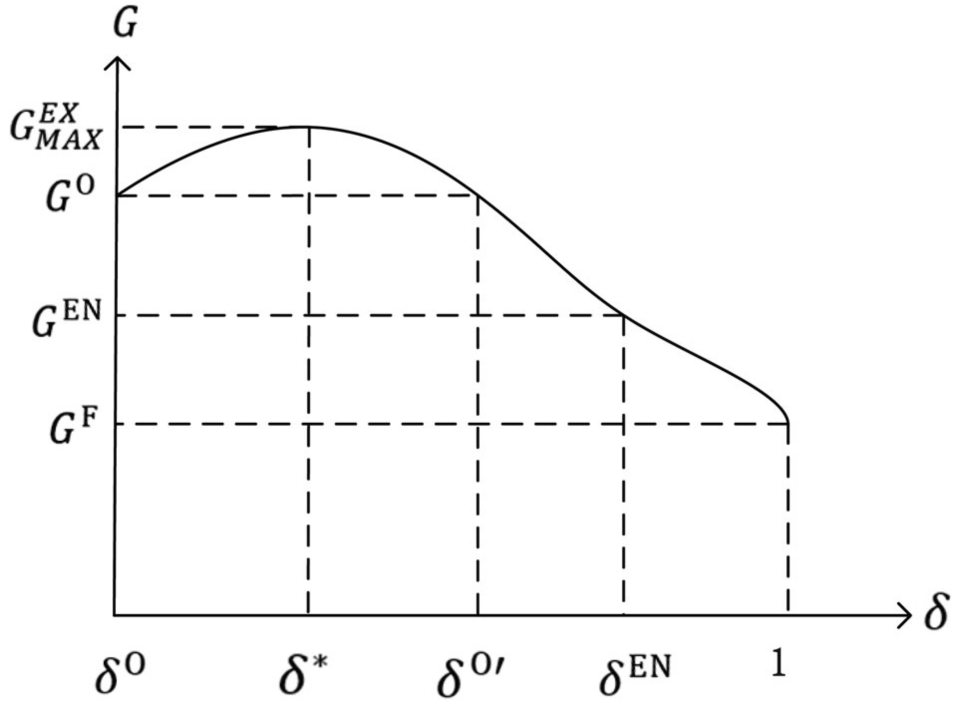


Figure 4.1 The IPI coverages and corresponding growth rates

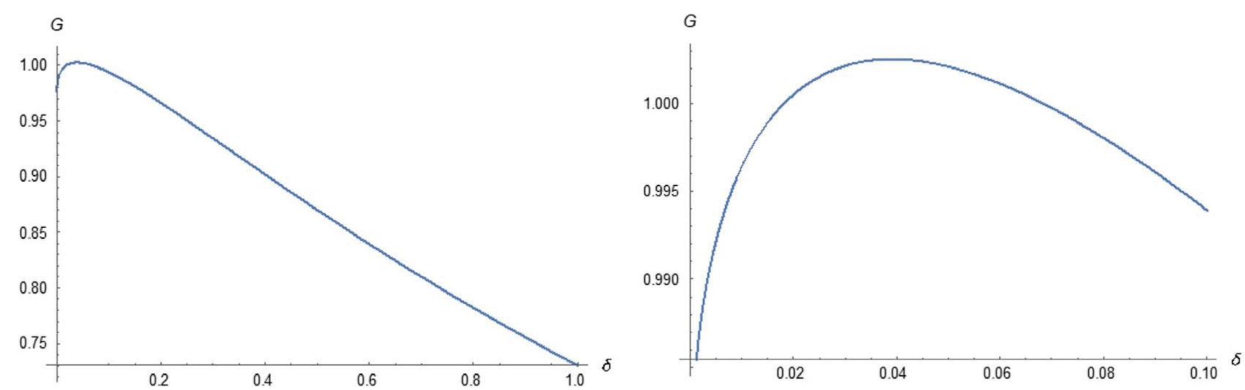


Figure 4.2 Growth rate when $\boldsymbol{\delta} \in [\mathbf{0}, \mathbf{1}]$ and when $\boldsymbol{\delta} \in [\mathbf{0}, \mathbf{0.1}]$, $\boldsymbol{\beta} = \mathbf{0.2}$, $\boldsymbol{\theta} = \mathbf{2.05}$, $\boldsymbol{\pi} = \mathbf{0.2}$

The intuition for δ^{EN} is as following: Higher θ and lower π mean a higher expected return from education. To invest in IPI, individuals would have to sacrifice their investment in education, which will be a higher loss with a higher expected return from education. So, in that situation, individuals would instead invest less money in IPI and invest more in education.

Now, we would like to discuss the welfare implication of a different IPI. Of course, the preferred individual IPI would yield the highest utility for individuals and the current generation's highest welfare. The growth-optimal IPI coverage is between 0 and preferred by individual IPI coverage to give the second-best welfare to the current generation. However, as the economy has infinite generations, if we consider future generations' welfare, it will be plausible for the government to sacrifice some current welfare to ensure continuous growth, especially when the economy is in a poverty trap.

4.4 A numerical example

To get some concrete impression of the above analysis, we present a numerical example. By setting $\beta = 0.2,$ $\theta = 2.05,$ and $\pi = 0.2$, we can get the optimal growth rate when $\delta \in [0,1]$ as shown in Figure 4.2.

When $\delta = 0,$ the growth rate is 0.977, which means human capital decreases over time. When $\delta = 1$, the growth rate becomes even lower: 0.730. In that situation, growth-optimal IPI will make a big difference. The maximum growth rate of 1.0025 can be obtained when we set $\delta = \delta^* = 0.039$. That is, growth-optimal IPI can help the economy escape the poverty trap.

What about the freely-chosen case? Now we get the freely-chosen coverage rate $\delta^{EN} = 0.372$. The corresponding growth rate is: $G^{EN} = 0.911$.

We find in this particular case, $0 < \delta^* < \delta^{EN} < 1,$ $G^{EN} < G^O < 1 < G^{EX}_{MAX}$. In other words, only the growth-optimal IPI can drive the economy out of the poverty trap, and the optimal growth-optimal coverage rate is smaller than the freely-chosen coverage rate, which is smaller than one.

4.5 Concluding remarks

We got some interesting findings through our analysis when we allow the government to control the IPI coverage. The "freely-chosen" and "growth-optimal" IPIs are different.

First, we can observe the changes in economic growth rates as the coverage of IPI changes. If the illness can cause a total income loss, some level of IPI is necessary to guarantee the return of human capital investment. The economic growth will first increase with IPI. However, as IPI will also need the current income to support, if IPI coverage is too higher, IPI's total effect can be a decrease in human capital investment.

Second, individuals tend to be safer than "growth-optimal" IPI allows them to be. As a result, government interventions will become necessary for IPI coverage limitations to achieve better economic growth. In that case, appropriate government interventions are not a bad thing for economic growth.

5 Conclusion

Through our analysis, we can get our main conclusions.

Chapter 2 discusses how government interventions can influence the zero-sum game in the higher education arms race. We got the following three findings:

(i) The education arms race, a zero-sum game, exacerbates the inefficient signaling problem of higher education and lowers graduates' average productivity. Of course, this means more social welfare loss and lower wages for graduates. (ii) Higher fertility rates can reduce the distortion due to the education arms race dramatically regardless of credentialism. Even in a society with extremely high credentialism, if we allow each family to choose the smartest child as the "proxy" to receive "vicarious education," we can reduce the impact of the education arms race on such an acceptable level. However, under the low fertility rate, especially under China's one-child policy, too many students are involved in the education arms race. The result is higher education inflation, a lower wage for graduates, and a social welfare loss. (iii) To overcome the education arms race problem, we do not need to increase the fertility rate too much. Under the "vicarious education" assumption, just two children in each family can mitigate that problem greatly. In other words, that problem will remain moderate when the fertility rate is above two children. However, if the fertility rate continues to decrease (which is also a big problem for most developed economies), that problem will become serious suddenly.

Chapter 3 discussed the human capital accumulation with a specific kind of insurance, IPI, and social restrictions that nobody can save. Through our analysis, we got the following six conclusions:

(i) From the healthiest to the most unhealthy, we can divide all individuals into 4 types: the healthiest, the second healthiest, the third healthiest, and the most unhealthy, each with different attitude towards IPI and IPI will influence their human capital accumulation differently; (ii) the healthiest individuals will choose no IPI, and IPI will not influence their human capital growth; (iii) the second healthiest individuals will choose partial IPI, and IPI will decrease their human capital accumulation; (iv) the third healthiest individuals will choose full IPI and IPI will decrease their human capital accumulation, and people will choose full life insurance when the net return from education is less than zero; (v) the individuals with the worst health will choose full IPI and IPI will increase their human capital accumulation; (vi) the impact of IPI on the human capital growth of the whole economy depends on health distribution, if more individuals have extreme health, especially extreme bad health, IPI tend to enhance human capital growth of the whole economy.

As for the policy implication, chapter 3 shows that if we bring IPI into those poor developing countries to reduce poverty, we need to consider the country's health distribution. For those countries with relatively bad health, such as in Western Africa (where the life expectancy is very low, only 56 for men and 58 for women, according to Statista), IPI will tend to improve economic growth and reduce poverty. For those countries with moderate health distribution, such as some country in Northern Africa (where the life expectancy is moderate, 71 for men and 74 for women, according to Statista), although IPI will surely improve current generations' welfare, it may deter the long-run economic growth and increase the long-run poverty due to the "crowding-out" effect.

Chapter 4 extended the overlapping generation model in Lu & Yanagihara's (2013) and Liu's (2020) research by allowing the government to restrict IPI coverage. We have the following findings:

(i) Under the assumption that an economy has the potential to escape from the poverty trap, and when illness means a total loss of income, we find that if individuals can choose IPI coverage freely, IPI will not help the economy escape from poverty. (ii) If we can raise the coverage from little or none to an optimal level, IPI will help the economy escape poverty. That growth-optimal coverage is lower than the coverage preferred by individuals. (iii) The coverage preferred by individuals will increase with unhealthy probability, decrease with education efficiency, and be independent of the discount rate; the optimal coverage proportion will increase with the discount rate and decrease with education efficiency.

Chapter 4 has implications for introducing IPI into developing countries.

(i) In the least developed economies where insurance markets are either non-existent or underdeveloped, just as in the interval $\delta \in (0, \delta^*)$ in Figure 4.1, higher coverage will enhance economic growth. As a result, it is necessary and beneficial for the government to implement some public insurance to give individuals more incentive to enhance their education and economic growth. (ii) Higher IPI coverage is not always a good thing for economic growth, and there is an optimal level. When the available IPI exceeds a certain point, $\delta > \delta^*$, the increase of IPI coverage will not help economic growth. Although this is a rare case in the developing world, too much insurance may slow down economic growth and keep an economy in poverty. In that situation, the government should set some benefit limitations to maximize economic growth.

From the above analysis, we get some general conclusions.

First, human capital accumulation under social restrictions and government interventions can differ from under free economy assumptions. We need to change the model's assumptions and setting from the very beginning to analyze those situations.

Second, generally, government interventions or social restrictions can cause distortion and social welfare loss, just like the one-child policy in China's case. As an implicit form of restriction, social circumstances will also limit an economy's growth and development.

Third, when there is already some distortion, government interventions, as a second-best solution, can help improve human capital accumulation and economic growth. In other words, the degree of welfare loss, underdevelopment, and inefficiency are not positively related to the number of distortions. The interaction of those distortions can make a big difference. Proper government intervention can mitigate the negative effects of other distortions.

Appendices

Appendix A

Maximizing (3.15) subject to (3.16), we can get the following Lagrangian function:

$$\mathcal{L} = 2\sqrt{c_{1,t}} + \frac{2}{1+\beta}\left[(1-\pi)\sqrt{h_{2,t+1}}\right] + \frac{2}{1+\beta}\left[\pi\sqrt{\delta\phi h_{2,t+1} + (1-\phi)h_{2,t+1}}\right]$$
$$+\lambda\left[c_{1,t} + \frac{h_{2,t+1}}{\theta} + \delta\pi\phi h_{2,t+1} - h_{1,t}\right]. \quad \text{(A1)}$$

When there are interior solutions, the first-order conditions should be:

$$\begin{cases} \frac{\partial\mathcal{L}}{\partial c_{1,t}} = \frac{1}{\sqrt{c_{1,t}}} + \lambda = 0 \\ \frac{\partial\mathcal{L}}{\partial h_{2,t+1}} = \frac{1-\pi}{1+\beta}\frac{1}{\sqrt{h_{2,t+1}}} + \frac{1}{1+\beta}\left[\pi\frac{\sqrt{\delta\phi+(1-\phi)}}{\sqrt{h_{2,t+1}}}\right] + \lambda\left[\frac{1}{\theta} + \delta\pi\phi\right] = 0 \\ \frac{\partial\mathcal{L}}{\partial\delta} = \frac{1}{1+\beta}\left[\pi\sqrt{h_{2,t+1}}\right]\frac{\phi}{\sqrt{\delta\phi+(1-\phi)}} + \lambda\pi\phi h_{2,t+1} = 0 \\ c_{1,t} + \frac{h_{2,t+1}}{\theta} + \delta\pi\phi h_{2,t+1} - h_{1,t} = 0 \end{cases}. \quad \text{(A2)}$$

From the second and third equation of (A2), we further have

$$\frac{1}{\left[\frac{1}{\theta}+\delta\pi\phi\right]}\left[(1-\pi) + \pi\sqrt{\delta\phi + (1-\phi)}\right] = \frac{1}{\sqrt{\delta\phi+(1-\phi)}}. \quad \text{(A3)}$$

After some transformation, we get

$$(1-\pi)\sqrt{\delta\phi + (1-\phi)} = \frac{1}{\theta} - \pi(1-\phi). \quad \text{(A4)}$$

However, if $\frac{1}{\theta} - \pi(1-\phi) < 0$, $(1-\pi)\sqrt{\delta\phi + (1-\phi)} > \frac{1}{\theta} - \pi(1-\phi)$, there is only a corner solution $\delta^{EN} = 0$.

When $\frac{1}{\theta} - \pi(1-\phi) \geq 0$, we can get the δ value:

$$\delta = \frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi)}{(1-\pi)^2\phi}. \tag{A5}$$

However, we must notice that $\delta^{EN} \in (0,1)$, so when

$$\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi) \leq 0. \tag{A6}$$

Or we can say, when

$$0 \leq \frac{1}{\theta} - \pi(1-\phi) \leq (1-\pi)\sqrt{1-\phi}. \tag{A7}$$

$\frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi)}{(1-\pi)^2\phi} < 0$, we can only have the corner solution $\delta^{EN} = 0$.

We can sum up the above two cases and get Proposition 3.1.

Appendix B

The proof of proposition 3:

We have got the endogenous coverage:

$$\delta^{EN} = \frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi)}{(1-\pi)^2\phi} \in (0,1), \tag{B1}$$

then human capital accumulation is:

$$h_{2,t+1} = \frac{h_{1,t}}{\frac{(1+\beta)^2\left[\frac{1}{\theta}+\delta\pi\phi\right]^2}{\left[(1-\pi)+\pi\sqrt{\delta\phi+(1-\phi)}\right]^2} + \frac{1}{\theta} + \delta\pi\phi}. \tag{B2}$$

Their personal human capital growth rate is:

$$G^{ENP} = \frac{h_{2,t+1}}{h_{1,t}} = \frac{1}{\frac{(1+\beta)^2\left[\frac{1}{\theta}+\delta\pi\phi\right]^2}{\left[(1-\pi)+\pi\sqrt{\delta\phi+(1-\phi)}\right]^2} + \frac{1}{\theta} + \delta\pi\phi}, \tag{B3}$$

where $\delta = \delta^{EN} = \frac{\left[\frac{1}{\theta} - \pi(1-\phi)\right]^2 - (1-\pi)^2(1-\phi)}{(1-\pi)^2\phi} \in (0,1)$

The human capital growth between generations is

$$G^{EN} = \frac{h_{2,t+1}}{\bar{h}_{2,t}} = \frac{\chi}{\frac{(1+\beta)^2\left[\frac{1}{\theta}+\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi\right]^2}{\left[(1-\pi)+\pi\frac{\frac{1}{\theta}-\pi(1-\phi)}{(1-\pi)}\right]^2} + \frac{1}{\theta} + \frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi}. \tag{B4}$$

It is convenient to compare the inverses:

$$\frac{\chi}{G^{EN}}-\frac{\chi}{G^{O}}$$
$$=\frac{(1+\beta)^2\left[\frac{1}{\theta}+\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi\right]^2}{\left[(1-\pi)+\pi\frac{\frac{1}{\theta}-\pi(1-\phi)}{(1-\pi)}\right]^2}+\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi-\frac{(1+\beta)^2}{\left[(1-\pi)+\pi\sqrt{1-\phi}\right]^2\theta^2}.$$

(B5)

We define

$$\frac{\frac{1}{\theta}-\pi(1-\phi)}{(1-\pi)}=x;\sqrt{1-\phi}=y, \tag{B6}$$

then we have

$$\frac{\chi}{G^{EN}}-\frac{\chi}{G^{O}}=\frac{(1+\beta)^2}{\theta^2}\left(\frac{1+(x^2-y^2)\pi\theta}{(1-\pi)+\pi x}-\frac{1}{(1-\pi)+\pi y}\right)+\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi. \tag{B7}$$

We define

$$T=\frac{1+(x^2-y^2)\pi\theta}{(1-\pi)+\pi x}-\frac{1}{(1-\pi)+\pi y}. \tag{B8}$$

Through transformation, we get

$$T=\frac{(x-y)\pi((x+y)\theta((1-\pi)+\pi y)-1)}{((1-\pi)+\pi x)((1-\pi)+\pi y)}. \tag{B9}$$

When $\delta=\delta^{EN}=\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2\phi}>0$, $\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)>0$, then

$$x - y = \frac{\frac{1}{\theta} - \pi(1-\phi)}{(1-\pi)} - \sqrt{1-\phi} > 0.$$

Also, $\big((1-\pi)+\pi x\big)\big((1-\pi)+\pi y\big) > 0$. So, the sign of T is the same with

$$Q = (x+y)\theta((1-\pi)+\pi y) - 1,$$

or

$$Q = \left(\frac{\frac{1}{\theta} - \pi(1-\phi)}{(1-\pi)} + \sqrt{1-\phi}\right)\theta\left[(1-\pi) + \pi\sqrt{1-\phi}\right] - 1.$$

We define $t = \sqrt{1-\phi}$

$$Q = \left(\frac{1}{(1-\pi)} - \frac{\pi t^2}{1-\pi}\theta + \theta t\right)\big((1-\pi)+\pi t\big) - 1.$$

Through transformation, we know when $Q = 0$

$$Q = t\frac{\pi + \theta - 2\pi\theta + \pi^2(1-t^2)\theta}{1-\pi} = 0.$$

We know that $\phi = 1 - t^2$, and we know the minimum ϕ (when $\pi = 1$) that individual choose to buy IPI is: $\underline{\phi} = 1 - \frac{1}{\theta}$, so we know

$$\pi + \theta - 2\pi\theta + \pi^2\theta\phi \geq \pi + \theta - 2\pi\theta + \pi^2\theta\left(1 - \frac{1}{\theta}\right) = \pi - \pi^2 + \theta(1-\pi)^2.$$

When $\pi \in (0,1)$,

$$\pi - \pi^2 + \theta(1-\pi)^2 > 0,$$

$$\pi + \theta - 2\pi\theta + \pi^2\theta\phi > 0.$$

When $t = \sqrt{1-\phi} \in (0,1)$

$$Q = t\,\frac{\pi+\theta-2\pi\theta+\pi^2(1-t^2)\theta}{1-\pi} > 0,$$

$$T > 0,$$

Also, we know

$$\frac{\left[\frac{1}{\theta}-\pi(1-\phi)\right]^2-(1-\pi)^2(1-\phi)}{(1-\pi)^2}\pi > 0.$$

As a result, $\frac{1}{G^{EN}} - \frac{1}{G^{O}} > 0$, $G^{EN} < G^{O}$ ■

Appendix C

We define $\mathrm{K} = \frac{1}{G^{EX}}$

$$\frac{\partial K}{\partial \delta} = (1+\beta)^2 \frac{2\left(\frac{1}{\theta}+\delta\pi\right)\pi\left(1-\pi+\pi\sqrt{\delta}\right) - \left(\frac{1}{\theta}+\delta\pi\right)^2 \pi \frac{1}{\sqrt{\delta}}}{\left(1-\pi+\pi\sqrt{\delta}\right)^3} + \pi,$$

we define

$$(1+\beta)^2 = Q > 1,$$

$$\frac{\partial K}{\partial \delta} = \frac{\pi[2\left(\frac{1}{\theta}+\delta\pi\right)\left(1-\pi+\pi\sqrt{\delta}\right)Q - \left(\frac{1}{\theta}+\delta\pi\right)^2 \frac{1}{\sqrt{\delta}} Q + \left(1-\pi+\pi\sqrt{\delta}\right)^3]}{\left(1-\pi+\pi\sqrt{\delta}\right)^3},$$

then, we define

$$F = 2\left(\frac{1}{\theta}+\pi t^2\right)(1-\pi+\pi t)Q - \left(\frac{1}{\theta}+\pi t^2\right)^2 \frac{1}{t} Q + (1-\pi+\pi t)^3.$$

$$\mathrm{t} = \sqrt{\delta} \in [0,1].$$

F is increasing in t because

$$\frac{\partial \mathrm{F}}{\partial t} = 3\pi(1+\pi(-1+t))^2 + 4\pi Q t(1-\pi) + 3\pi^2 Q t^2 + \frac{Q}{t^2\theta^2} > 0.$$

$$F_{t\to 0^+} = 2\left(\frac{1}{\theta}\right)(1-\pi)Q - \left(\frac{1}{\theta}\right)^2 \frac{1}{t} Q + (1-\pi)^3 = -\infty < 0.$$

$$F_{t=1} = 2\left(\frac{1}{\theta} + \pi\right) Q - \left(\frac{1}{\theta} + \pi\right)^2 Q + 1 = \left(\frac{1}{\theta} + \pi\right) Q \left[2 - \left(\frac{1}{\theta} + \pi\right)\right] + 1 > 0.$$

So, there is only one single $\hat{t} = \sqrt{\delta^*} \in (0,1)$ to make $\hat{F} = 0$, $\frac{\partial K}{\partial \delta} = 0$, which is corresponding to the minimum K and maximum G^{EX}. So, we get $G^{EX} > G^{O}$.

From the above analysis, we know that as the coverage proportion δ increases, the growth rate G will increase first, peak in δ^*, and then drop, as shown in Figure 4.1.

As $G^{EN} < G^{O} < G_{MAX}^{EX}$, the freely-chosen coverage proportion will be located between 1 and $\delta^{O\prime}$, where $\delta^{O\prime}$ is the coverage that makes the growth rate the same as G^{O}.■

Appendix D

From the expression of freely chosen IPI coverage $\delta^{EN} = \frac{1}{\theta^2(1-\pi)^2}$, we can get the results about freely-chosen IPI coverage directly: The freely-chosen coverage δ^{EN} will decrease with education efficiency θ and increase with the unhealthy probability π.

As for the growth-optimal IPI coverage δ^*, following Appendix I, we know $\sqrt{\delta^*} = \hat{t}$

$$F_{\delta=\delta^*} = 2\left(\frac{1}{\theta} + \pi\hat{t}^2\right)(1-\pi+\pi\hat{t})Q - \left(\frac{1}{\theta} + \pi\hat{t}^2\right)^2 \frac{1}{\hat{t}} Q + (1-\pi+\pi\hat{t})^3 = 0,$$

$$\frac{\partial F}{\partial Q}_{\delta=\delta^*} = 2\left(\frac{1}{\theta} + \pi t^2\right)(1-\pi+\pi t) - \left(\frac{1}{\theta} + \pi t^2\right)^2 \frac{1}{t} = -\frac{(1-\pi+\pi\hat{t})^3}{Q}.$$

As $(1+\beta)^2 = Q > 0$, $(1-\pi+\pi\hat{t})^3 > 0$. So, $\frac{\partial F}{\partial Q}_{\delta=\delta^*} < 0$. Finally, we have $\frac{\partial F}{\partial \beta}_{\delta=\delta^*} < 0$

That means in the critical point, with higher β (which means higher Q), F will be lower than $F_{\delta=\delta^*} = 0$, as F is monotonically increasing with δ, as shown in Figure D1 if F is lower than 0 in the original δ^*, the new optimal δ_1^* can only be reached in a higher value, and the intersection of F_1 and the x-axis is to the right of the intersection of F_0 and x. So, $\delta_1^* > \delta^*$.

A higher discounting rate β means a higher optimal coverage proportion, vice versa.

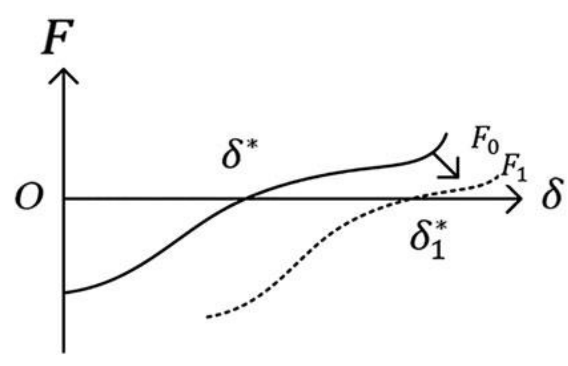


Figure D1 Growth-optimal coverage and discount rate

Similarly, we define $\frac{1}{\theta} = s$

$$F_{\delta=\delta^*} = 2(s+\pi\hat{t}^2)(1-\pi+\pi\hat{t})Q - (s+\pi\hat{t}^2)^2\frac{1}{\hat{t}}Q + (1-\pi+\pi\hat{t})^3 = 0.$$

$$\frac{\partial \mathrm{F}}{\partial \mathrm{s}}_{\delta=\delta^*} = 2(1-\pi+\pi\hat{t})Q - 2(s+\pi\hat{t}^2)\frac{1}{\hat{t}}Q = 2Q\left(1-\pi-\frac{s}{\hat{t}}\right),$$

as $2Q > 0,\ 1-\pi-\frac{s}{\hat{t}} = 1-\pi-\frac{1}{\sqrt{\delta^*}\theta}$,

We know $\delta^* < \frac{1}{\theta^2(1-\pi)^2} = \delta^{EN}$, so,

$$\frac{1}{\sqrt{\delta^*}\theta} > 1-\pi, 1-\pi-\frac{s}{\hat{t}} < 0,$$

$$\frac{\partial \mathrm{F}}{\partial \mathrm{s}}_{\delta=\delta^*} < 0, \frac{\partial \mathrm{F}}{\partial \theta}_{\delta=\delta^*} > 0,$$

as θ is the inverse of s.

As we can see in Figure D2, that is equivalent to: as θ increases, F will move upward to F_2, the new intersection will be at $\delta = \delta_2^* < \delta^*$.

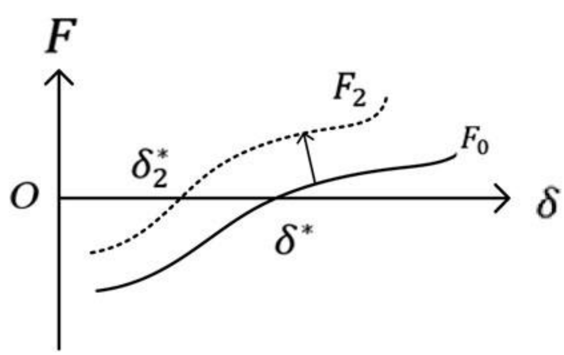


Figure D2 Growth-optimal coverage and education efficiency

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