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Abstract

This paper develops a dynamic dual-economy model and examines how the long-run outcome of an economy depends on the initial distribution of wealth and sectoral productivity. It is shown that, for fast transformation into a developed economy, the initial distribution must be such that extreme poverty is not prevalent so that most people can take education to acquire basic skills and the size of "middle class" is enough so that an adequate number of people can access education to acquire advanced skills. Both conditions seem to have held in successful East Asian nations, where, as in the model economy undergoing such transformation, the fraction of workers with advanced skills rose greatly and inequalities between these workers and others fell over time. In contrast, if the former condition holds but the latter does not, which would be the case for many nations falling into "middle income trap", consistent with facts, the fraction of workers with basic skills and the share of the modern sector rise, but inequality between workers with advanced skills and with basic skills worsens and the traditional sector remains for long periods. If the former condition does not hold, which would be true for poorest economies, the dual structure and large inequality between workers without basic skills and others persist for very long periods. Consistently, Hanushek and Woessmann (2009) find that both the share of students with basic skills and that of top performance have significant effects on economic growth that are *complementary each other*.

JEL Classification Numbers: I25, J31, O15, O17

Keyword: dual economy, modernization, education, wealth distribution

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1 Introduction

In the post-WWII era, most developing economies had decent but not spectacular growth. Except some oil-rich nations, only a small number of economies in East Asia and Europe had persistent high growth and evolved into developed economies. With current income levels and growth trends, the great majority of developing economies are unlikely to achieve such transformation in near future.

The following facts on typical developing nations would corroborate such negative prospect. First, the dual economic structure, i.e. the coexistence of the modern/formal sector characterized by advanced technology, large establishment sizes, skilled jobs, and high wages, and the traditional/informal sector with the contrasting features, is persistent (La Porta and Shleifer, 2008; OECD, 2009).[1,2] Second, although average years of schooling rose greatly, quality of education remains low and thus *skill* accumulation, especially the growth of the share of high-skill workers, seems to be modest, judging from persistent enormous gaps in cognitive skills with developed nations (Hanushek and Woessmann, 2008).[3] Third, while wage inequality between workers with and without basic skills (essential skills taught at the primary and secondary education level) fell greatly, the inequality between workers with basic skills and with advanced skills rose over time (Colclough, Kingdon, and Patrinos, 2010).[4] This might indicate that basic education has become less effective in mitigating poverty and taking further education, especially of good quality, is increasingly difficult for the poor.

Why is the growth experience of typical developing economies unspectacular? How is it

[1]To be exact, the modern-traditional classification is mainly based on technologies, while the formal-informal one is mainly based on official registrations of businesses, so they are distinct. Firms with modern technology may choose the informal sector due to heavy regulations or taxation (OECD, 2009).

[2]The traditional/informal sector can be divided into the urban informal sector, traditional agriculture, and the household production sector (see footnote 7). Rapid urbanization lowered the share of agricultural employment significantly, but it did not raise the share of the modern/formal sector greatly in many countries. According to OECD (2009), informal employment, defined as the sum of urban informal-sector employment and formal-sector one without social protection (such as social security benefits) accounts for the majority of non-agricultural employment in developing economies.

[3]According to Hanushek and Woessmann (2008), the share of students without basic literacy in cognitive skills is more than 30% (as high as 82%) in most developing nations, while it is less than 10% (as low as 3%) in developed nations. Further, the share of high-performing students in the skills is more than 10% (as high as 22%) in most developed nations, while it is *less than 1%* (as low as 0.1%) in many developing nations. Reviewing the literature, they conclude that there is compelling evidence that cognitive skills, *rather than mere school attainment*, are strongly related to individual earnings and economic growth.

[4]Colclough, Kingdon, and Patrinos (2010) combine estimated returns to education in developing nations from recent cross-section studies (32 studies for 35 countries) with those from earlier studies (more than 100 studies using data from the 1960s to early 1990s), and find that, on average, the return to primary education fell rapidly over time and became lower than post-primary returns, which, particularly the return to tertiary education, fell very moderately. Since quality of education deteriorated over time in most developing nations due to rapid population growth under harsh budget, *quality-adjusted returns* to advanced education seem to have risen. They also review a limited number of country studies using time-series data after the 1980s, which find that the return to tertiary education *rose greatly* and the one to primary education fell.

related to the facts on economic structure, skill accumulation, and inequality? What differentiates a small number of the successful economies from them? To tackle these questions, this paper develops a dynamic dual-economy model and examines how the long-run outcome of an economy depends on the initial distribution of wealth and sectoral productivity.

It is shown that, for fast transformation into a developed economy, the initial distribution must be such that extreme poverty is not prevalent and the size of "middle class" is enough. Both conditions seem to have held in successful East Asian nations largely because of extensive land redistribution and effective public school system, where, as in the model economy undergoing such transformation, inequality between workers with advanced skills and others fell over time (Wood, 1994). In contrast, if the former condition holds but the latter does not, which would be the case for many economies falling into "middle income trap", the fraction of workers with basic skills and the share of the modern sector rise greatly, but the fraction of workers with advanced skills grows only moderately, inequality between these workers and those with basic skills worsens, and the traditional sector remains for long periods, consistent with the above facts.[5] If the former condition does not hold, which would be true for poorest economies, the dual structure and large inequality between workers without basic skills and others persist for very long periods.

The analysis is based on a deterministic small-open OLG economy populated by a continuum of two-period-lived individuals. In childhood, an individual receives a transfer from her parent and spends it on assets and education. She must take basic education, which corresponds to school and non-school education needed to acquire essential skills taught at the primary and secondary education level in real economy, to become a middle-skill worker, and more-costly advanced education to become a high-skill worker.[6] No credit market for education investment exists, so she cannot invest more than the received transfer. Since she can spend wealth on assets too, she spends on education only if it is financially accessible *and* profitable. In adulthood, she obtains income from assets and work and spends it on *basic consumption*, *non-basic consumption*, and a transfer to her single child.

The economy is composed of *up to* two sectors, the *modern sector* producing good M and the *traditional sector* producing good T. The modern sector using advanced technology employs high-skill and middle-skill workers, and the traditional sector employs low-skill workers. Both goods can be used for basic consumption, while only good M can be used for non-basic consumption. In other words, goods for basic needs, such as clothing, food,

[5] Although skill-biased technical change is a possible contributor to the increasing inequality in recent years, particularly in middle-income economies, Colclough, Kingdon, and Patrinos (2010) find that this trend started well before IT technologies became economically important (see footnote 4).

[6] Thus, in an economy where quality of school education is low, a large part of the cost of basic (advanced) education is spending on non-school education such as private tutoring and education at cram school.

and shelter, can be produced using either technology, while the advanced technology is required to produce goods such as electric appliances and IT gadgets. It is assumed that good M is tradable and good T is nontradable. The traditional sector produces goods for basic needs using primitive technology, thus it corresponds to the urban informal sector, traditional agriculture, and the household production sector in real economy, all of which supply goods mainly for domestic markets.[7] By contrast, the modern sector corresponds to modern manufacturing and commercial agriculture, which compete more directly with foreign producers. If good T is relatively cheap, only the traditional sector supplies goods for basic consumption, otherwise, the modern sector too or only the sector does.

Because the distribution of wealth in the initial period is unequal and the inequality is transmitted intergenerationally through transfers, generally, individuals are heterogeneous in accessibility to two types of education. Hence, those without enough wealth cannot take basic or advanced education even if the return to the education net of its cost is positive. Their descendants, however, may become accessible to it if enough wealth is accumulated. (Opposite is true for descendants of relatively wealthy individuals.)

Main results, which are concerned with the situation where sectoral productivities are not very low, are summarized as follows. First, the model has four types of steady states, which are different in proportions of the *poor* (those who cannot access advanced education) and the *extreme poor* (those who cannot access basic education), wage inequality, the size of the traditional sector, etc. The best steady state (in terms of aggregate output, aggregate net income, and average utility) has features of a typical developed economy: no poverty (universal access to advanced education), low wage inequality (wages net of education costs are equal), high relative price of basic consumption, and no traditional sector (thus goods for basic consumption are totally supplied by the modern sector).[8,9] Other three types of steady states share the contrasting features, but differ in characteristics of poverty and wage inequality: in one type, no extreme poverty (universal access to basic education) but prevalent mild poverty, and high inequality between high-skill workers and others and low inequality between middle-skill and low-skill workers, features of many middle-income economies; in another type, no mild poverty (those who can access basic education can afford advanced education) but widespread extreme poverty, and high inequality between

[7] The urban informal sector supplies basic nontradable services, such as petty trading of commodities and basic meals, and basic manufacturing goods mostly for domestic markets. Traditional agriculture is operated on a small scale by family farms and produces agricultural products mainly for basic needs of domestic consumers. And, the household sector produces basic goods and services mostly for self-consumption.

[8] Since net returns of two types of education are equal, some individuals just take basic education.

[9] Although wage inequality rose in most developed economies in recent decades, the level of the inequality is still much lower than a typical developing economy. Further, the cost of higher education too rose greatly in many of the economies, thus disparities in wages *net of education costs* enlarged more moderately.

low-skill workers and others and low inequality between high-skill and middle-skill workers; in yet another type, as observed in poorest economies, pervasive extreme and mild poverty and typically high inequalities among the three types of workers.

Second, to which type of steady states the economy converges depends on the initial distribution of wealth. In particular, for the best steady state to be realized, the initial distribution must be such that the extreme poor are not large in number and the non-poor must be enough relative to the poor.[10] If the initial size of the extreme poor is large, the dual structure and large inequality between low-skill workers and others (especially, high-skill workers) remain in the long run, i.e. the economy converges to either of the last two types of steady states. If its size is not large but the non-poor are scarce relative to the poor, the fraction of middle-skill workers and the share of the modern sector rise, and inequality between middle-skill and low-skill workers shrinks over time. However, inequality between high-skill and middle-skill workers worsens, and typically the traditional sector remains in the long run, i.e. the economy converges to the second type.

These results are obtained from the model with time-invariant sectoral productivities. When the productivity of the modern sector grows continuously over time, ultimately, the economy converges to the best steady state from any initial condition, but the speed of convergence depends critically on the initial condition and thus the qualitative results of the constant productivity case hold approximately. Hence, as stated earlier, the model can explain the facts described at the beginning.[11]

The main implication is that, for fast modernization of an economy, the initial distribution of wealth must be such that extreme poverty is not prevalent so that most people can afford education to acquire basic skills and the size of "middle class" is enough so that an adequate number of people can afford education to acquire advanced skills. Consistent with this and the above results, Hanushek and Woessmann (2009), using data on international tests for 50 countries, find that both the share of students with basic skills and that of top performance have significant effects on economic growth that are *complementary each other*. The model provides a sectoral-shift-based explanation for their finding. The model's implications are also consistent with findings by Deininger and Olinto (2000) on relations

[10]Note, however, that the economy *can* converge to the second and third types of steady states too, depending on details of the initial distribution. The best steady state is more likely to be reached as the size of the very poor is smaller and the proportion of the non-poor to the poor is higher.

[11]The paper also examines the case where sectoral productivities are very low initially and grow over time. When the modern sector's productivity is very low, the best steady state does not exist and, even with a good initial condition, the fraction of high-skill workers is constant (that of middle-skill workers rises) and inequality between high-skill and middle-skill workers (low-skill workers too after some point) worsens. After the productivity reaches a certain level, however, the fraction rises, the inequality falls, and the economy converges to the best steady state. The dynamics may resemble experiences of many developed economies.

among initial inequality, education, and growth, Easterly (2001) on the importance of the size of middle class in education and development, and La Porta and Shleifer (2008) on the importance of educated managers in the expansion of the modern sector.[12]

In contrast, Galor, Moav, and Vollrath (2009) argue that, land inequality negatively affects the implementation of public schooling and structural change, whereas capital inequality among the landless has *no* effect and greater capital holdings by large landlords have a *positive* effect. They develop a model in which human capital is important in manufacturing, but not in agriculture, and its accumulation is determined by public expenditure on education whose level must be agreed by all groups, landowners, capitalists, and workers. While the latter two groups support public schooling, landowners oppose it, unless their capital wealth becomes large enough. A threshold wealth level for public education increases with land inequality. They show that the implication that land inequality adversely affects educational expenditures holds for U.S. state-level data in the period 1880–1940. The present model and their model have different implications on structural change, which could be empirically distinguished, as discussed in the result section.

A direct policy implication is that large-scale wealth redistribution is very effective in changing the fate of an economy, but such policy would be very difficult to be implemented in normal times: successful East Asian economies executed large-scale land redistribution after a major war. More realistically, the government can subsidize education, improve quality of public schools (so that spending on costly private schools, study materials, or tutoring ceases to be crucial to acquire skill), and develop financial markets, all of which ease the financial burden of education to parents, and raise the modern sector's productivity, which raises wages of both sectors. Under present conditions of developing countries, these policies cannot be performed on large enough scales to negate the importance of the initial condition on the dynamics, but they can speed up convergence to the best steady state. Which level of education should be prioritized in the subsidy policy depends on the initial condition.

The model abstracts from physical capital accumulation and population growth for tractability and the focus on education and structural change. By contrast, Galor and Moav (2004, 2006) develop models in which human capital accumulation starts only after physical capital is accumulated enough in the course of development, and unified growth theories surveyed in Galor (2005) model interactions among population growth, human capital

[12] Deininger and Olinto (2000) find that growth is affected negatively by initial land inequality and positively by mean years of schooling, which in turn is negatively affected by the initial inequality. Easterly (2001) finds that a greater size of middle class, measured as the share of income held by second through fourth quintiles of the distribution, is associated with more education, higher income, and higher growth. La Porta and Shleifer (2008) find a large difference between formal and informal firms in the human capital of managers and indicates that this drives other differences such as the quality of inputs and access to finance.

accumulation, and technological change to explain the transition from Malthusian stagnation to modern economic growth. The last part of the paper discusses how they would affect results. Consistent with their works, the full modernization of an economy would not be possible while the level of physical capital is low or population growth is rapid.

Aside from these works, this paper is related to the theoretical literature on dual economy models, such as Galor and Zeira (1993), Banerjee and Newman (1998), Lucas (2004), Wang and Xie (2004), Proto (2007), Yuki (2007, 2008), Vollrath (2009), and Gersback and Siemens (2010).[13] Banerjee and Newman (1998) examine implications of differences in technological and institutional conditions between rural traditional and urban modern sectors for development and urbanization. Lucas (2004) examines rural-urban migration in a model where urban workers allocate time between human capital accumulation and production. Wang and Xie (2004) explore factors affecting the activation of a modern industry using a static two-sector model with non-homothetic preferences and uncompensated spillovers in the IRS modern sector. Based on a three-sector (agrarian, manufacturing, and informal) model, Proto (2007) analyzes how the initial number of unskilled landless workers, through its effect on their bargaining power against landlords and land rents, determines wealth and human capital accumulations and development. Vollrath (2009) shows that the marginal product of labor in the modern sector can be higher than in the traditional sector and such allocation is welfare-maximizing based on a model in which individuals allocate time between market and non-market activities. Gersback and Siemens (2010) examine effects of land redistribution on education and development using a dynamic two-sector model.

The more closely related are Galor and Zeira (1993) and Yuki (2007, 2008), which develop dual economy models where, as in this paper, lumpy skill investment is constrained by intergenerational transfers motivated by impure altruism and examine the relationship between initial distribution and long-run outcome.[14] Unlike the present paper, however, the type of education (skill investment) is single, and either the traditional sector produces the same good as the modern sector (Galor and Zeira) or only the sector produce goods for basic consumption (Yuki). Their models cannot explore different roles basic education and advanced education play in structural change and development. Further, they cannot capture the shift of the production of goods for basic consumption from the traditional sector to the modern sector with development, which is universally observed in real economy: in the models of Yuki (2007, 2008), the traditional sector remains even in the best steady state.

[13] This paper is also related to the theoretical literature on structural change, which concerns the shift from agriculture to manufacturing and services in the process of development, such as Laitner (2000), Kongsamut, Rebelo, and Xie (2001), Hansen and Prescott (2002), Ngai and Pissarides (2007), and Akbulut (2011).

[14] McDonald and Zhang (2012) examine the effect of inequality on growth using a one-sector dynastic model with bequests and human capital accumulation (tractable due to a focus on household production).

The paper is somewhat related to the empirical literature showing the existence of multiple growth paths, such as van Paap, Franses, and Dijk (2005) and Owen, Videras, and Davis (2009). Also, Alfo, Trovato, and Waldman (2008) find that countries can be clustered into groups with different per capita GDP levels and with no sign of convergence across groups.

The paper is organized as follows. Since the model is a sequence of quasi-static economies in which single generations make decisions, for ease of presentation, Section 2 presents and analyzes the model without taking into account intergenerational linkages, then Section 3 considers the linkages. Section 4 analyzes the model and derives and discusses main results, and Section 5 concludes. Appendix B contains proofs of lemmas and propositions.

2 Model

Although the model is dynamic, it is a sequence of quasi-static economies in which single generations make decisions. Thus, this section presents and analyzes the model without taking into account intergenerational linkages, which are considered in the next section.[15]

2.1 Setup

Consider a deterministic, discrete-time, and small-open OLG economy inhabited by a continuum of two-period-lived individuals. Each adult has a single child and thus the population is constant over time. The population of each generation is normalized to be 1.

Lifetime of an individual: In childhood, individual i receives a transfer b^i from her parent and spends it on assets a^i and education to maximize future income. She must take basic education (costs e_m), which corresponds to school and non-school education needed to acquire essential skills taught at the primary and secondary education level in real economy, to become a middle-skill worker, and advanced education (costs $e_h > e_m$) to become a high-skill worker.[16] If she spends e_j $(j = h, m)$ on education, $a^i = b^i - e_j$, and $a^i = b^i$ if not. Since no credit market exists for education investment, she cannot invest more than b^i, i.e. $a^i \geq 0$.

In adulthood, she obtains income from assets and work and spends it on *basic consumption* c_B^i, *non-basic consumption* c_N^i, and a transfer to her single child $(b^i)'$. A unit of non-basic consumption is a numeraire. Characteristics of the two types of consumption are explained later. She maximizes the Cobb-Douglas utility subject to the budget constraint:

$$\max \; U = (c_B^i)^{\gamma_B} (c_N^i)^{\gamma_N} [(b^i)']^{\gamma_b}, \;\; \gamma_i \in (0,1), \;\; \gamma_B + \gamma_N + \gamma_b = 1, \tag{1}$$

$$s.t. \quad P c_B^i + c_N^i + (b^i)' = w^i + (1+r) a^i, \tag{2}$$

[15] All variables are presented without time subscripts in this section.

[16] The cost of advanced education includes the cost of acquiring skills at the basic education level. In an economy where quality of school education is low, a large part of the cost of basic or advanced education is spending on non-school education such as private tutoring and education at cram school.

where P is the relative price of basic consumption and w^i is her gross wage. By solving the maximization problem, the following consumption and transfer rules are obtained.

$$Pc_B^i = \gamma_B[w^i + (1+r)a^i], \tag{3}$$

$$c_N^i = \gamma_N[w^i + (1+r)a^i], \tag{4}$$

$$(b^i)' = \gamma_b[w^i + (1+r)a^i]. \tag{5}$$

Production: The small open economy (thus interest rate r is exogenous) is composed of *up to* two sectors, the modern sector producing good M and the traditional sector producing good T. The modern sector, which utilizes advanced technology, employs high-skill and middle-skill workers, and the traditional sector using primitive technology employs low-skill workers.[17] Production functions of the two sectors are:

$$Y_M = A_M(L_h)^\alpha(L_m)^{1-\alpha}, \quad \alpha \in (0,1), \tag{6}$$

$$Y_T = A_T L_l, \tag{7}$$

where L_h, L_m, and L_l are numbers of high-skill, middle-skill, and low-skill workers respectively, and A_i $(i = M, T)$ is the exogenous productivity of sector i.[18]

Characteristics of goods and consumption: Both good M and good T can be used for basic consumption, while only good M can be used for non-basic consumption. In other words, goods for basic needs, such as clothing, food, and shelter, can be produced using either technology, while goods such as cars, electric appliances, and IT gadgets can be produced using the advanced technology only. Specifically, a unit of basic consumption can be fulfilled by the consumption of either a unit of good T or θ units of good M. The unit of measurement of non-basic consumption is good M, so $P \leq \theta$ must hold.[19]

Assume that good M is tradable and good T is nontradable. The assumption would be better understood by associating the two sectors with sectors in real economy. The traditional sector produces consumption goods for basic needs using primitive technology, thus it corresponds to the urban informal sector, traditional agriculture, and the household sector. The urban informal sector supplies basic nontradable services (such as the retail of commodi-

[17]Ray (1998, pages 353−54) notes that the traditional (modern) sector can have several meanings: agricultural (industrial) sector, the sector employing old labor-intensive (new capital-intensive) technology, and the sector with forms of organization based on family (capitalist principles). This paper's use of the terms is similar to the second one, reflecting its concern on the coexistence of sectors employing different technologies and types of workers in developing economies. Unlike the more typical last classification, as detailed below, the traditional sector in the paper corresponds to the urban informal sector, which is organized based on capitalist principles, as well as traditional agricultural sector and the household sector in real economy.

[18]Because free international capital mobility is assumed, the production function of the modern sector may be considered as a reduced form of the function that includes physical capital K as an input:

$$Y_M = \widetilde{A_M}(L_h)^\beta(L_m)^\gamma(K)^{1-\beta-\gamma}, \quad \beta, \gamma \in (0,1).$$

When (6) is the reduced-form function, A_M depends positively on $\widetilde{A_M}$ and negatively on r.

[19]Good M is used for education too: the education cost is that of purchasing a fixed amount of the good.

ties and meals) and basic manufacturing goods mostly for domestic markets, and accounts for the majority of non-agricultural employment in many developing economies (OECD, 2009). Traditional agriculture is operated by family farms and supplies products mainly for basic needs of domestic consumers.[20] And, the household sector produces basic goods and services mostly for self-consumption, whose size is large in developing countries. By contrast, the modern sector corresponds to modern manufacturing and commercial agriculture, which compete more directly with foreign producers (La Porta and Shleifer, 2008).[21]

Determination of wages: Goods and labor markets are competitive, thus wages of high-skill, middle-skill, and low-skill workers are given by:

$$w_h = \alpha A_M \left(\frac{L_m}{L_h}\right)^{1-\alpha}, \tag{8}$$

$$w_m = (1-\alpha) A_M \left(\frac{L_h}{L_m}\right)^{\alpha}, \tag{9}$$

$$w_l = P A_T. \tag{10}$$

For later use, denote wages of high-skill and middle-skill workers *net of costs of education* by $\widetilde{w_j} = w_j - (1+r)e_j$ $(j = h, m)$, which are:

$$\widetilde{w_h} = \widetilde{w_h}\left(\frac{L_h}{L_m}\right) \equiv \alpha A_M \left(\frac{L_m}{L_h}\right)^{1-\alpha} - (1+r)e_h, \tag{11}$$

$$\widetilde{w_m} = \widetilde{w_m}\left(\frac{L_h}{L_m}\right) \equiv (1-\alpha) A_M \left(\frac{L_h}{L_m}\right)^{\alpha} - (1+r)e_m. \tag{12}$$

Determination of P: When the relative price of good T is low, only good T of the traditional sector is used for basic consumption and thus its market-clearing condition is:

$$P A_T L_l = \gamma_B [w_h L_h + w_m L_m + w_l L_l + (1+r)\int a^i di], \tag{13}$$

where the right-hand side is obtained by aggregating (3) over the adult population. Denote aggregate intergenerational transfers by B. Then, $\int a^i di = B - (e_h L_h + e_m L_m)$ holds. By plugging this expression, $w_l = P A_T$, and $L_l = 1 - (L_h + L_m)$ into (13) and solving for P,

$$P = \frac{\gamma_B}{1-\gamma_B} \frac{[w_h - (1+r)e_h]L_h + [w_m - (1+r)e_m]L_m + (1+r)B}{A_T[1-(L_h+L_m)]}, \tag{14}$$

which is expressed as an increasing function of L_h, L_m, and B by using (8) and (9):

$$P = P(L_h, L_m, B) \equiv \frac{\gamma_B}{1-\gamma_B} \frac{A_M (L_h)^{\alpha} (L_m)^{1-\alpha} + (1+r)[B - e_h L_h - e_m L_m]}{A_T[1-(L_h+L_m)]}. \tag{15}$$

$P(L_h, L_m, B) \leq \theta$ must hold for $P = P(L_h, L_m, B)$ to be true.

When L_h, L_m, and B are large, the demand (supply) for good T is high (low) enough that $P(L_h, L_m, B) > \theta$ holds. Thus, good M too is used for basic consumption and $P = \theta$.

[20] As in Yuki (2007), traditional agriculture may be introduced as a separate tradable sector operated by low-skill farmers. The analysis would be much more complicated without affecting most qualitative results.

[21] In real economy, there exist skill-intensive modern sectors supplying nontradables. However, in developing countries, most of skill-intensive nontradables are public services, health services, and education, where market forces have limited roles, while sectors such as finance and consulting services are limited in size.

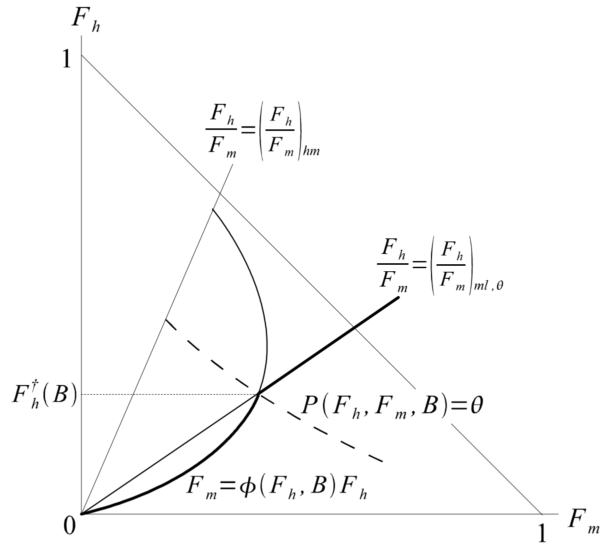

Figure 1: Shapes of critical loci determining educational choices and wages

From these results, the low-skill wage equals:

$$w_l = w_l(L_h, L_m, B) \equiv \begin{cases} P(L_h, L_m, B)A_T & \text{when } P(L_h, L_m, B) \leq \theta \\ \theta A_T & \text{when } P(L_h, L_m, B) \geq \theta \end{cases}. \tag{16}$$

2.2 Equilibrium educational choices and wages

Individuals are heterogenous in received transfer b^i. Let F_h be the proportion of those who can afford e_h to become a high-skill worker, and let F_m be the proportion of those who *cannot* afford e_h but can afford e_m to become a middle-skill worker (thus $F_h + F_m \leq 1$). Since an individual can spend wealth on assets too, she spends on education only if it is affordable *and* profitable: an individual with $b^i \geq e_h$ spends e_h only if $\widetilde{w_h} \geq \max\{\widetilde{w_m}, w_l\}$, and one with $b^i \geq e_m$ spends at least e_m only if $\widetilde{w_m} \geq w_l$. Thus, $L_h \leq F_h$ and $L_h + L_m \leq F_h + F_m$ must hold, but $L_h = F_h$ and $L_m = F_m$ may not. This section examines how L_h, L_m, and wages are determined depending on key variables in the analysis, F_h, F_m, and B.

2.2.1 Critical equations determining educational choices and wages

As can be seen from the above discussion, magnitude relations of $\widetilde{w_h}$ to $\widetilde{w_m}$ and of $\widetilde{w_m}$ to w_l at $L_h = F_h$ and $L_m = F_m$ are critical in determining L_h and L_m. For example, if $\widetilde{w_h} \geq \widetilde{w_m}$ and $\widetilde{w_m} \geq w_l$ at $L_h = F_h$ and $L_m = F_m$, $L_h = F_h$ and $L_m = F_m$ hold in equilibrium, i.e. if each level of education is profitable when all individuals take highest affordable education, they do take such education. Hence, combinations of F_h and F_m satisfying $\widetilde{w_h}(\frac{F_h}{F_m}) = \widetilde{w_m}(\frac{F_h}{F_m})$ and the combinations satisfying $\widetilde{w_m}(\frac{F_h}{F_m}) = w_l(F_h, F_m, B)$ are crucial. Denote $\frac{F_h}{F_m}$ satisfying $\widetilde{w_h}(\frac{F_h}{F_m}) = \widetilde{w_m}(\frac{F_h}{F_m})$ by $(\frac{F_h}{F_m})_{hm}$ and $\frac{F_h}{F_m}$ satisfying $\widetilde{w_m}(\frac{F_h}{F_m}) = \theta A_T$ (w_l when $P = \theta$) by $(\frac{F_h}{F_m})_{ml,\theta}$.

Assumption 1 $(\frac{F_h}{F_m})_{hm} > (\frac{F_h}{F_m})_{ml,\theta}$.

The assumption implies $\widetilde{w_h} = \widetilde{w_m} > \theta A_T$ at $\frac{L_h}{L_m} = (\frac{F_h}{F_m})_{hm}$, that is, the highest (lowest) net middle-skill (high-skill) wage is strictly greater than the highest low-skill wage.

As for F_h and F_m satisfying $\widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$ (w_l when $P<\theta$), Lemma A1 of Appendix A examines its existence and properties. In particular, the lemma shows that it can be expressed as $F_m = \phi(F_h,B)F_h$, where $\phi(\cdot)$ is a decreasing function.

From (16), $F_m = \phi(F_h,B)F_h \Leftrightarrow \widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$ affects educational choices when $P(F_h,F_m,B) \leq \theta$, and $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta} \Leftrightarrow \widetilde{w_m}(\frac{F_h}{F_m}) = \theta A_T$ affects the choices when $P(F_h,F_m,B) \geq \theta$. Hence, relative positions of $P(F_h,F_m,B) = \theta$ to these loci are important, which is investigated in Lemma A2 of Appendix A.

Figure 1 illustrates shapes of the critical loci on the (F_m, F_h) plane. ($F_h^\dagger(B)$ is the intersection of $F_m = \phi(F_h,B)F_h$ with $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta}$, which decreases with B.) Since $P(F_h,F_m,B) <$ $(>)\theta$ below (above) $P(F_h,F_m,B) = \theta$, $F_m = \phi(F_h,B)F_h$ affects educational choices below $P(F_h,F_m,B) = \theta$, and $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta}$ affects the choices above the locus.

2.2.2 Educational choices and wages

The next proposition presents educational choices and thus sectoral choices of individuals. Henceforth, individuals with $b^i \geq e_h$, those with $b^i \in [e_m, e_h)$, and those with $b^i < e_m$ are named the *non-poor*, the *poor*, and the *extreme poor*, respectively.

Proposition 1 (Educational choices) *Suppose* $F_h > 0$.

(i) If $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, *the non-poor are indifferent between two education* ($\widetilde{w_h} = \widetilde{w_m}$), *the poor take basic education,* $L_h = \frac{(\frac{F_h}{F_m})_{hm}}{1+(\frac{F_h}{F_m})_{hm}}(F_h+F_m) \leq F_h$, $L_m = \frac{F_h+F_m}{1+(\frac{F_h}{F_m})_{hm}} \geq F_m$, *and* $L_l = 1-F_h-F_m$.

(ii) Otherwise, the non-poor take advanced education and thus $L_h = F_h$.

(a) If $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta}, (\frac{F_h}{F_m})_{hm})$, *the poor take basic education, thus* $L_m = F_m$ *and* $L_l = 1-F_h-F_m$.

(b) If $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$,

1. *When* $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$ *and* $F_h < F_h^\dagger(B)$, *if* $F_m \geq \phi(F_h,B)F_h$, *the poor are indifferent between basic education and no education* ($\widetilde{w_m} = w_l$), $L_m = \phi(F_h,B)F_h \leq F_m$, *and* $L_l = 1-(1+\phi(F_h,B))F_h$; *otherwise, same as (a).*
2. *Or else,* $\widetilde{w_m} = w_l$, $L_m = [(\frac{F_h}{F_m})_{ml,\theta}]^{-1}F_h \leq F_m$, *and* $L_l = 1-\{1+[(\frac{F_h}{F_m})_{ml,\theta}]^{-1}\}F_h$.

Figure 2 illustrates how L_h and L_m are determined depending on F_h and F_m when $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$.[22] As for $F_m = \phi(F_h,B)F_h$ and $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta}$, only portions of the loci that are *effective* (affect the determination of L_h and L_m) are drawn.

[22]Loci are drawn for *given* B satisfying $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$. When B increases, $F_m = \phi(F_h,B)F_h$ shifts to the left and $F_h^\dagger(B)$ falls. When $\frac{\gamma_B}{1-\gamma_B}(1+r)B \geq \theta A_T$, $P = \theta$ always and the region $F_h \leq F_h^\dagger(B)$ disappears.

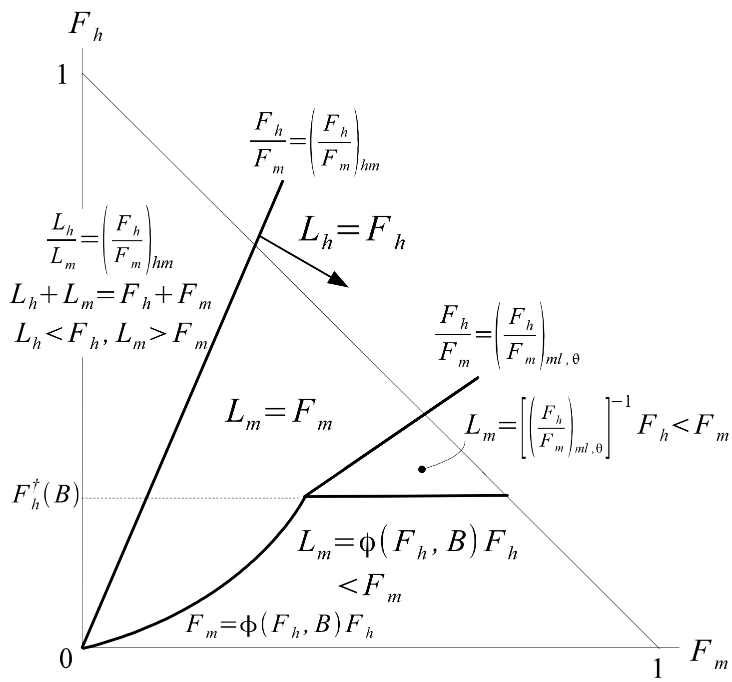

Figure 2: Educational choices when $\frac{\gamma_B}{1-\gamma_B}(1+r)B<\theta A_T$ (Proposition 1)

When $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, the non-poor (those with $b^i \geq e_h$) are abundant relative to the poor (those with $b^i \in [e_m, e_h)$) and thus net wages of high-skill and middle-skill workers are equal. Hence, some of the non-poor do not take advanced education (when $\frac{F_h}{F_m} > (\frac{F_h}{F_m})_{hm}$), while all the poor take basic education, i.e. $L_h < F_h$ and $L_h + L_m = F_h + F_m$.

By contrast, when $\frac{F_h}{F_m} < (\frac{F_h}{F_m})_{hm}$, the net high-skill wage is strictly higher than the net middle-skill wage and thus all the non-poor take advanced education, i.e. $L_h = F_h$. As for the poor, when $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta}, (\frac{F_h}{F_m})_{hm})$ and thus the non-poor are not very scarce relative to the poor, the net middle-skill wage is strictly higher than the low-skill wage and all of them take basic education, i.e. $L_m = F_m$. When the non-poor are scarcer, i.e. $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$, choices of the poor depend on F_h as well as $\frac{F_h}{F_m}$. For given $\frac{F_h}{F_m}$, when F_h (thus F_m too) is small, i.e. $F_m < \phi(F_h, B)F_h$ ($\phi(\cdot)$ is a decreasing function), the size of the modern sector is small. Hence, the demand for good T, its relative price, and the low-skill wage are low and thus $L_m = F_m$ holds. In contrast, when F_h is not small, the low-skill wage equals the net middle-skill wage and some of the poor do not take basic education.[23]

Proposition 2 shows how net wages depend on F_h, F_m, and B.

Proposition 2 (Net wages) *Suppose* $F_h > 0$.

[23]Specifically, when the non-poor are not abundant ($F_h < F_h^{\dagger}(B)$), $P < \theta$ and $L_m = \phi(F_h, B)F_h < F_m$, while when they are large in number ($F_h \geq F_h^{\dagger}(B)$), $P = \theta$ and $L_m = [(\frac{F_h}{F_m})_{ml,\theta}]^{-1} F_h < F_m$.

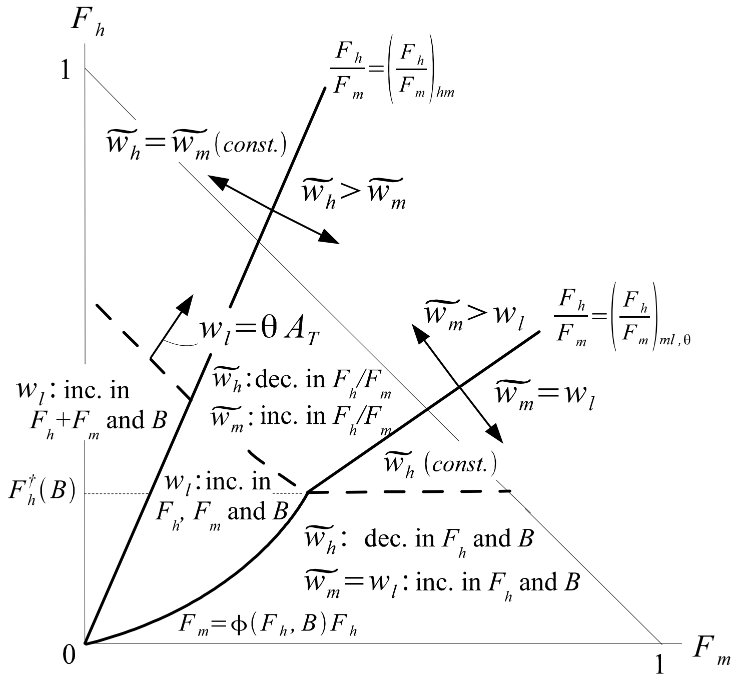

Figure 3: Net wages when $\frac{\gamma_B}{1-\gamma_B}(1+r)B<\theta A_T$ (Proposition 2)

(i) If $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, $\widetilde{w_h} = \widetilde{w_m} = \widetilde{w_m}((\frac{F_h}{F_m})_{hm})(> w_l)$, *and* $w_l = \frac{\gamma_B}{1-\gamma_B}\frac{\widetilde{w_m}((\frac{F_h}{F_m})_{hm})(F_h+F_m)+(1+r)B}{1-(F_h+F_m)}$ *when* $F_h+F_m<\frac{(1-\gamma_B)\theta A_T-\gamma_B(1+r)B}{\gamma_B\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+(1-\gamma_B)\theta A_T}$, $w_l=\theta A_T$ *otherwise.*

(ii) Otherwise,

(a) If $\frac{F_h}{F_m}\in((\frac{F_h}{F_m})_{ml,\theta},(\frac{F_h}{F_m})_{hm})$, $\widetilde{w_j}=\widetilde{w_j}(\frac{F_h}{F_m})$ $(j=h,m)$, $w_l=P(F_h,F_m,B)A_T$ *when* $P(F_h,F_m,B)\leq\theta$ *and* $w_l=\theta A_T$ *otherwise, where* $\widetilde{w_h}>\widetilde{w_m}>w_l$.

(b) If $\frac{F_h}{F_m}\leq(\frac{F_h}{F_m})_{ml,\theta}$,

1. *When* $\frac{\gamma_B}{1-\gamma_B}(1+r)B<\theta A_T$ *and* $F_h<F_h^\dagger(B)$, *if* $F_m\geq\phi(F_h,B)F_h$, $\widetilde{w_h}=\widetilde{w_h}([\phi(F_h,B)]^{-1})$ *and* $\widetilde{w_m}=w_l=\widetilde{w_m}([\phi(F_h,B)]^{-1})$ $(<\theta A_T<\widetilde{w_h})$*; otherwise, same as (a) when* $P(F_h,F_m,B)\leq\theta$.
2. *Or else,* $\widetilde{w_h}=\widetilde{w_h}((\frac{F_h}{F_m})_{ml,\theta})$ *and* $\widetilde{w_m}=w_l=\theta A_T(<\widetilde{w_h})$.

Figure 3 illustrates magnitude relations of $\widetilde{w_h}$, $\widetilde{w_m}$, and w_l and how the wages depend on F_h, F_m, and B when $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$. In the figure, the locus $P(F_h,F_m,B) = \theta$ is represented by a bold dashed line and $P=\theta$ on or above the line.

When $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, the non-poor are abundant relative to the poor (those with $b^i \in [e_m, e_h))$ and $\widetilde{w_h}=\widetilde{w_m}=\widetilde{w_m}((\frac{F_h}{F_m})_{hm})$ holds (the same wage level for any F_h and F_m in this region). w_l increases with F_h+F_m unless F_h+F_m is high enough that $P=\theta$ and $w_l=\theta A_T$ hold, because the non-poor and the poor receive the same level of net wage and thus the demand for good T and P increase with $L_h+L_m=F_h+F_m$.

When $\frac{F_h}{F_m}<(\frac{F_h}{F_m})_{hm}$, the non-poor are scarce relative to the poor and thus $\widetilde{w_h}>\widetilde{w_m}$ and $L_h = F_h$. When they are not very scarce, i.e. $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta},(\frac{F_h}{F_m})_{hm})$, and thus $\widetilde{w_m} > w_l$

and $L_m = F_m$ hold, $\widetilde{w_h}$ decreases and $\widetilde{w_m}$ increases with $\frac{F_h}{F_m}$, while $w_l = P(F_h,F_m,B)A_T$ increases with F_h, F_m, and B, unless they are high enough that $P = \theta$. When the non-poor are scarcer, i.e. $\frac{F_h}{F_m} \le (\frac{F_h}{F_m})_{ml,\theta}$, the result depends on F_h and $\frac{F_h}{F_m}$. For given $\frac{F_h}{F_m}$, if F_h (and thus F_m) is small, i.e. $F_m < \phi(F_h,B)F_h$, the result is same as the previous case, whereas if F_h is higher, the demand for good T (and thus P) is high enough that $\widetilde{w_m} = w_l$ holds. When $F_h < F_h^\dagger(B)$ and thus $L_m = \phi(F_h,B)F_h$ (see Figure 2), $\widetilde{w_h} = \widetilde{w_h}([\phi(F_h,B)]^{-1})$ and $\widetilde{w_m} = w_l = \widetilde{w_m}([\phi(F_h,B)]^{-1})$, that is, $\widetilde{w_h}$ decreases and $\widetilde{w_m} = w_l$ increases with F_h and B, while when $F_h \ge F_h^\dagger(B)$ and thus $P = \theta$ and $L_m = [(\frac{F_h}{F_m})_{ml,\theta}]^{-1}F_h$, $\widetilde{w_m} = w_l = \theta A_T$ and $\widetilde{w_h} = \widetilde{w_h}((\frac{F_h}{F_m})_{ml,\theta})$, that is, the wages are constant.

To summarize magnitude relations of wages, when $\frac{F_h}{F_m} \ge (\frac{F_h}{F_m})_{hm}$, $\widetilde{w_h} = \widetilde{w_m} > w_l$; when $\frac{F_h}{F_m} < (\frac{F_h}{F_m})_{hm}$ and either $\frac{F_h}{F_m} > (\frac{F_h}{F_m})_{ml,\theta}$ or $F_m < \phi(F_h,B)F_h$, $\widetilde{w_h} > \widetilde{w_m} > w_l$; and $\widetilde{w_h} > \widetilde{w_m} = w_l$ in the remaining case.[24]

3 Dynamics

As noted earlier, the model can be considered as a sequence of quasi-static economies connected by intergenerational transfers. Based on results of the previous section, this section takes into account the intergenerational linkages.

3.1 Dynamics of individual transfers

Remember that the individual transfer rule is given by (now with time subscripts):

$$b_{t+1}^i = \gamma_b[w_t^i + (1+r)a_t^i], \tag{17}$$

where w_t^i and a_t^i are the wage and the asset of individual i born in period $t-1$ and being adult in period t, and b_{t+1}^i is the transfer to her child (whose adulthood is in period $t+1$).

Since a_t^i depends on b_t^i, the dynamic equation linking the received transfer b_t^i to the transfer given to the next generation b_{t+1}^i can be derived from the above equation. For a high-skill worker, by substituting $a_t^i = b_t^i - e_h$ into (17) and using $\widetilde{w_{ht}} = w_{ht} - (1+r)e_h$,

$$b_{t+1}^i = \gamma_b\{\widetilde{w_{ht}} + (1+r)b_t^i\}, \tag{18}$$

where $b_t^i \ge e_h$. $\gamma_b(1+r) < 1$ is assumed so that the fixed point for given $\widetilde{w_{ht}}$, $b^*(\widetilde{w_{ht}}) \equiv \frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_{ht}}$, exists. For a middle-skill worker, a similar equation with the net wage $\widetilde{w_{mt}}$ and $b_t^i \ge e_m$ holds. Finally, for a low-skill worker, since $a_t^i = b_t^i$,

$$b_{t+1}^i = \gamma_b\{w_{lt} + (1+r)b_t^i\}. \tag{19}$$

[24] A.2 of Appendix A examines how aggregate welfare, aggregate output, and sectoral composition depend on F_h, F_m, and B. It is shown that increased access to education bringing higher net wages, i.e. higher $F_h + F_m$ when $\widetilde{w_h} = \widetilde{w_m}$, higher F_h and F_m when $\widetilde{w_h} > \widetilde{w_m} > w_l$, and higher F_h when $\widetilde{w_m} = w_l$, raises welfare, output, and the modern sector's shares in production and basic consumption (when $P = \theta$), while higher B raises welfare, output when $P < \theta$, and the consumption share, but *lowers* the production share when $P < \theta$.

The equations show that the dynamics of transfers within a lineage depend on the time evolution of wages, which in turn are determined by the dynamics of F_{ht}, F_{mt}, and B_t.

3.2 Aggregate dynamics

Given the initial distribution of wealth over the population, F_{h0}, F_{m0}, and B_0 are determined directly, while levels of the aggregate variables in subsequent periods are determined by the dynamics of the distribution of transfers. However, detailed information on the distributional dynamics is *not* required to obtain main implications of the model. What is needed is information on *directions of motion* of the aggregate variables, which is examined in this subsection. For exposition, the dynamics of F_{ht} and F_{mt} and those of B_t are examined separately fixing the other variable(s) first, then their interactions are taken into account.

3.2.1 Dynamics of F_{ht} and F_{mt}

The dynamics of F_{ht} and F_{mt} are determined by the dynamics of individual transfers. As for the dynamics of F_{ht}, if children of some middle-skill workers become accessible to advanced education through wealth accumulation, $F_{ht+1} > F_{ht}$ holds.[25] This takes places iff there exist lineages satisfying $b_t^i < e_h$ and $b_{t+1}^i \geq e_h$. From (18) with $\widetilde{w_{ht}}$ replaced by $\widetilde{w_{mt}}$, the following condition must hold for such lineages to exist:

$$b^*(\widetilde{w_{mt}}) = \frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_{mt}} > e_h. \tag{20}$$

If the equation holds, $F_{ht+1} \geq F_{ht}$, otherwise, $F_{ht+1} = F_{ht}$. (In the former case, $F_{ht+1} = F_{ht}$ is possible depending on the distribution of transfers, but, if the inequality holds for certain periods, F_{ht} does increase eventually.)

Regarding levels of $b^*(\widetilde{w_{ht}})$ and $b^*(\widetilde{w_{mt}})$, the following is assumed.

Assumption 2 $b^*(\widetilde{w_h}((\frac{F_h}{F_m})_{hm})) = b^*(\widetilde{w_m}((\frac{F_h}{F_m})_{hm})) = \frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm}) > e_h$.

The assumption implies that offspring of high-skill workers can afford advanced education even when their wage is lowest and thus F_{ht} never decreases. Assume that the initial distribution of wealth is such that $F_{h0} > 0$. Then, $F_{ht} > 0$ for any $t > 0$.

As for the dynamics of F_{mt}, since $F_{ht+1} \geq F_{ht}$ is true, if $b^*(w_{lt}) > e_m$, $F_{ht+1} + F_{mt+1} \geq F_{ht} + F_{mt}$; if $b^*(\widetilde{w_{mt}}) < e_m$, $F_{ht+1} = F_{ht}$ and $F_{mt+1} \leq F_{mt}$; otherwise, $F_{ht+1} + F_{mt+1} = F_{ht} + F_{mt}$.

Hence, directions of motion of F_{ht} and F_{mt} can be known from magnitude relations of $b^*(\widetilde{w_{mt}})$ to e_h and e_m and of $b^*(w_{lt})$ to e_m, except when $b^*(\widetilde{w_{mt}}) > e_h$ and $b^*(w_{lt}) > e_m$, in which the direction of motion of F_{mt} is ambiguous ($F_{ht+1} \geq F_{ht}$ and $F_{ht+1} + F_{mt+1} \geq F_{ht} + F_{mt}$).

Regarding the value of $b^*(w_{lt})$, the following is assumed.

Assumption 3 $\frac{\gamma_b}{1-\gamma_b(1+r)}\theta A_T \in (e_m, e_h)$.

[25] From Assumption 3 below, children of low-skill workers never become accessible to advanced education.

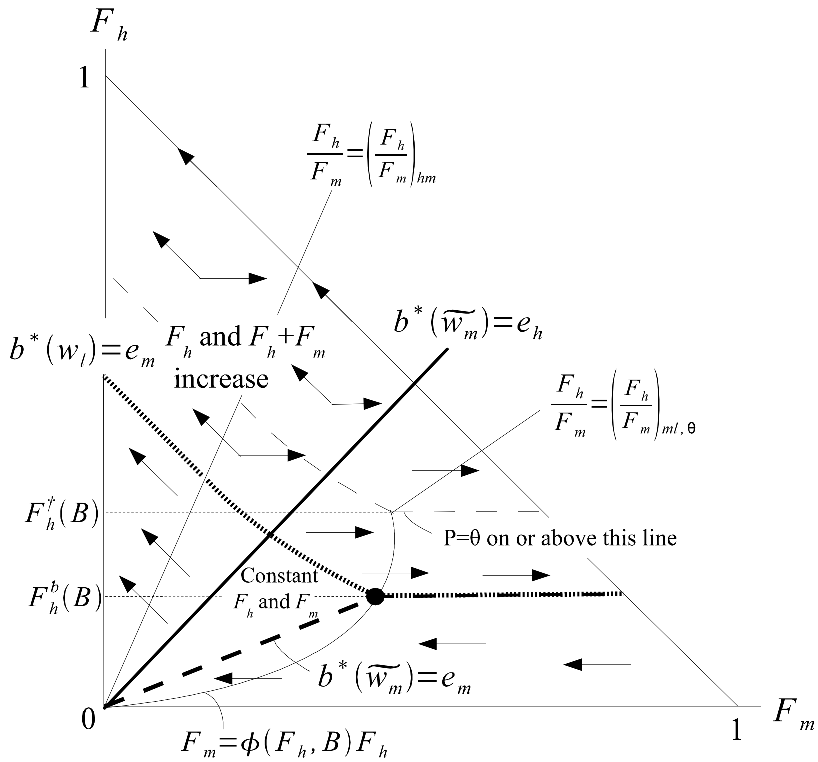

Figure 4: Dynamics of F_{ht} and F_{mt} for given B

The assumption states that children of some low-skill workers can afford basic education but not advanced education when their wage is highest. The two assumptions are maintained until Section 4.3 where effects of productivity growth are examined.

From these assumptions and Proposition 2, there exist combinations of F_h and F_m satisfying $b^*(\widetilde{w_m})=e_h$, those satisfying $b^*(\widetilde{w_m})=e_m$, and those satisfying $b^*(w_l)=e_m$ (see Figure 4). $b^*(\widetilde{w_m})=e_h$ equals a $\frac{F_h}{F_m}\in((\frac{F_h}{F_m})_{ml,\theta},(\frac{F_h}{F_m})_{hm})$ such that $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}(\frac{F_h}{F_m})=e_h$. $b^*(\widetilde{w_m})=e_m$ equals a $\frac{F_h}{F_m}<(\frac{F_h}{F_m})_{ml,\theta}$ such that $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}(\frac{F_h}{F_m})=e_m$ for $F_m<\phi(F_h^\flat(B),B)F_h^\flat(B)$ and equals $F_h=F_h^\flat(B)$ for higher F_m, where $F_h^\flat(B)$ (a decreasing function) denotes F_h satisfying $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}(\frac{1}{\phi(F_h,B)})=e_m$. Finally, $b^*(w_l)=e_m$ equals:

$$\text{for } \frac{F_h}{F_m}\ge(\frac{F_h}{F_m})_{hm},\ \ F_h+F_m=\frac{\frac{1-\gamma_b(1+r)}{\gamma_b}e_m-\frac{\gamma_B}{1-\gamma_B}(1+r)B}{\frac{\gamma_B}{1-\gamma_B}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}; \tag{21}$$

$$\text{for } \frac{F_h}{F_m}\in\left(\widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\right],(\frac{F_h}{F_m})_{hm}\right),\ \ \frac{\gamma_b}{1-\gamma_b(1+r)}P(F_h,F_m,B)A_T=e_m; \tag{22}$$

$$\text{and for lower } \frac{F_h}{F_m},\quad F_h=F_h^\flat(B). \tag{23}$$

Figure 4 illustrates the dynamics of F_{ht} and F_{mt} for *given* B by placing the three critical loci on the (F_m,F_h) plane. In the figure, $b^*(\widetilde{w_m})>(<)e_h$ at the left (right) side of $b^*(\widetilde{w_m})=e_h$

(the bold solid line), $b^*(\widetilde{w_m}) > (<) e_m$ above (below) $b^*(\widetilde{w_m}) = e_m$ (the bold dashed line), and $b^*(w_l) > (<) e_m$ above (below) $b^*(w_l) = e_m$ (the bold dotted line). Positions of F_{ht} and F_{mt} relative to the three loci determine directions of motion of the two variables. In regions with horizontal arrows only, only F_{mt} changes: for example, in the region below $b^*(\widetilde{w_m}) = e_m$, $b^*(\widetilde{w_m}) < e_m$ and thus F_{mt} decreases. Arrows with slope -1 are present in the region above $b^*(\widetilde{w_m}) = e_h$ and on or below $b^*(w_l) = e_m$, because $b^*(\widetilde{w_m}) > e_h$ and $b^*(w_l) \leq e_m$ and thus F_{ht} increases with $F_{ht} + F_{mt}$ constant. In the region above $b^*(w_l) = e_m$ and $b^*(\widetilde{w_m}) = e_h$ (thus $b^*(w_l) > e_m$ and $b^*(\widetilde{w_m}) > e_h$) and below $F_h + F_m = 1$, both arrows with slope -1 and horizontal arrows are drawn, since F_{ht} and $F_{ht} + F_{mt}$ increase but the direction of motion of F_{mt} is ambiguous (F_{ht} and F_{mt} move in the direction between the two arrows). Finally, both F_{ht} and F_{mt} are constant and thus no arrows are present in the region on or below $b^*(\widetilde{w_m}) = e_h$ and $b^*(w_l) = e_m$ and on or above $b^*(\widetilde{w_m}) = e_m$.

Note that positions of $b^*(\widetilde{w_m}) = e_m$ and $b^*(w_l) = e_m$ as well as those of $P(F_h, F_m, B) = \theta$ and $F_m = \phi(F_h, B)F_h$ *change with* B. Thus, the dynamics of F_{ht} and F_{mt} must be examined together with those of B_t. Before examining the joint dynamics, the dynamic equation of B_t is derived and the direction of motion of B_t for *given* F_{ht} and F_{mt} is examined next.

3.2.2 Dynamics of aggregate transfers

The dynamic equation of aggregate transfers is obtained by aggregating the dynamic equations for individual transfers over the population:

$$B_{t+1} = \gamma_b \left\{ \widetilde{w_{ht}} L_{ht} + \widetilde{w_{mt}} L_{mt} + w_{lt}(1 - L_{ht} - L_{mt}) + (1+r)B_t \right\}, \tag{24}$$

where the expression inside the curly bracket is aggregate income net of education costs, which can be expressed as a function of F_{ht}, F_{mt}, and B_t.

A.3 of Appendix A analyzes the equation. It is shown that the equation differs depending on F_{ht} and F_{mt}, and for given F_{ht} and F_{mt}, the direction of motion of B_t is determined by the magnitude relation of B_t to the fixed point: B_t increases (decreases) when it is smaller (greater) than the value at the fixed point. For later use, notations of the fixed points are: $\widehat{B}^*(F_{ht} + F_{mt})$ when $\frac{F_{ht}}{F_{mt}} \geq (\frac{F_h}{F_m})_{hm}$, $B^*(F_{ht}, F_{mt})$ when $\frac{F_{ht}}{F_{mt}} \in (\min\{[\phi(F_{ht}, B_t)]^{-1}, (\frac{F_h}{F_m})_{ml,\theta}\}, (\frac{F_h}{F_m})_{hm})$, and $\overline{B}^*(F_{ht})$ for lower $\frac{F_{ht}}{F_{mt}}$, all of which are increasing functions.

3.3 Joint dynamics of the aggregate variables

As mentioned earlier, as B_t changes over time, positions of $P(F_h, F_m, B) = \theta$, $F_m = \phi(F_h, B)F_h$, $b^*(\widetilde{w_m}) = e_m$, and $b^*(w_l) = e_m$ in Figure 4 change and thus directions of motion of F_{ht} and F_{mt} could be affected. Thus, analyzing the joint dynamics are generally difficult.

However, it turns out that under the following weak assumption on B_0, characteristics of the dynamics are mostly determined by relative positions of F_{ht} and F_{mt} to these loci when aggregate transfers are *at fixed point levels* (and the relative positions to the remaining loci).

Assumption 4 *$B_0 \leq \widehat{B}^*(F_{h0}+F_{m0})$ for $\frac{F_{h0}}{F_{m0}} \geq (\frac{F_h}{F_m})_{hm}$, $B_0 \leq B^*(F_{h0},F_{m0})$ for $\frac{F_{h0}}{F_{m0}} \in (\min\{[\phi(F_{h0},B_0)]^{-1}, (\frac{F_h}{F_m})_{ml,\theta}\}, (\frac{F_h}{F_m})_{hm})$, and $B_0 \leq \overline{B}^*(F_{h0})$ for lower $\frac{F_{h0}}{F_{m0}}$.*

The assumption states that the initial level of aggregate transfers is less than the fixed point level at $(F_h,F_m)=(F_{h0},F_{m0})$, that is, initial wealth accumulation is not very large.

$P(F_h,F_m,B^*(F_h,F_m))=\theta$ equals, from (15) and (34):

$$\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\frac{A_M(F_h)^{\alpha}(F_m)^{1-\alpha}-(1+r)(e_hF_h+e_mF_m)}{A_T[1-(F_h+F_m)]}=\theta. \tag{25}$$

As for $F_m = \phi(F_h,\overline{B}^*(F_h))F_h$, Lemma A3 of Appendix A shows that $\phi(F_h,\overline{B}^*(F_h))$ is decreasing in F_h. $b^*(\widetilde{w_m}) = e_m$ equals a $\frac{F_h}{F_m} < (\frac{F_h}{F_m})_{ml,\theta}$ such that $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}(\frac{F_h}{F_m}) = e_m$ for $F_m < \phi(F_h^\flat,\overline{B}^*(F_h^\flat))F_h^\flat$ and $F_h = F_h^\flat$ for higher F_m, where $F_h^\flat$ denotes F_h satisfying $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}(\frac{1}{\phi(F_h,\overline{B}^*(F_h))})=e_m$. Finally, $b^*(w_l)=e_m$ equals, from (21) and (30):

$$\text{for } \frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}, \qquad F_h+F_m=\frac{\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}{\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}; \tag{26}$$

$$\text{for } \frac{F_h}{F_m} \in \left(\widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\right], (\frac{F_h}{F_m})_{hm}\right), \quad \frac{\gamma_b}{1-\gamma_b(1+r)}P(F_h,F_m,B^*(F_h,F_m))A_T=e_m; \tag{27}$$

$$\text{and for lower } \frac{F_h}{F_m}, \qquad F_h=F_h^\flat. \tag{28}$$

Hence, shapes of these loci are similar to the case of constant B, and their positions on the (F_h,F_m) plane can be illustrated by a figure similar to Figure 4.

4 Main Results

4.1 Characteristics of steady states

First, characteristics of steady states are investigated. The next proposition shows that there exist four types of steady states. ($F_h^\dagger$ denotes F_h satisfying $[\phi(F_h,\overline{B}^*(F_h))]^{-1} = (\frac{F_h}{F_m})_{ml,\theta}$.)

Proposition 3 (Steady states) *There exist the following four types of steady states.*[26]

[SS 1] $(F_h,F_m,B) = (1,0,\widehat{B}^*(1))$. *$L_h$ and L_m satisfy $\frac{L_h}{L_m} = (\frac{F_h}{F_m})_{hm}$ and $L_h+L_m=1$ ($L_l=0$), $P=\theta$, and $\widetilde{w_h}=\widetilde{w_m}=\widetilde{w_m}((\frac{F_h}{F_m})_{hm})$.*

[SS 2] *$F_h = L_h$ satisfies $F_h>F_h^\flat$ and $b^*(\widetilde{w_m})\leq e_h \Leftrightarrow \frac{F_h}{1-F_h} \leq \widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\right]$, $F_m = 1-F_h$.*

a. If $\frac{F_h}{1-F_h} \leq (\frac{F_h}{F_m})_{ml,\theta}$, $B = \overline{B}^*(F_h)$, $L_m=\max\{\phi(F_h,\overline{B}^*(F_h)),[(\frac{F_h}{F_m})_{ml,\theta}]^{-1}\}F_h$, $P=P(F_h,L_m,\overline{B}^*(F_h))<\theta$ for $F_h<F_h^\dagger$ and $P=\theta$ for higher F_h, and $\widetilde{w_h}=\widetilde{w_h}(\min\{[\phi(F_h,\overline{B}^*(F_h))]^{-1},(\frac{F_h}{F_m})_{ml,\theta}\})>\widetilde{w_m}=w_l=PA_T$.

[26] Actually, there exists another type of steady states satisfying $F_h=F_h^\flat$, $F_m>\phi(F_h,\overline{B}^*(F_h))F_h$, and $B = \overline{B}^*(F_h)$, but this cannot be reached out of the steady states and thus is not considered.

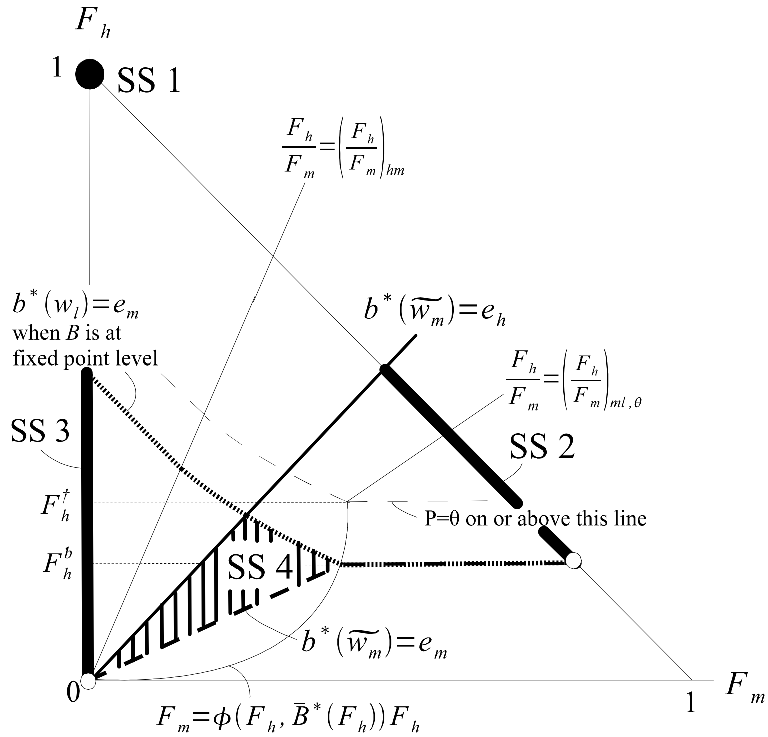

Figure 5: Steady states (Proposition 3)

b. Otherwise, $B=B^*(F_h,F_m)$*,* $L_m=F_m=1-F_h$*,* $P=\theta$*, and* $\widetilde{w_h}=\widetilde{w_h}(\frac{F_h}{F_m})>\widetilde{w_m}=\widetilde{w_m}(\frac{F_h}{F_m})$*.*

[SS 3] F_h *satisfies* $b^*(w_l)\le e_m \Leftrightarrow F_h \le \frac{\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}{\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}$ *and* $(F_m,B)=(0,\widehat{B}^*(F_h))$*.*

L_h *and* L_m *satisfy* $\frac{L_h}{L_m}=(\frac{F_h}{F_m})_{hm}$ *and* $L_h+L_m=F_h$*,* $P=\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\frac{\widetilde{w_m}((\frac{F_h}{F_m})_{hm})F_h}{A_T(1-F_h)}<\theta$*, and* $\widetilde{w_h}=\widetilde{w_m}=\widetilde{w_m}((\frac{F_h}{F_m})_{hm})>w_l=PA_T$*.*

[SS 4] F_h *and* F_m *satisfy* $\frac{F_h}{F_m}\in\left[\widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\right],\widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\right]\right]$ *and* $P(F_h,F_m,B^*(F_h,F_m))A_T\le \frac{1-\gamma_b(1+r)}{\gamma_b}e_m$*, and* $B=B^*(F_h,F_m)$*.* $L_h=F_h$*,* $L_m=F_m$*,* $P=P(F_h,F_m,B^*(F_h,F_m))<\theta$*, and* $\widetilde{w_h}=\widetilde{w_h}(\frac{F_h}{F_m})>\widetilde{w_m}=\widetilde{w_m}(\frac{F_h}{F_m})>w_l=PA_T$*.*

Figure 5 illustrates four types of steady states, which differ in proportions of the poor and the extreme poor, wage inequality, the size of the traditional sector, etc. In SS 1, all individuals are non-poor, i.e. they have enough wealth to take advanced education ($F_h=1$), net wages of high-skill and middle-skill workers are equal ($\widetilde{w_h}=\widetilde{w_m}$), and the traditional sector does not exist (thus $L_l=0$ and $P=\theta$). In SS 2, the extreme poor do not exist, i.e. everyone can access at least basic education ($F_h+F_m=1$), but inequality between high-skill workers and others exists ($\widetilde{w_h}>\widetilde{w_m}$). When $\frac{F_h}{1-F_h}\le(\frac{F_h}{F_m})_{ml,\theta}$, net wages of middle-skill and low-skill workers are equal ($\widetilde{w_m}=w_l$) and thus some do not take basic education ($L_l>0$) and find jobs in the traditional sector, while when $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$, everyone takes at least basic education ($L_l = 0$) and works in the modern sector. In SS 3, there are no poor people ($F_m = 0$) and $\widetilde{w_h} = \widetilde{w_m} = \widetilde{w_m}((\frac{F_h}{F_m})_{hm})$ holds as in SS 1, but the extreme poor exist ($F_h < 1$) and become low-skill workers, inequality between low-skill workers and others is high, and only the traditional sector supplies goods for basic consumption (thus $P < \theta$). In SS 4, both the poor and the extreme poor exist, there are inequalities among the three types of workers ($\widetilde{w_h} > \widetilde{w_m} > w_l$), and the traditional sector is the sole supplier of goods for basic consumption.

SS 1 has features of a typical developed economy: no poverty, low wage inequality (wages net of education costs are equal), high relative price of basic consumption (e.g. the relative price of a meal to a cell phone is higher than in developing nations), and no traditional sector (thus goods for basic consumption are supplied by the modern sector). Other types of steady states share the contrasting features (except no traditional sector when $\frac{F_h}{1-F_h} > (\frac{F_h}{F_m})_{ml,\theta}$ of SS 2), but differ in characteristics of poverty and wage inequality. In SS 2, extreme poverty does not exist but many cannot access education to acquire advanced skills, thus wage inequality between high-skill and other workers is high, while inequality between middle-skill and low-skill workers is low, features of many middle-income economies. In SS 3, those who can afford basic education can access advanced education as well, but many cannot afford even basic education, hence wage inequality between low-skill workers and others is high, while net wages of high-skill and middle-skill workers are equal as in SS 1. And, in SS 4, as observed in poorest economies, many cannot afford basic or advanced education, and typically inequality between middle-skill and low-skill workers as well as the one between high-skill and middle-skill workers are high.

Proposition A3 of Appendix A examines welfare, output, and sectoral composition of the steady states. It confirms that SS 1 is the best in terms of aggregate net income, average utility, and aggregate output. Other steady states cannot be ranked definitely, but if they are to be ranked, SS 2 is the second best, SS 3 follows, and SS 4 is the worst. In each type of steady states, the welfare and output measures increase with the proportion(s) of those accessible to education for jobs with higher net wages, i.e. F_h in SS 2 and SS 3, and F_h and F_m in SS 4 (see Figure 5). Somewhat consistent with a finding by La Porta and Shleifer (2008), in SS 2 and SS 4, the production share of the traditional sector *increases* with $\frac{F_h}{F_m}$ when $\frac{F_h}{F_m}$ is relatively low.[27]

[27] La Porta and Shleifer (2008) find that the difference in the average GDP share of the informal sector between countries in the bottom quartile of the income distribution and in the second quartile is very small, and in one measure, the latter group's share is a little higher, although the employment share is much lower.

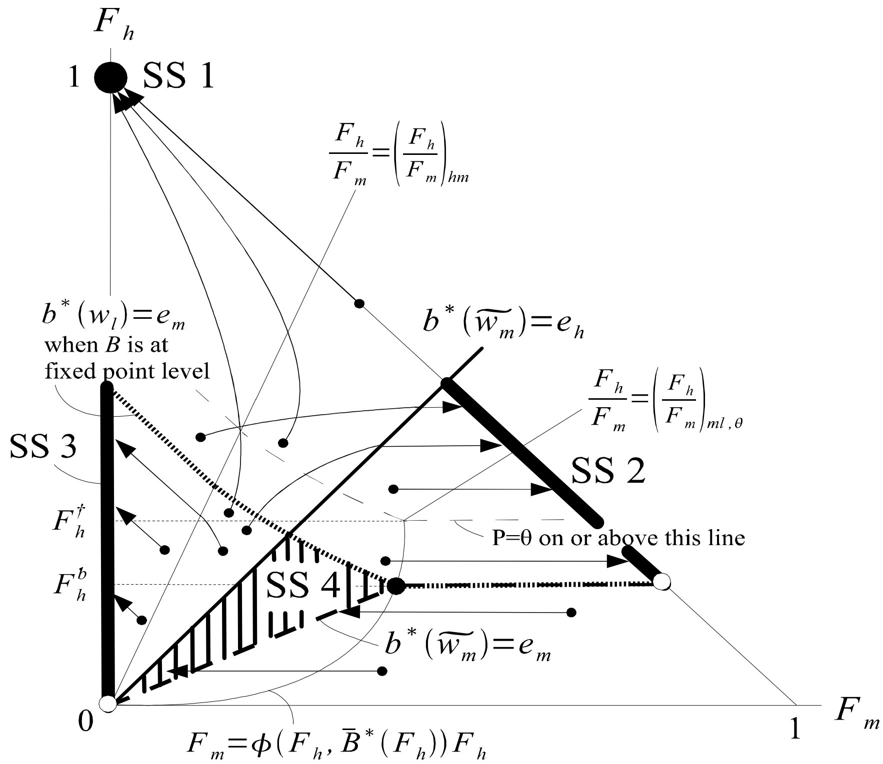

Figure 6: Initial conditions and steady states (Proposition A4)

4.2 Relationship between initial conditions and steady states

From a given initial distribution of wealth, to which type of steady states does the economy converge in the long run? Proposition A4 of Appendix A analyzes the issue in detail.

Figure 6 presents illustrative trajectories of the dynamics based on the proposition. The position of $(F_h,F_m) = (F_{h0},F_{m0})$ relative to $b^*(\widetilde{w_m})=e_h$ essentially determines whether the economy can converge to SS 1 or not. When $\frac{F_{h0}}{F_{m0}} \leq \widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\right]$ (the region on or below $b^*(\widetilde{w_m})=e_h$), SS 1 cannot be reached except rare possibilities described in the proposition. Because high-skill workers are scarce relative to middle-skill workers, the middle-skill wage is not high enough for children of middle-skill workers to access advanced education, i.e. F_{ht} is constant. If F_{h0} and F_{m0} are relatively high, the low-skill wage is high enough that $b^*(w_l)>e_m$ holds initially, descendants of low-skill workers become accessible to basic education over time, i.e. F_{mt} increases, and the economy converges to SS 2. By contrast, if $b^*(w_l) \leq e_m$ holds initially, F_{mt} non-increases (F_{mt} decreases while $\frac{F_{ht}}{F_{mt}}$ is low enough that $b^*(\widetilde{w_m})<e_m$ is satisfied), and the economy converges to SS 4.

When $\frac{F_{h0}}{F_{m0}} > \widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\right]$, the middle-skill wage is high enough that descendants of middle-skill workers become accessible to advanced education over time, i.e. F_{ht} increases.

Unless $\frac{F_{h0}}{F_{m0}} \geq (\frac{F_h}{F_m})_{hm}$ and $b^*(w_l) \leq e_m$, in which case $F_{ht}+F_{mt}$ is constant and the final state is SS 3, the economy could converge to SS 1 through rises in $\frac{F_{ht}}{F_{mt}}$ and F_{ht} (thus inequality between high-skill workers and others falls), although it could converge to SS 2 and SS 3 too depending on details of the initial distribution. SS 1 is more likely to be reached when wages of low-skill and middle-skill wages are high relative to the high-skill wage, i.e. when F_{h0}, F_{m0}, and $\frac{F_{h0}}{F_{m0}}$ are relatively high.

The result suggests that, for the best long-run outcome to be realized, the initial distribution of wealth must be such that the extreme poor (those who cannot afford education to acquire basic skills) are not large in number *and* the non-poor (those who can afford education to acquire advanced skills) must be sufficient relative to the poor. Both conditions seem to have held in a small number of East Asian economies evolving into developed economies, largely because of large-scale land redistribution and effective public school system. As in the model economy converging to SS 1, inequality between workers with advanced skills and others fell over time in the course of development in these economies (Wood, 1994).

If the initial size of the extreme poor is large, i.e. $F_{h0} + F_{m0}$ is low, which would be true for poorest economies, the dual structure and large inequality between low-skill workers and others persist, because good T is cheap and thus low-skill workers with meager earnings cannot escape from misery (SS 3 and SS 4). If the size of the extreme poor is not large but the non-poor are scarce relative to the poor, i.e. $F_{h0} + F_{m0}$ is not low but $\frac{F_{h0}}{F_{m0}}$ is low, which would be the case for typical developing nations with modest growth, low-skill workers are better-paid, thus the fraction of middle-skill workers and the share of the modern sector rise and inequality between middle-skill and low-skill workers shrinks over time.[28] However, since children of middle-skill workers have difficulty in "moving up" due to low middle-skill wage, inequality between these workers and high-skill workers worsens over time. And, the lack of adequate number of high-skill workers typically restrains the growth of the modern sector and thus the traditional sector continues to supply goods for basic consumption (SS 2). These are what typical developing economies have experienced, as described at the beginning of the introduction. Note that average years of schooling did increase greatly in most of these economies, but skill accumulation, especially the growth of the share of high-skill individuals, seems to be modest, judging from lingering enormous gaps in cognitive skills with developed economies (see footnote 3 in the introduction). Quality of public schools remains low (and even declined in many economies) and thus people have to rely on costly private schools, study materials, and tutoring to become high-skill workers.

The main implication is that, for the full modernization of an economy, the initial dis-

[28]To be precise, if the size of the non-poor is very small, i.e. $F_{h0} < F_h^\flat$, this description does not apply. As is clear from Figure 6, F_{mt} falls over time and the long-run state becomes same as the case of low $F_{h0} + F_{m0}$.

tribution of wealth must be such that extreme poverty is not prevalent so that most people can afford education to acquire basic skills and the size of "middle class" is enough so that an adequate number of people can afford education to acquire advanced skills. Consistent with this and the above results, Hanushek and Woessmann (2009), using data on international student achievement tests for 50 countries, find that both the share of students with basic skills and that of top performance have significant effects on economic growth that are *complementary each other*. The model provides a sectoral-shift-based explanation for their finding. The model's implications are also consistent with findings by Deininger and Olinto (2000) on relations among initial inequality, education, and growth, Easterly (2001) on the importance of the size of middle class in education and development, and La Porta and Shleifer (2008) on the importance of educated managers in the expansion of the modern sector (see footnote 12 in the introduction for details).

In contrast, Galor, Moav, and Vollrath (2009) argue that, land inequality negatively affects the implementation of public schooling and structural change, whereas capital inequality among the landless has *no* effect and greater capital holdings by large landlords have a *positive* effect. They develop a model in which human capital is important in manufacturing, but not in agriculture, and its accumulation is determined by public expenditure on education whose level must be agreed by all groups, landowners, capitalists, and workers. While the latter two groups support public schooling, landowners oppose it, unless their capital wealth becomes large enough. A threshold wealth level for public education increases with land inequality. They show that the implication that land inequality adversely affects educational expenditures holds for U.S. state-level data in the period 1880–1940. Hippe and Baten (2012) also find a negative relationship between land inequality and numeracy development for European regions in the 19th and the first decades of the 20th century.

In the present model, distributions of land and capital have similar effects on results, while they have distinct effects in Galor, Moav, and Vollrath (2009). Further, dimensions of the distributions important for structural change are different: in this model, large shares in both the bottom and the middle of wealth distribution are critical, whereas, a low share of land and a large share of capital held by large landowners are important in their model. If data on both land and capital holdings are available, the different implications can be empirically distinguished. If only data on one of them or combined holdings are available, the implications could be partially tested by looking at whether the particular dimensions of the distributions have important effects, and whether the strength of the effects are different depending on the importance of agriculture in an economy.

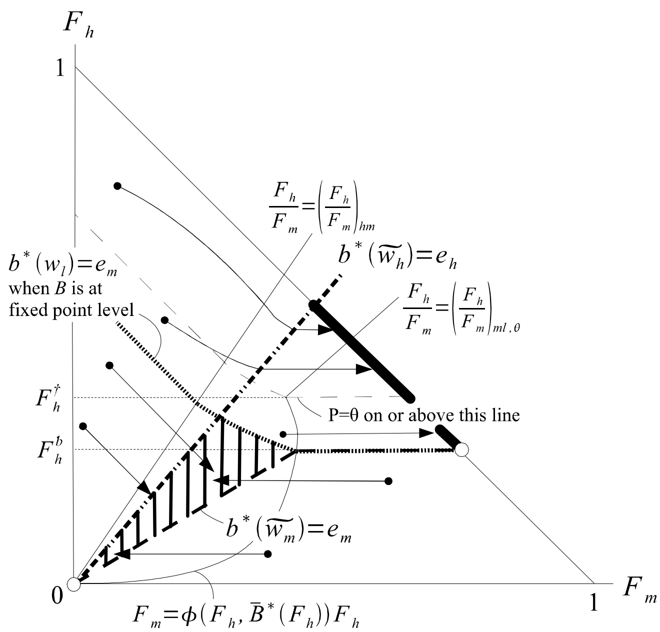

Figure 7: Case of low A_M, i.e. $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})\leq e_h$

4.3 Productivity growth

So far, productivity levels of the two sectors, A_M and A_T, are assumed to be time-invariant. In real economy, they change over time, in particular, A_M usually grows persistently due to technological growth. What happens to the dynamics and steady states when A_M increases over time? From the equations for the critical loci in Section 3, an increase in A_M shifts $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{hm}$ upward and shifts the other loci except $F_m = \phi(F_h,\overline{B}^*(F_h))F_h$ (the effect is ambiguous) downward on the (F_m,F_h) plane with the relative positions unchanged (see Figure 6). Hence, over time, the economy becomes more likely to converge to SS 1 and, as observed in developed nations, the relative number of high-skill workers to middle-skill workers in the best steady state rises. This is because the growth of A_M raises formal-sector wages directly and the low-skill wage indirectly through increased demand for good T. With the continuous productivity growth, the economy ultimately converges to the best steady state from any initial condition, but the speed of convergence depends critically on the initial condition. Hence, qualitative results of the constant A_M case continue to hold approximately.

Another assumption maintained until now is Assumption 2, $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm}) > e_h$, which states that A_M is high enough that offspring of high-skill (middle-skill) workers can afford advanced education at $\widetilde{w_h} = \widetilde{w_m}$, i.e. when their wage is lowest (highest). It would be plausible today but may not in the past, considering the historical growth of A_M. If $\frac{\gamma_b}{1-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})\leq e_h$ holds but A_M is not extremely low, for given A_M, the phase diagram

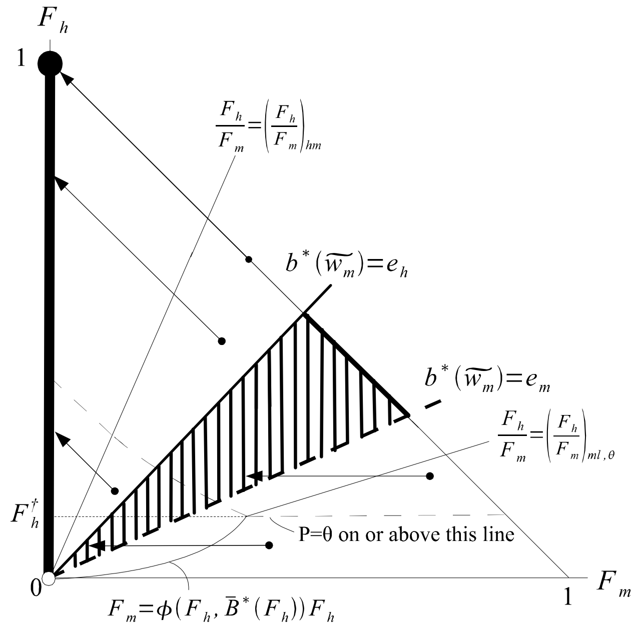

Figure 8: Case of low A_T, i.e. $\frac{\gamma_b}{1-\gamma_b(1+r)}\theta A_T \le e_m$

looks like Figure 7.[29] Unlike Figure 6, $b^*(\widetilde{w_h})=e_h$, not $b^*(\widetilde{w_m})=e_h$, exists below $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{hm}$ and above $b^*(\widetilde{w_m})=e_m$. Since F_{ht} decreases above $b^*(\widetilde{w_h})=e_h$, $F_h=F_m$=1 is *not* a steady state. There exist two types of steady states similar to SS 2 and SS 4 of the original economy, where the convergence to the former type is more likely as F_{h0} and F_{m0} are higher.

The related assumption on A_T is Assumption 3, $\frac{\gamma_b}{1-\gamma_b(1+r)}\theta A_T \in (e_m, e_h)$. The productivity of the traditional sector is less affected by the advancement of science and technology, but it would grow slowly in real economy, thus the assumption may not hold far in the past or in the future. When $\frac{\gamma_b}{1-\gamma_b(1+r)}\theta A_T \le e_m$, children of low-skill workers cannot access basic education even at $P=\theta$ and F_{mt} non-increases. As illustrated in Figure 8, unlike the original economy, $b^*(w_l)=e_m$ does not exist, $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{ml,\theta}$ is located below $b^*(\widetilde{w_m})=e_m$, and the dividing locus between $P<\theta$ and $P=\theta$ is located at the lower position on the (F_m,F_h) plane. For given A_T, two kinds of steady states exist, one "combining" SS 1 and SS 3 and the other "combining" SS 2 and SS 4, and if $b^*(\widetilde{w_m})>e_h$ at $(F_h,F_m)=(F_{h0},F_{m0})$, the economy converges to the former type, and to the latter one otherwise. Convergence to $F_h=F_m$=1 is impossible unless the economy starts without the extreme poor. By contrast, when $\frac{\gamma_b}{1-\gamma_b(1+r)}\theta A_T > e_h$, i.e. even children of low-skill workers can access advanced education at $P=\theta$, the result is somewhat similar to the original economy, but the economy is more (less) likely to converge

[29] When A_M is extremely low, $b^*(\widetilde{w_h})=e_h$ is located below $b^*(\widetilde{w_m})=e_m$, and the economy converges to $F_h=F_m=0$ from any initial distribution, which is clearly not realistic in modern times.

to SS 1 (SS 2).[30] Unlike A_M, the growth of A_T does not make SS 1 the unique steady state since the positive effect on the low-skill wage is canceled out by lower P when $P<\theta$.[31]

These results can be used to examine the dynamics from the far past when the sectoral productivities grow over time. As for an economy whose initial A_M does not satisfy Assumption 2 but initial A_T satisfies Assumption 3, the dynamics are illustrated by Figure 7 at first and by Figure 6 after some point.[32] If F_{h0} and F_{m0} are relatively high, at first, F_{mt}, but *not* F_{ht}, rises and the inequality between high-skill and middle-skill workers (low-skill workers too when $P=\theta$) *enlarges* over time, but after A_M becomes high enough for Assumption 2 to hold, F_{ht} rises, the inequality shrinks, and the economy converges to the best steady state. The dynamics may resemble historical experiences of many developed economies.

4.4 Policy implications

The paper stresses the importance of the initial distribution of wealth in determining human capital accumulation and structural change of an economy, which is supported by empirical studies cited in Section 4.2. A straightforward policy implication is that large-scale wealth redistribution is very effective in changing the fate of an economy. However, it would be very difficult to implement such redistribution in normal times: successful East Asian economies carried out large-scale land redistribution after a major war. Then, what can be done to put an economy on a faster track to the best steady state, SS 1?

One thing that can be done is reducing the financial burden of education to parents. While people must self-finance education costs in the model, many can borrow a part of costs in real economy, suggesting that the development of financial markets might be important. Indeed, Beck, Demirgüç-Kunt, and Levine (2007) show empirically that financial development boosts incomes of the poor through increased aggregate growth and reduced income inequality. However, making education loans widely available to the poor would be difficult because of the nature of educational investment: reaping fruits of the investment takes many years. A more effective way to ease the burden would be governmental subsidy to education, including public provision of education. But, under tight budget, providing generous subsidies to too many students (e.g. the introduction of tuition-free education

[30]In this case, $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{ml,\theta}$ is located above $b^*(\widetilde{w_m})=e_h$; $b^*(w_l)=e_h$ exists and is located between $b^*(w_l)=e_m$ and the dividing locus between $P<\theta$ and $P=\theta$; and $b^*(w_l)=e_h$ and $b^*(\widetilde{w_m})=e_h$ intersect on $F_m=\phi(F_h,\overline{B}^*(F_h))F_h$ (see Figure 6). If the initial economy is located above $b^*(w_l)=e_h$, it converges to Steady state 1 for certain, otherwise, the dynamics are qualitatively same as the original economy.

[31]The growth of A_T shifts $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{ml,\theta}$ and the dividing locus between $P<\theta$ and $P=\theta$ upward but does not change the loci affecting the dynamics of F_{ht} and F_{mt} such as $b^*(w_l)=e_m$.

[32]As mentioned before, the growth of A_M shifts $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{hm}$ and $b^*(\widetilde{w_h})=e_h$ upward and the remaining loci except $F_m=\phi(F_h,\overline{B}^*(F_h))F_h$ (the effect is ambiguous) downward. The growth of A_T, by contrast, shifts $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{ml,\theta}$ and the dividing locus between $P<\theta$ and $P=\theta$ *upward*. If A_M grows faster than A_T, a realistic assumption, the two loci shift *downward*, so the transition from Figure 7 to Figure 6 takes place.

in poor countries) worsens quality of education, as has occurred in many countries. The government must find ways to subsidize education effectively. The analysis in Section 4.2 indicates that effective subsidy depends on an economy's initial condition. If the size of the extreme poor is not large but the non-poor are scarce relative to the poor and thus the economy is on a track to SS 2, subsidizing advanced education should be given priority, which lowers e_h and shifts $b^*(\widetilde{w_m}) = e_h$ downward (see Figure 6). If an economy is approaching SS 3, subsidizing basic education (so that $b^*(w_l) = e_m$ is lowered) is the priority, while if it is in SS 4, both levels of education should be assisted. Improving quality of public schools is also important in easing the financial burden, because it is hard to become high-skill workers without spending on costly private schools, study materials, and tutoring in many countries.

Increasing wages by boosting the productivity of the modern sector is also worthwhile. According to the analysis in Section 4.3, when the productivity is very high, wages of both sectors become high enough that quick convergence to SS 1 is possible from any initial condition. However, raising the productivity greatly in a short time would not be realistic, because studies point out not only difficulties in adopting advanced technology from abroad (Acemoglu and Zilibotti, 2001) but also enormous cross-country productivity gaps not explained by technology gaps, which depend on factors such as differences in quality of economic and political institutions (Weil, 2013, Chapter 10). While raising the sector's productivity enables convergence to the best steady state faster, the initial condition would largely direct the dynamics. Raising the productivity of the traditional sector, by contrast, is not very effective, because the analysis in Section 4.3 suggests that the growth of A_T does not affect the speed of convergence to SS 1 (unless the initial condition is very good). Further, raising A_T would be much harder than raising A_M: it is much less affected by technological progress and the productivity of traditional agriculture is largely determined by climate and geographical conditions of an economy.

In sum, the government can speed up convergence to the best steady state by subsidizing appropriate education, developing financial markets, and raising the modern sector's productivity, although the initial condition would largely determine the dynamics. Which level of education should be prioritized in the subsidy policy depends on the initial condition.

4.5 Discussions

The model abstracts from physical capital accumulation and population growth for tractability and the focus on education and structural change. This subsection discusses how they would affect results. The main implication is that the full modernization of an economy would not be possible while the level of physical capital is low or population growth is rapid.

4.5.1 Role of physical capital accumulation

As noted in footnote 18 of Section 2, the modern sector's production function can be considered as a reduced form of the function that includes physical capital as an additional input, in which case the sector's productivity A_M depends negatively on r. Physical capital is not considered explicitly since its accumulation does not affect results in a small open economy.

When the capital market is not perfectly open, the accumulation affects human capital accumulation and structural change. As physical capital is accumulated over time, r falls and thus A_M rises. A rise in A_M has positive effects on wages of modern-sector workers and, when $P < \theta$, the wage of traditional-sector workers. A fall in r also has direct negative effects on wealth accumulation of many individuals. If the former effects through A_M dominate the latter ones, the dynamics would be similar to the growing A_M case analyzed in Section 4.3. In particular, when the level of physical capital is low, the dynamics would be illustrated by a diagram similar to the one for the low A_M case, Figure 7, where the best steady state ($F_h = F_m = 1$) does not exist. Because the relative productivity of the modern sector is low, the sector cannot generate sufficient numbers of jobs for educated workers and typically the traditional sector absorbs uneducated workers. Only after physical capital is accumulated enough, a phase diagram would look like the original one, Figure 6.

In sum, when the capital market is not perfectly open, physical capital accumulation plays a critical role in human capital accumulation and structural change. In particular, the best steady state of no traditional sector and high human capital cannot be realized unless physical capital is accumulated enough. Relatedly, Galor and Moav (2004, 2006) develop models in which human capital accumulation starts only after physical capital is accumulated enough in the course of development.

4.5.2 Role of population growth

As far as economic growth in the very long run, that is, the transition from Malthusian stagnation to modern economic growth, is concerned, population growth is a crucial factor. Unified growth theories (Galor, 2005) model interactions among population growth, human capital accumulation, and technological change to explain such transition.[33] Although this paper's concern is on current situations of developing economies, it would be important to see how results are affected by population growth, considering that population growth has changed over time in modern times (for example, it has been slowing down recently).

As population growth becomes higher, resources parents leave to their children are diluted. Such dilution would be captured by a fall in γ_b in the equation describing intergenerational transfers of wealth. With less inherited wealth, less children can afford education. Thus, $b^*(\widetilde{w_m}) = e_h$ shifts to the right ($b^*(\widetilde{w_m}) = e_m$ and $b^*(\widetilde{w_l}) = e_m$ shift to the left) in Figure

[33]Rahman (2013) develops a model with endogenous directed technical change and demography.

6, and the best steady state becomes more difficult to be reached. If population growth is rapid and thus γ_b is very low, the dynamics could be illustrated by a diagram similar to the one for the low A_M case, Figure 7, where the best steady state does not exist. Hence, the full modernization of an economy may not be possible while population growth is rapid.

5 Conclusion

This paper develops a dynamic dual-economy model and examines how the long-run outcome of an economy depends on the initial distribution of wealth and sectoral productivity. It is shown that, for fast transformation into a developed economy, the initial distribution must be such that extreme poverty is not prevalent so that most people can take education to acquire basic skills and the size of "middle class" is enough so that an adequate number of people can access education for advanced skills. Both conditions seem to have held in successful East Asian nations, where, as in the model economy undergoing such transformation, the fraction of workers with advanced skills rose greatly and inequalities between these workers and others fell over time. In contrast, if the former holds but the latter does not, which would be the case for many nations falling into "middle income trap", consistent with facts, the fraction of workers with basic skills and the share of the modern sector rise, but inequality between workers with advanced skills and with basic skills worsens and the traditional sector remains for long periods. If the former condition does not hold, which would be true for poorest economies, the dual structure and large inequality between workers without basic skills and others persist for very long periods. Consistently, Hanushek and Woessmann (2009) find that both the share of students with basic skills and that of top performance have significant effects on economic growth that are *complementary each other*.

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Appendix A: Supplementary analysis

A.1 Critical equations determining educational choices and wages

This section examines critical equations determining educational choices and wages, in particular, F_h and F_m satisfying $\widetilde{w_m}(\frac{F_h}{F_m})=P(F_h,F_m,B)A_T \Leftrightarrow F_m=\phi(F_h,B)F_h$ and $P(F_h,F_m,B)=\theta$. Remember that $(\frac{F_h}{F_m})_{hm}$ is $\frac{F_h}{F_m}$ satisfying $\widetilde{w_h}(\frac{F_h}{F_m}) = \widetilde{w_m}(\frac{F_h}{F_m})$, which exists and is unique since $\widetilde{w_h}$ ($\widetilde{w_m}$) decreases (increases) with $\frac{F_h}{F_m}$ and $\widetilde{w_h} > (<) \widetilde{w_m}$ at $\frac{F_h}{F_m} = 0 (= +\infty)$ from (11) and (12), and $(\frac{F_h}{F_m})_{ml,\theta}$ is $\frac{F_h}{F_m}$ satisfying $\widetilde{w_m}(\frac{F_h}{F_m})=\theta A_T$ (w_l when $P=\theta$).

Lemma A1 shows the existence of F_h and F_m satisfying $\widetilde{w_m}(\frac{F_h}{F_m})=P(F_h,F_m,B)A_T$ when $\frac{\gamma_B}{1-\gamma_B}(1+r)B<\theta A_T$ and describes its shape and its relation with $(\frac{F_h}{F_m})_{hm}$ and $(\frac{F_h}{F_m})_{ml,\theta}$. (When $\frac{\gamma_B}{1-\gamma_B}(1+r)B\geq\theta A_T$, $P(F_h,F_m,B)>\theta$ from (15) and thus $P=\theta$.)

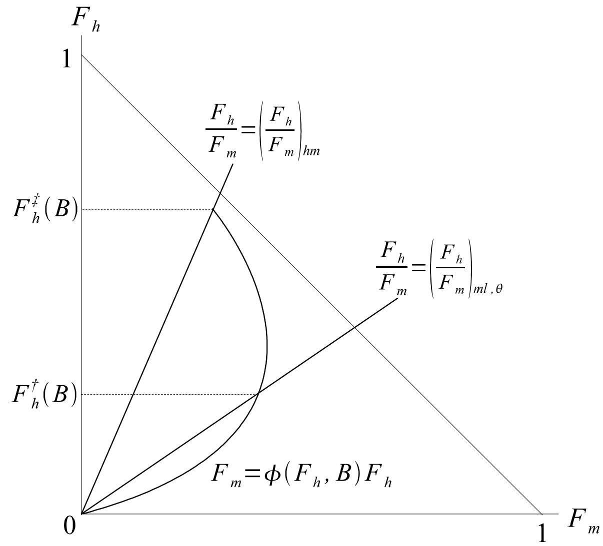

Figure 9: Lemma A1

Lemma A1 *Suppose* $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$*. Then, positive* F_h *and* F_m *satisfying* $\widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$ *exists and is expressed as* $F_m = \phi(F_h,B)F_h$*, where* $\phi(\cdot)$ *is a function satisfying* $\lim_{F_h\to 0}\phi(F_h,B) = \overline{\phi}(B) \equiv \left[\frac{(1-\alpha)A_M}{(1+r)(\frac{\gamma_B}{1-\gamma_B}B+e_m)}\right]^{\frac{1}{\alpha}}$*. When* $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{hm}$*,* $\phi(\cdot)$ *is a decreasing function of its arguments, and, for given* B*, there exists a unique* $F_h > 0$ *satisfying* $[\phi(F_h,B)]^{-1} = (\frac{F_h}{F_m})_{hm}$*, denoted* $F_h^{\ddagger}(B)$*, and the one satisfying* $[\phi(F_h,B)]^{-1} = (\frac{F_h}{F_m})_{ml,\theta}$*, denoted* $F_h^{\dagger}(B)$*, where* $F_h^{\ddagger}(\cdot)$ *and* $F_h^{\dagger}(\cdot)$ *are decreasing functions and* $F_h^{\ddagger}(B) > F_h^{\dagger}(B)$*.*

Figure 9 illustrates $F_m = \phi(F_h,B)F_h$ ($\widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$), $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{hm}$, and $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta}$ on the (F_m, F_h) plane. $F_h^{\ddagger}(B)$ and $F_h^{\dagger}(B)$ are unique intersections of $F_m = \phi(F_h,B)F_h$ with $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{hm}$ and $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{ml,\theta}$, respectively. As $F_h \to 0$, F_m satisfying $F_m = \phi(F_h,B)F_h$ approaches 0 (since $\lim_{F_h\to 0}\phi(F_h,B) = \overline{\phi}(B) < \infty$). $\frac{F_h}{F_m} = \frac{1}{\phi(F_h,B)}$ increases with F_h, thus F_m increases with F_h on the curve for low $\frac{F_h}{F_m}$, but the relationship turns negative for high $\frac{F_h}{F_m}$. As B increases, $\phi(F_h,B)$ decreases, thus the curve shifts leftward and $F_h^{\ddagger}(B)$ and $F_h^{\dagger}(B)$ fall.

Lemma A2 describes the shape of $P(F_h,F_m,B) = \theta$ and its relation with $F_m = \phi(F_h,B)F_h$.

Lemma A2 *Suppose* $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$*. When* $\frac{F_h}{F_m} \in [[\overline{\phi}(0)]^{-1}, (\frac{F_h}{F_m})_{hm}]$ *(*$[\overline{\phi}(0)]^{-1}$ *is the smallest* $\frac{F_h}{F_m}$ *satisfying* $F_m = \phi(F_h,0)F_h$*),* $P(F_h,F_m,B)$ *is an increasing function of its arguments. Given* B*, for any* $\frac{F_h}{F_m} \in [[\overline{\phi}(0)]^{-1}, (\frac{F_h}{F_m})_{hm}]$*,* F_h *and* F_m *satisfying* $P(F_h,F_m,B) = \theta$ *exist and are unique, and for* $\frac{F_h}{F_m} > (<) (\frac{F_h}{F_m})_{ml,\theta}$*,* $F_m < (>) \phi(F_h,B)F_h$ *when* $P(F_h,F_m,B) = \theta$*.*

A.2 Effects of F_h, F_m, and B on welfare, output, and sectoral composition

This section examines effects of F_h, F_m, and B on aggregate income net of education costs ($NI \equiv \widetilde{w_h}L_h + \widetilde{w_m}L_m + w_l(1-L_h-L_m) + (1+r)B$), average utility, aggregate output ($Y = Y_M + PY_T$), the share of the modern sector in production ($\frac{Y_M}{Y}$), and the sector's share in basic consumption when $P=\theta$ ($\frac{C_{BM}}{PC_B}$), where C_{BM} denotes the amount of good M used for basic consumption. Proofs of the following two propositions are provided in Appendix D posted on the author's website (http://www.econ.kyoto-u.ac.jp/˜yuki/english.html).

Proposition A1 (Net aggregate income and average utility) *Suppose $F_h > 0$.*

(i) If $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, NI and average utility increase with F_h+F_m and B.

(ii) Otherwise,

(a) If $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta}, (\frac{F_h}{F_m})_{hm})$, they increase with F_h, F_m, and B.

(b) If $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$,

1. *When $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$ and $F_h < F_h^{\dagger}(B)$, if $F_m \geq \phi(F_h,B)F_h$, they increase with F_h and B; otherwise, same as (a).*
2. *Or else, they increase with F_h and B.*

Both net aggregate income and average utility increase with B and the proportion(s) of individuals accessible to education for jobs with higher net wages, i.e. F_h+F_m when $\widetilde{w_h} = \widetilde{w_m}$, F_h and F_m when $\widetilde{w_h} > \widetilde{w_m} > w_l$, and F_h when $\widetilde{w_m} = w_l$. As for NI and average utility when $P=\theta$, this is because the negative effect through $\widetilde{w_h}$ or $\widetilde{w_m}$ (except when $\widetilde{w_h} = \widetilde{w_m} > w_l = \theta A_T$ or $\widetilde{w_h} > \widetilde{w_m} = w_l = \theta A_T$) is dominated by positive effects through other wages (except when $\widetilde{w_h} = \widetilde{w_m} > w_l = \theta A_T$), proportions of workers with higher net wages, and B. When $P < \theta$, increases in these variables raise P and thus have a negative effect on average utility, but the positive effect through net aggregate income dominates.

Proposition A2 (Aggregate output and sectoral composition) *Suppose $F_h > 0$.*

(i) When $\frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$, if $F_h+F_m < \frac{(1-\gamma_B)\theta A_T - \gamma_B(1+r)B}{\left[\gamma_B \widetilde{w_m}((\frac{F_h}{F_m})_{hm}) + (1-\gamma_B)\theta A_T\right]}$, Y increases with F_h+F_m and B, and $\frac{Y_M}{Y}$ increases with $\frac{F_h+F_m}{B}$; otherwise, they increase with F_h+F_m, and $\frac{C_{BM}}{PC_B}$ increases with F_h+F_m and B.

(ii) When $\frac{F_h}{F_m} < (\frac{F_h}{F_m})_{hm}$,

(a) If $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta}, (\frac{F_h}{F_m})_{hm})$, when $P(F_h,F_m,B) \leq \theta$ (possible only when $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$), Y increases with F_h, F_m, and B, and $\frac{Y_M}{Y}$ increases with F_h and F_m and decreases with B; otherwise, they increase with F_h and F_m, and $\frac{C_{BM}}{PC_B}$ increases with F_h, F_m, and B.

(b) If $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$,

1. *When $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$ and $F_h < F_h^{\dagger}(B)$, if $F_m \geq \phi(F_h,B)F_h$, Y increases with F_h and B, and $\frac{Y_M}{Y}$ decreases with B (depends on F_h too); otherwise, same as (a) when $P(F_h,F_m,B) \leq \theta$.*
2. *Or else, Y and $\frac{Y_M}{Y}$ increase with F_h, and $\frac{C_{BM}}{PC_B}$ increases with F_h and B.*

When $P < \theta$, aggregate output increases with B and the proportion(s) of individuals accessible to education for jobs with higher net wages, as NI and average utility do. In the case of $F_m < \phi(F_h,B)F_h$, this is because the increased proportion(s) raises L_h and L_m and shifts production to the more productive modern sector (an increase in Y_M is greater than a decrease in Y_T), plus they and B increase NI, thereby raising the demand for good T and thus P.[34] The modern sector's share in production increases with the proportion(s) (except the case $F_m \geq \phi(F_h,B)F_h$ of (b) 1, where the effect is ambiguous) but *decreases* with B.

When $P = \theta$, by contrast, P does not depend on NI and thus Y and $\frac{Y_M}{Y}$ are independent of B (and increase with the proportion(s)). The modern sector too produces goods for basic consumption, i.e. $C_{BM} > 0$, in this case. The proportion of basic consumption supplied by the sector increases with B as well as the proportion(s), because $\frac{C_{BM}}{PC_B} = \frac{PC_B - PY_T}{PC_B} = 1 - \frac{\theta Y_T}{\gamma_B NI}$ and thus it increases with NI and decreases with $Y_T = A_T(1 - L_h - L_m)$.

A.3 The dynamic equation of B_t and its fixed point

This section examines the dynamic equation of B_t, (24), of Section 3.2 and its fixed point.

When $\frac{F_{ht}}{F_{mt}} \geq (\frac{F_h}{F_m})_{hm}$, if $F_{ht} + F_{mt} < \frac{(1-\gamma_B)\theta A_T - \gamma_B(1+r)B_t}{\gamma_B \widetilde{w_m}((\frac{F_h}{F_m})_{hm}) + (1-\gamma_B)\theta A_T}$ and thus $P_t < \theta$, the equation is:

$$B_{t+1} = \frac{\gamma_b}{1-\gamma_B}\{\widetilde{w_m}((\tfrac{F_h}{F_m})_{hm})(F_{ht} + F_{mt}) + (1+r)B_t\}. \tag{29}$$

$\frac{\gamma_b}{1-\gamma_B}(1+r) < 1$ is assumed so that the fixed point for given $F_{ht} + F_{mt}$ exists, which equals:

$$\widehat{B}^*(F_{ht} + F_{mt}) = \frac{\gamma_b}{1-\gamma_B - \gamma_b(1+r)}\widetilde{w_m}((\tfrac{F_h}{F_m})_{hm})(F_{ht} + F_{mt}). \tag{30}$$

Clearly, when $B_t < (>) \widehat{B}^*(F_{ht} + F_{mt})$, $B_{t+1} > (<) B_t$. If $F_{ht} + F_{mt} \geq \frac{(1-\gamma_B)\theta A_T - \gamma_B(1+r)B_t}{\gamma_B \widetilde{w_m}((\frac{F_h}{F_m})_{hm}) + (1-\gamma_B)\theta A_T}$ and thus $P_t = \theta$, the dynamic equation and its fixed point equal:

$$B_{t+1} = \gamma_b\{\widetilde{w_m}((\tfrac{F_h}{F_m})_{hm})(F_{ht} + F_{mt}) + \theta A_T[1 - (F_{ht} + F_{mt})] + (1+r)B_t\}, \tag{31}$$

$$\widehat{B}^*(F_{ht} + F_{mt}) = \frac{\gamma_b}{1-\gamma_b(1+r)}\{\widetilde{w_m}((\tfrac{F_h}{F_m})_{hm})(F_{ht} + F_{mt}) + \theta A_T[1 - (F_{ht} + F_{mt})]\}, \tag{32}$$

where $\widehat{B}^*(F_{ht} + F_{mt})$ is an increasing function.

When $\frac{F_{ht}}{F_{mt}} \in ((\frac{F_h}{F_m})_{ml,\theta}, (\frac{F_h}{F_m})_{hm})$, if $P_t = P(F_{ht}, F_{mt}, B_t) \leq \theta$, they equal:

$$B_{t+1} = \frac{\gamma_b}{1-\gamma_B}\{[A_M(F_{ht})^\alpha(F_{mt})^{1-\alpha} - (1+r)(e_h F_{ht} + e_m F_{mt})] + (1+r)B_t\}, \tag{33}$$

$$B^*(F_{ht}, F_{mt}) = \frac{\gamma_b}{1-\gamma_B - \gamma_b(1+r)}\{A_M(F_{ht})^\alpha(F_{mt})^{1-\alpha} - (1+r)(e_h F_{ht} + e_m F_{mt})\}, \tag{34}$$

where $B^*(F_{ht}, F_{mt})$ is an increasing function. If $P(F_{ht}, F_{mt}, B_t) > \theta$ (thus $P_t = \theta$), they are:

[34] In the case $F_m \geq \phi(F_h,B)F_h$ of (b) 1, the effect of F_h on Y_M is ambiguous and that of B is negative, but their effects on PY_T are positive and dominate.

$$B_{t+1}=\gamma_b\{A_M(F_{ht})^{\alpha}(F_{mt})^{1-\alpha}-(1+r)(e_hF_{ht}+e_mF_{mt})+\theta A_T(1-F_{ht}-F_{mt})+(1+r)B_t\}, \quad (35)$$

$$B^*(F_{ht},F_{mt})=\frac{\gamma_b}{1-\gamma_b(1+r)}\{A_M(F_{ht})^{\alpha}(F_{mt})^{1-\alpha}-(1+r)(e_hF_{ht}+e_mF_{mt})+\theta A_T(1-F_{ht}-F_{mt})\}, \quad (36)$$

where $B^*(F_{ht},F_{mt})$ is an increasing function since $\widetilde{w_{ht}}>\widetilde{w_{mt}}>w_{lt}=\theta A_T$.

When $\frac{F_{ht}}{F_{mt}}\le(\frac{F_h}{F_m})_{ml,\theta}$, $\frac{\gamma_B}{1-\gamma_B}(1+r)B_t<\theta A_T$, and $F_{ht}<F_h^{\dagger}(B_t)$, if $F_{mt}<\phi(F_{ht},B_t)F_{ht}$, the equations are (33) and (34) above. If $F_{mt}\ge\phi(F_{ht},B_t)F_{ht}$, the dynamic equation is:

$$B_{t+1}=\frac{\gamma_b}{1-\gamma_B}\left\{\left[A_M(\phi(F_{ht},B_t))^{1-\alpha}-(1+r)(e_h+\phi(F_{ht},B_t)e_m)\right]F_{ht}+(1+r)B_t\right\}. \quad (37)$$

The next lemma shows that, given F_{ht}, B_t converges monotonically to the unique fixed point of (37), $\overline{B}^*(F_{ht})$, and $\overline{B}^*(F_{ht})$ increases and $\phi(F_{ht},\overline{B}^*(F_{ht}))$ decreases with F_{ht}.

Lemma A3 *When the dynamics of B_t follow* (37), *given F_{ht}, B_t converges monotonically to unique $\overline{B}^*(F_{ht})$, which is a solution to*

$$\overline{B}^*(F_{ht})=\frac{\gamma_b}{1-\gamma_B-\gamma_b(1+r)}\{A_M(\phi(F_{ht},\overline{B}^*(F_{ht})))^{1-\alpha}-(1+r)(e_h+\phi(F_{ht},\overline{B}^*(F_{ht}))e_m)F_{ht}\}, \quad (38)$$

and when $B_t<(>)\overline{B}^*(F_{ht})$, $B_{t+1}>(<)B_t$. $\overline{B}^*(F_{ht})$ is increasing and $\phi(F_{ht},\overline{B}^*(F_{ht}))$ is decreasing in F_{ht} and $\lim_{F_{ht}\to 0}\phi(F_{ht},\overline{B}^*(F_{ht}))=\overline{\phi}(0)\equiv\lim_{F_{ht}\to 0}\phi(F_{ht},0)$.

When $\frac{F_{ht}}{F_{mt}}\le(\frac{F_h}{F_m})_{ml,\theta}$ and either $\frac{\gamma_B}{1-\gamma_B}(1+r)B_t<\theta A_T$ and $F_{ht}\ge F_h^{\dagger}(B_t)$ or $\frac{\gamma_B}{1-\gamma_B}(1+r)B_t\ge\theta A_T$,

$$B_{t+1}=\gamma_b\{\widetilde{w_h}((\tfrac{F_h}{F_m})_{ml,\theta})F_{ht}+\theta A_T(1-F_{ht})+(1+r)B_t\}, \quad (39)$$

$$\overline{B}^*(F_{ht})=\frac{\gamma_b}{1-\gamma_b(1+r)}\{\widetilde{w_h}((\tfrac{F_h}{F_m})_{ml,\theta})F_{ht}+\theta A_T(1-F_{ht})\}, \quad (40)$$

where $\overline{B}^*(F_{ht})$ is an increasing function.

A.4 Welfare, output, and sectoral composition in steady states

The next proposition examines the steady states in terms of welfare, output, and sectoral composition, based on Propositions A1 and A2 and Proposition 3 of Section 4.1.

Proposition A3 (Welfare, output, and sectoral composition in steady states)

(*i*) *Aggregate net income and average utility are highest in SS 1. They increase with F_h in SS 2 and SS 3, and with F_h and F_m in SS 4. Their maxima in SS 2 and SS 3 are strictly higher than in SS 4, and the infinima in SS 2 are strictly higher than in SS 3 and SS 4.*

(*ii*) *The same result as* (*i*) *holds for aggregate output, except that the magnitude relation of the maxima in SS 3 and SS 4 is unclear. In SS 1, $\frac{Y_M}{Y}=\frac{C_{BM}}{PC_B}=1$. In SS 2, if $F_h<F_h^{\dagger}$, $\frac{Y_M}{Y}$ increases (decreases) with $\frac{F_h}{F_m}=[\phi(F_h,\overline{B}^*(F_h))]^{-1}$ for $[\phi(F_h,\overline{B}^*(F_h))]^{-1}>(<)\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$, where $\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}>\widetilde{w_m}^{-1}\left[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\right]$; if $F_h\ge F_h^{\dagger}$ and $\frac{F_h}{1-F_h}\le(\frac{F_h}{F_m})_{ml,\theta}$, $\frac{Y_M}{Y}$ and $\frac{C_{BM}}{PC_B}$ increase with F_h; otherwise, $\frac{Y_M}{Y}=\frac{C_{BM}}{PC_B}=1$. In SS 3, $\frac{Y_M}{Y}$ is constant. In SS 4, $\frac{Y_M}{Y}$ increases (decreases) with $\frac{F_h}{F_m}$ for $\frac{F_h}{F_m}>(<)\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$.*[35]

[35] $C_{BM}=0$ in the case $F_h<F_h^{\dagger}$ of SS 2 and in SS 3 and SS 4.

The proposition proves that SS 1 is the best in terms of aggregate net income, average utility, and aggregate output. Other steady states cannot be ranked definitely, but if they are to be ranked, SS 2 is the second best, SS 3 follows, and SS 4 is the worst: the maximum values of these variables in SS 2 and SS 3 (except aggregate output in SS 3) are strictly higher than the ones in SS 4, and the infinima in SS 2 are strictly higher than the ones in SS 3 and SS 4. The three variables increase with the proportion(s) of those accessible to education for jobs with higher net wages, i.e. F_h in SS 2 and SS 3, and F_h and F_m in SS 4.

As for shares of the modern sector in production and in basic consumption, when $P<\theta$ (thus $\frac{C_{BM}}{PC_B}=0$), $\frac{Y_M}{Y}$ depends on $\frac{F_h}{F_m}$ and the relation can be *non-monotonic*: in the case $F_h<F_h^\dagger$ of SS 2 and in SS 4, $\frac{Y_M}{Y}$ decreases with $\frac{F_h}{F_m}$ for $\frac{F_h}{F_m}<\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$ (note $\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}>\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big]$) and the relation turns positive for $\frac{F_h}{F_m}>\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$ if $\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}<\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\Big]$. That is, the production share *decreases* with $\frac{F_h}{F_m}$ when $\frac{F_h}{F_m}$ is relatively low. By contrast, when $P=\theta$, i.e. in the case $F_h\geq F_h^\dagger$ and $\frac{F_h}{1-F_h}\leq(\frac{F_h}{F_m})_{ml,\theta}$ of SS 2, $\frac{Y_M}{Y}$ and $\frac{C_{BM}}{PC_B}$ increase with F_h. (They equal 1 in SS 1 and in the case $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$ of SS 2; $\frac{Y_M}{Y}(<1)$ is constant and $\frac{C_{BM}}{PC_B}=0$ in SS 3.)

A.5 Relationship between initial conditions and steady states

The next proposition presents the relationship between initial conditions and steady states. Since the lengthy analysis of the dynamics is involved, the proof is provided in Appendix C posted on the author's website (http://www.econ.kyoto-u.ac.jp/˜yuki/english.html).

Proposition A4 (Initial conditions and steady states)

(i) When $\frac{F_{h0}}{F_{m0}}<\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big]$

a. If $F_{h0}<F_h^\flat$, F_{ht} is constant, F_{mt} falls, and the economy most likely converges to SS 4.[36]

b. If $F_{h0}\geq F_h^\flat$, when $F_{h0}\geq F_h^\flat(B_0)$, F_{ht} is constant, F_{mt} increases, and the economy converges to SS 2.[37] *When $F_{h0}<F_h^\flat(B_0)$, at first, F_{ht} is constant and F_{mt} decreases, and it could converge to any type of steady states or cycle.*[38]

(ii) When $\frac{F_{h0}}{F_{m0}}\in\Big[\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big],\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\Big]\Big]$

a. If $b^*(w_l)\leq e_m$ at $(F_h,F_m,B)=(F_{h0},F_{m0},B^*(F_{h0},F_{m0}))$, F_{ht} and F_{mt} are constant and the final state is SS 4.

b. Otherwise, F_{ht} is constant, F_{mt} rises, and the economy converges to SS 2.

(iii) When $\frac{F_{h0}}{F_{m0}}>\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\Big]$ *, F_{ht} increases and $F_{ht}+F_{mt}$ non-decreases at first.*

[36] F_{mt} could "jump over" the region $\frac{F_h}{F_m}\in\Big[\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big],\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\Big]\Big]$ depending on the initial distribution, in which case it converges to another type of steady states, particularly SS 3.

[37] The exception is when $F_{h0}=F_h^\flat$ and $B_0=\overline{B}^*(F_{h0})$, in which case both F_{mt} and B_t are constant.

[38] The economy possibly cycles between the region $\frac{F_h}{F_m}<\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big]$ and $F_h\in[F_h^\flat,F_h^\flat(B))$ and the region $\frac{F_h}{F_m}\in\Big[\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m\Big],\widetilde{w_m}^{-1}\Big[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h\Big]\Big]$.

a. If $\frac{F_{h0}}{F_{m0}} \geq (\frac{F_h}{F_m})_{hm}$ *and* $b^*(w_l) \leq e_m$ *at* $(F_h,F_m) = (F_{h0},F_{m0})$ *and* $B = \widehat{B}^*(F_{h0}+F_{m0})$*,* $F_{ht}+F_{mt}$ *is constant and the economy converges to SS 3.*

b. If $\frac{F_{h0}}{F_{m0}} < (\frac{F_h}{F_m})_{hm}$ *and* $b^*(w_l) \leq e_m$ *at* $(F_h,F_m) = (F_{h0},F_{m0})$ *and* $B = B^*(F_{h0},F_{m0})$*, the following three scenarios are possible depending on details of the initial distribution.*

1. *The more likely is the same scenario as a.*
2. $F_{ht}+F_{mt}$ *rises from the start or after some period and the final state is SS 1.*
3. *After* $F_{ht}+F_{mt}$ *increases for a while,* F_{ht} *becomes constant,* F_{mt} *increases, and the economy converges to SS 2.*

The first scenario is more likely as F_{h0} *and* F_{m0} *are lower, and the second one is more likely than the third one as* $\frac{F_{h0}}{F_{m0}}$ *is higher.*

c. Otherwise, the same scenarios as 2. *and* 3. *of b. are possible.*

Appendix B: Proofs of lemmas and propositions

Proof of Lemma A1. (Existence of function $\phi(\cdot)$) Let $\phi = \frac{F_m}{F_h}$. Then, from (12) and (15), $\widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$ is expressed as:

$$(1-\alpha)A_M(\phi)^{-\alpha} - (1+r)e_m = \frac{\gamma_B}{1-\gamma_B}\frac{A_M(\phi)^{1-\alpha}F_h + (1+r)[B-(e_h+\phi e_m)F_h]}{1-(1+\phi)F_h}, \tag{41}$$

where $F_h < \frac{1}{1+\phi} \Leftrightarrow \phi < \frac{1-F_h}{F_h}$ must be true. When $F_h \to 0$, the equation becomes:

$$(1-\alpha)A_M(\phi)^{-\alpha} - (1+r)e_m = \frac{\gamma_B}{1-\gamma_B}(1+r)B, \tag{42}$$

whose solution $\phi = \overline{\phi}(B) \equiv [\frac{(1-\alpha)A_M}{(1+r)(\frac{\gamma_B}{1-\gamma_B}B+e_m)}]^{\frac{1}{\alpha}}$ satisfies $\overline{\phi}(B) \leq \overline{\phi} \equiv \overline{\phi}(0) = [\frac{(1-\alpha)A_M}{(1+r)e_m}]^{\frac{1}{\alpha}}$, where $\overline{\phi}$ is the solution to $\widetilde{w_m} = (1-\alpha)A_M(\phi)^{-\alpha} - (1+r)e_m = 0$. The LHS of (41) decreases and the RHS increases with ϕ for $\phi < \min\{\frac{1-F_h}{F_h}, \overline{\phi}\}$; as $\phi \to 0$, $LHS \to +\infty$ and thus $LHS > RHS$; and as $\phi \to \min\{\frac{1-F_h}{F_h}, \overline{\phi}\}$, $LHS < RHS$ since, at $\phi = \overline{\phi} < \frac{1-F_h}{F_h}$, $LHS = 0$ and $RHS > 0$ (from $\overline{\phi} > [(\frac{F_h}{F_m})_{ml,\theta}]^{-1} > [(\frac{F_h}{F_m})_{hm}]^{-1}$, $\widetilde{w_h} > \widetilde{w_m} = 0$ and $A_M(\phi)^{1-\alpha} - (1+r)(e_h+\phi e_m) = \widetilde{w_h} + \phi\widetilde{w_m} > 0$), and when $\frac{1-F_h}{F_h} \leq \overline{\phi}$, $RHS \to +\infty$ as $\phi \to \frac{1-F_h}{F_h}$. Hence, for given $F_h > 0$ and B, a unique $\phi \in (0,\min\{\frac{1-F_h}{F_h}, \overline{\phi}\})$ satisfying (41), denoted $\phi = \phi(F_h, B)$, exists, and $\lim_{F_h \to 0} \phi(F_h,B) = \overline{\phi}(B)$.

(Properties of $\phi(\cdot)$) The RHS of (41) is strictly increasing in F_h ($< \frac{1}{1+\phi}$) when $\phi \in [[(\frac{F_h}{F_m})_{hm}]^{-1}, \min\{\frac{1-F_h}{F_h}, \overline{\phi}\})$, because $A_M(\phi)^{1-\alpha} - (1+r)(e_h+\phi e_m) = \widetilde{w_h} + \phi\widetilde{w_m} > (1+\phi)\theta A_T > 0$ at $\phi = [(\frac{F_h}{F_m})_{hm}]^{-1}$ from Assumption 1. Thus, $\phi(F_h,B)$ is a decreasing function. $\overline{\phi}(B) > [(\frac{F_h}{F_m})_{hm}]^{-1}$ because $\widetilde{w_m} > \theta A_T$ at $\phi = [(\frac{F_h}{F_m})_{hm}]^{-1}$ from Assumption 1 and $\widetilde{w_m} = \frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$ at $\phi = \overline{\phi}(B)$ from (42). Then, since $\lim_{F_h \to 0} \phi(F_h,B) = \overline{\phi}(B) > [(\frac{F_h}{F_m})_{hm}]^{-1}$ and the limit of $\phi(F_h,B)$ when $F_h \to \frac{1}{1+[(\frac{F_h}{F_m})_{hm}]^{-1}}$ is strictly less than $[(\frac{F_h}{F_m})_{hm}]^{-1}$ (from eq. 41), for given B, there exists a unique $F_h > 0$ satisfying $\phi(F_h,B) = [(\frac{F_h}{F_m})_{hm}]^{-1}$, which is denoted as $F_h^{\ddagger}(B)$. The existence of $F_h^{\dagger}(B)$ can be proved similarly. $F_h^{\ddagger}(B) > F_h^{\dagger}(B)$ is from Assumption 1. ■

Proof of Lemma A2. From the proof of Lemma A1, $\overline{\phi}(0) \geq \overline{\phi}(B) > [(\frac{F_h}{F_m})_{hm}]^{-1}$, $\widetilde{w_m} \geq (>) 0$ for $\frac{F_h}{F_m} \geq (>) [\overline{\phi}(0)]^{-1}$, and $\widetilde{w_h} \geq \widetilde{w_m}$ for $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{hm}$ from the definition of $(\frac{F_h}{F_m})_{hm}$. Thus, the numerator of (15) and $P(F_h,F_m,B)$ increase with F_h and F_m for $\frac{F_h}{F_m} \in [[\overline{\phi}(0)]^{-1},(\frac{F_h}{F_m})_{hm}]$.

From (15) and $\phi = \frac{F_m}{F_h}$, $P(F_h,F_m,B) = \theta$ is expressed as:

$$\frac{1}{A_T}\frac{\gamma_B}{1-\gamma_B}\frac{A_M(\phi)^{1-\alpha}F_h + (1+r)[B-(e_h+\phi e_m)F_h]}{1-(1+\phi)F_h} = \theta, \tag{43}$$

where $F_h < \frac{1}{1+\phi}$. For given $\phi \in [[(\frac{F_h}{F_m})_{hm}]^{-1},\overline{\phi}(0)]$, $LHS = \frac{1}{A_T}\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta$ when $F_h = 0$; $LHS \to +\infty$ when $F_h \to \frac{1}{1+\phi}$; and the LHS increases with F_h ($A_M(\phi)^{1-\alpha} - (1+r)(e_h+\phi e_m) = \widetilde{w_h} + \phi\widetilde{w_m} > 0$). Hence, given B, for any $\frac{F_h}{F_m} \in [[\overline{\phi}(0)]^{-1},(\frac{F_h}{F_m})_{hm}]$, there exists a unique $F_h \in (0, \frac{1}{1+[\frac{F_h}{F_m}]^{-1}})$ satisfying $P(F_h,F_h,B) = \theta$. When $\frac{F_h}{F_m} > (<) (\frac{F_h}{F_m})_{ml,\theta}$ and thus $\widetilde{w_m}(\frac{F_h}{F_m}) > (<) \theta A_T$, at $P(F_h,F_m,B) = \theta$, $\widetilde{w_m}(\frac{F_h}{F_m}) > (<) \theta A_T = P(F_h,F_m,B)A_T$, that is, $F_m < (>) \phi(F_h,B)F_h$. ■

Proof of Proposition 1. Since $F_h > 0$, an equilibrium with L_h, $L_m > 0$ always exists from the shape of the production functions. Thus, equilibrium L_h and L_m must satisfy $\widetilde{w_h} \geq \widetilde{w_m}$ (thus $\frac{L_h}{L_m} \leq (\frac{F_h}{F_m})_{hm}$) and $\widetilde{w_m} \geq w_l$. Since $\widetilde{w_h} = \widetilde{w_m} > \theta A_T \geq w_l$ at $\frac{L_h}{L_m} = (\frac{F_h}{F_m})_{hm}$ (from Assumption 1) and $\widetilde{w_h}(\widetilde{w_m})$ decreases (increases) with $\frac{L_h}{L_m}$, equilibrium $\frac{L_h}{L_m}$ satisfying $\widetilde{w_h} = \widetilde{w_m} = w_l$ does not exist. Hence, when $\widetilde{w_h} = \widetilde{w_m}$, $\widetilde{w_m} > w_l$, and when $\widetilde{w_m} = w_l$, $\widetilde{w_h} > \widetilde{w_m}$. In the former case, $L_h \leq F_h$, $L_h + L_m = F_h + F_m$, and $\frac{L_h}{L_m} \leq \frac{F_h}{F_m}$, and in the latter, $L_h = F_h$, $L_m \leq F_m$, and $\frac{L_h}{L_m} \geq \frac{F_h}{F_m}$.

(i) $\widetilde{w_m} = w_l$ is not possible since $\widetilde{w_h} > \widetilde{w_m}$ and $\frac{L_h}{L_m} = \frac{F_h}{L_m} \geq \frac{F_h}{F_m} \geq (\frac{F_h}{F_m})_{hm}$ cannot hold together. Thus, $\widetilde{w_m} > w_l$, $L_h + L_m = F_h + F_m$ and $\frac{L_h}{L_m} = \frac{L_h}{F_h+F_m-L_h} \leq \frac{F_h}{F_m}$. When $\frac{F_h}{F_m} = (\frac{F_h}{F_m})_{hm}$, $\widetilde{w_h} > \widetilde{w_m}$ with $L_h < F_h$ (since $\frac{L_h}{L_m} < \frac{F_h}{F_m} = (\frac{F_h}{F_m})_{hm}$) and thus $L_h = F_h$, $L_m = F_m$, and $\widetilde{w_h} = \widetilde{w_m}$ in equilibrium. When $\frac{F_h}{F_m} > (\frac{F_h}{F_m})_{hm}$, $\widetilde{w_h} < \widetilde{w_m}$ with $L_h = F_h$ and thus $L_h < F_h$ and $\widetilde{w_h} = \widetilde{w_m}$ in equilibrium. Values of L_h and L_m are obtained from $\frac{L_h}{L_m} = (\frac{F_h}{F_m})_{hm}$ and $L_h + L_m = F_h + F_m$.

(ii) If $\widetilde{w_h} = \widetilde{w_m}$, as shown above, $\frac{L_h}{L_m} = \frac{L_h}{F_h+F_m-L_h} \leq \frac{F_h}{F_m}$ must hold, which implies $\frac{L_h}{L_m} \leq \frac{F_h}{F_m} < (\frac{F_h}{F_m})_{hm}$ and thus $\widetilde{w_h} > \widetilde{w_m}$, a contradiction. Hence, $\widetilde{w_h} > \widetilde{w_m}$ and $L_h = F_h$ in equilibrium.

When $\frac{\gamma_B}{1-\gamma_B}(1+r)B \geq \theta A_T$, the RHS of (15) is greater than θ for any equilibrium L_h and L_m (since $\widetilde{w_i} > 0$), thus $P = \theta$ and $w_l = \theta A_T$ in equilibrium. Hence, when $\frac{F_h}{F_m} \in ((\frac{F_h}{F_m})_{ml,\theta},(\frac{F_h}{F_m})_{hm})$, $\widetilde{w_m} > w_l$ and $L_m = F_m$, and when $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$, $\widetilde{w_m} = w_l$ and $\frac{L_h}{L_m} = \frac{F_h}{L_m} = (\frac{F_h}{F_m})_{ml,\theta}$.

When $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$, since $\frac{F_h}{F_m} < (\frac{F_h}{F_m})_{hm}$, from Lemma A1, F_h and F_m satisfying $\widetilde{w_m}(\frac{F_h}{F_m}) = P(F_h,F_m,B)A_T$ exist for any $\frac{F_h}{F_m} \geq [\overline{\phi}(B)]^{-1}$ and is expressed as $F_m = \phi(F_h,B)F_h$, where $\phi(\cdot)$ is a decreasing function, and from Lemma A2, F_h and F_m satisfying $P(F_h,F_m,B) = \theta$ exist for any $\frac{F_h}{F_m} \geq [\overline{\phi}(0)]^{-1}$, where $P(\cdot)$ is an increasing function. Note that $(\frac{F_h}{F_m})_{ml,\theta} > [\overline{\phi}(B)]^{-1} \geq [\overline{\phi}(0)]^{-1}$ from (41) and (42) in the proof of Lemma A1 and $\frac{\gamma_B}{1-\gamma_B}(1+r)B < \theta A_T$.

(a) When $P(F_h,F_m,B) < \theta$, $\widetilde{w_m}(\frac{F_h}{F_m}) > \theta A_T > P(F_h,F_m,B)A_T$ from $\frac{F_h}{F_m} > (\frac{F_h}{F_m})_{ml,\theta}$. Hence, $L_m = F_m$ and $\widetilde{w_m} > \theta A_T > w_l = P(F_h,F_m,B)A_T$ in equilibrium. When $P(F_h,F_m,B) \geq \theta$, $\widetilde{w_m} = \widetilde{w_m}(\frac{F_h}{L_m}) = P(F_h,L_m,B)A_T = w_l \geq \widetilde{w_m}(\frac{F_h}{F_m})$ cannot be true since $\widetilde{w_m}(\frac{F_h}{F_m}) > \theta A_T$ from

$\frac{F_h}{F_m} > (\frac{F_h}{F_m})_{ml,\theta}$. Hence, $\widetilde{w_m} > w_l$, $L_m = F_m$, and $P = \theta$ in equilibrium.

(b) 1. From Lemma A1 (see Figure 9 too), for any $\frac{F_h}{F_m} \in [\,[\overline{\phi}(B)]^{-1}, (\frac{F_h}{F_m})_{ml,\theta})$, there exists $F_h < F_h^{\dagger}(B)$ satisfying $F_m = \phi(F_h,B)F_h$. When $P(F_h,F_m,B) \geq \theta$ (then, $F_m > \phi(F_h,B)F_h$ from Lemma A2) or when $P(F_h,F_m,B) < \theta$ and $F_m \geq \phi(F_h,B)F_h$, $\widetilde{w_m}(\frac{F_h}{F_m}) \leq P(F_h,F_m,B)A_T$ and thus $\widetilde{w_m} = \widetilde{w_m}(\frac{F_h}{L_m}) = P(F_h,L_m,B)A_T = w_l$ and $L_m = \phi(F_h,B)F_h$ in equilibrium, where $\widetilde{w_m} = \widetilde{w_m}(\frac{F_h}{L_m}) < \theta A_T$ from $\frac{F_h}{L_m} = \frac{1}{\phi(F_h,B)} < \frac{1}{\phi(F_h^{\dagger}(B),B)} = (\frac{F_h}{F_m})_{ml,\theta}$. When $P(F_h,F_m,B) < \theta$ and $F_m < \phi(F_h,B)F_h$, $\widetilde{w_m} = \widetilde{w_m}(\frac{F_h}{F_m}) > P(F_h,F_m,B)A_T = w_l$ and $L_m = F_m$ in equilibrium.

2. When $\frac{F_h}{F_m} \leq (\frac{F_h}{F_m})_{ml,\theta}$ and $F_h \geq F_h^{\dagger}(B)$, from Lemma A2 (see Figure 1 too), $P(F_h,F_m,B) = P(F_h,[\frac{F_h}{F_m}]^{-1}F_h,B) \geq P(F_h,[(\frac{F_h}{F_m})_{ml,\theta}]^{-1}F_h,B) \geq P(F_h^{\dagger}(B),[(\frac{F_h}{F_m})_{ml,\theta}]^{-1}F_h^{\dagger}(B),B) = \theta$. From Lemma A2, when $P(F_h,F_m,B) \geq \theta$, $F_m \geq \phi(F_h,B)F_h$ and thus $\widetilde{w_m}(\frac{F_h}{F_m}) \leq \theta A_T \leq P(F_h,F_m,B)A_T$. Hence, $\widetilde{w_m} = \theta A_T = w_l$, $P = \theta$, $L_m = [(\frac{F_h}{F_m})_{ml,\theta}]^{-1}F_h$, and $\widetilde{w_h} = \widetilde{w_h}([(\frac{F_h}{F_m})_{ml,\theta}]^{-1})$ in equilibrium. Note that $\widetilde{w_m} = w_l = P(F_h,L_m,B)A_T < \theta A_T$ (thus $\frac{L_h}{L_m} = \frac{F_h}{L_m} > (\frac{F_h}{F_m})_{ml,\theta}$) is not possible because, from Lemma A2, if $\frac{F_h}{L_m} > (\frac{F_h}{F_m})_{ml,\theta}$, $\widetilde{w_m}(\frac{F_h}{L_m}) > P(F_h,L_m,B)A_T$ when $P(F_h,L_m,B) < \theta$. ■

Proof of Proposition 2. (i) From Proposition 1 (i), $\frac{L_h}{L_m} = (\frac{F_h}{F_m})_{hm}$ and thus $\widetilde{w_h} = \widetilde{w_m} = \widetilde{w_m}((\frac{F_h}{F_m})_{hm})$, which is strictly greater than θA_T (thus w_l) from Assumption 1. By substituting $\widetilde{w_h} = \widetilde{w_m} = \widetilde{w_m}((\frac{F_h}{F_m})_{hm})$ and $L_h + L_m = F_h + F_m$ into P (eq. 14) and equating it with θ,

$$\frac{\gamma_B}{1-\gamma_B}\frac{\widetilde{w_m}((\frac{F_h}{F_m})_{hm})(F_h+F_m)+(1+r)B}{1-(F_h+F_m)} = \theta A_T \Leftrightarrow F_h+F_m = \frac{(1-\gamma_B)\theta A_T - \gamma_B(1+r)B}{\gamma_B\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+(1-\gamma_B)\theta A_T}. \tag{44}$$

Thus, the result for w_l holds. (ii) Straightforward from proofs of Proposition 1 (ii). ■

Proof of Lemma A3. From the proof of Lemma A2, $\phi = \phi(F_{ht},B_t)$ is a solution to

$$(1-\alpha)A_M(\phi)^{-\alpha} - (1+r)e_m = \frac{\gamma_B}{1-\gamma_B}\frac{[A_M(\phi)^{1-\alpha} - (1+r)(e_h+\phi e_m)]F_{ht} + (1+r)B_t}{1-(1+\phi)F_{ht}}. \tag{45}$$

where the first term of the numerator of the RHS equals $\widetilde{w_{ht}} + \phi\widetilde{w_{mt}} > 0$ from (11) and (12). Since the LHS decreases with ϕ and the RHS and its denominator increase with ϕ, its numerator increases with B_t. Thus, the numerator of the RHS of (37) is positive at $B_t = 0$ and is increasing in B_t. Further, for any $B_t > 0$,

$$\frac{\partial RHS}{\partial B_t} = \frac{\gamma_b}{1-\gamma_B}\left\{\left[(1-\alpha)A_M(\phi(F_{ht},B_t))^{-\alpha} - (1+r)e_m\right]F_{ht}\frac{\partial\phi(F_{ht},B_t)}{\partial B_t} + (1+r)\right\} < \frac{\gamma_b(1+r)}{1-\gamma_B} < 1. \tag{46}$$

Hence, for given F_{ht}, B_t converges monotonically to the unique solution to (38), $\overline{B}^*(F_{ht})$, and when $B_t < (>) \overline{B}^*(F_{ht})$, $B_{t+1} > (<) B_t$. From (45) and (38), $\phi = \phi(F_{ht},\overline{B}^*(F_{ht}))$ is a solution to:

$$(1-\alpha)A_M(\phi)^{-\alpha} - (1+r)e_m = \frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\frac{A_M(\phi)^{1-\alpha} - (1+r)(e_h+\phi e_m)}{1-(1+\phi)F_{ht}}F_{ht}. \tag{47}$$

Thus, $\phi(F_{ht},\overline{B}^*(F_{ht}))$ is decreasing in F_{ht} and, as $F_{ht} \to 0$, $\phi(F_{ht},\overline{B}^*(F_{ht})) \to \overline{\phi}(0) \equiv [\frac{(1-\alpha)A_M}{(1+r)e_m}]^{\frac{1}{\alpha}}$. Finally, $\frac{d\overline{B}^*(F_{ht})}{dF_{ht}} > 0$ is from (24) and Proposition A1 (ii)(b) 1. ■

Proof of Proposition 3. In a steady state, relative positions of the critical loci determining the dynamics of F_h and F_m and the magnitude relation of P and θ are illustrated by Figure 5. In the region satisfying $b^*(\widetilde{w_m})>e_h$ and $b^*(w_l)>e_m$ of the figure, F_h and F_h+F_m increase when $F_h<1$, thus $F_h<1$ cannot be a steady state. Hence, $(F_h,F_m)=(1,0)$ is the only steady state (SS 1). Since $\frac{F_h}{F_m}=+\infty>(\frac{F_h}{F_m})_{hm}$ and $P=\theta$ from the figure, $B=\widehat{B}^*(1)$ holds from (32). In the region satisfying $b^*(\widetilde{w_m})\leq e_h$ and $b^*(w_l)>e_m$, F_h is constant and F_m increases when $F_h+F_m<1$, thus steady states are such that $F_m=1-F_h$ and F_h satisfies $b^*(\widetilde{w_m})\leq e_h \Leftrightarrow \frac{F_h}{F_m}=\frac{F_h}{1-F_h}\leq \widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h]$ (from the paragraph just after Assumption 3) and $b^*(w_l)>e_m \Leftrightarrow F_h>F_h^\flat$ (from eq. 28) [SS 2]. Since $L_m=\max\{\phi(F_h,\overline{B}^*(F_h)),[(\frac{F_h}{F_m})_{ml,\theta}]^{-1}\}F_h$ when $\frac{F_h}{F_m}=\frac{F_h}{1-F_h}\leq(\frac{F_h}{F_m})_{ml,\theta}$ and $L_m=F_m$ when $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$ from Proposition 1, $B=\overline{B}^*(F_h)$ when $\frac{F_h}{1-F_h}\leq(\frac{F_h}{F_m})_{ml,\theta}$ from (38) and (40), and $B=B^*(F_h,F_m)$ when $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$ from $P=\theta$ and (36). In the region satisfying $b^*(\widetilde{w_m})>e_h$ and $b^*(w_l)\leq e_m$, F_h increases and F_m decreases when $F_m>0$, thus steady states are such that $F_m=0$ and F_h satisfies $b^*(w_l)\leq e_m \Leftrightarrow F_h\leq \frac{\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}{\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\widetilde{w_m}((\frac{F_h}{F_m})_{hm})+\frac{1-\gamma_b(1+r)}{\gamma_b}e_m}$ (from eq. 26) [SS 3]. Since $P<\theta$ from the figure, $B=\widehat{B}^*(F_h)$ holds from (30). In the region satisfying $b^*(\widetilde{w_m})\leq e_h$ and $b^*(w_l)\leq e_m$, F_h is constant and F_m decreases (is constant) when $b^*(\widetilde{w_m})<(\geq)e_m$, thus steady states are: F_h and F_m satisfying $e_m\leq b^*(\widetilde{w_m})\leq e_h \Leftrightarrow \frac{F_h}{F_m}\in\left[\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m],\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h]\right]$ and $b^*(w_l)\leq e_m \Leftrightarrow P(F_h,F_m,B^*(F_h,F_m))A_T\leq\frac{1-\gamma_b(1+r)}{\gamma_b}e_m$ (from eq. 27), and $B=B^*(F_h,F_m)$ (from eq. 34) [SS 4]; and $F_h=F_h^\flat$, $F_m\geq\phi(F_h^\flat,\overline{B}^*(F_h^\flat))F_h^\flat$ (thus $\frac{F_h}{F_m}<\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m]$), and $B=\overline{B}^*(F_h)$ (see footnote 26).

In SS 2, from the figure and the result on B, $P=P(F_h,L_m,\overline{B}^*(F_h))<\theta$ if $F_h\leq F_h^\dagger$ and $P=\theta$ otherwise. In SS 3, $P=P(L_h,L_m,\widehat{B}^*(F_h))=\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}\frac{\widetilde{w_m}((\frac{F_h}{F_m})_{hm})F_h}{A_T(1-F_h)}$ from (15), (30), and $\widetilde{w_h}=\widetilde{w_m}=\widetilde{w_m}((\frac{F_h}{F_m})_{hm})$. Levels of L_h, L_m, and L_l, and wages are from Propositions 1 and 2 and the result on P. ■

Proof of Proposition A3. (i) From Proposition A1 (i), aggregate net income (NI) and average utility of SS 1 are strictly greater than those of SS 3, and they increase with F_h in SS 3 ($B=\widehat{B}^*(F_h)$ from Proposition 3.). In SS 2, when $\frac{F_h}{1-F_h}\leq(\frac{F_h}{F_m})_{ml,\theta}$, they increase with F_h from Propositions A1 (ii)(b) and 3 ($B=\overline{B}^*(F_h)$), while when $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$, they increase with F_h because $NI=\frac{1}{1-\gamma_b(1+r)}\{A_M(F_h)^\alpha(1-F_h)^{1-\alpha}-(1+r)[e_hF_h+e_m(1-F_h)]\}$ (note $\widetilde{w_h}>\widetilde{w_m}$) and average utility equals a constant times NI from the proof of Proposition A1 (ii)(a), Proposition 3 ($F_m=1-F_h$, $B=B^*(F_h,F_m)$, and $P=\theta$), and (36). Since NI and average utility of SS 1 equal those when $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{hm}$ and $F_m=1-F_h$, and the above proof of their being increasing in F_h when $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$ applies when $\frac{F_h}{1-F_h}\in(\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h],(\frac{F_h}{F_m})_{hm}]$ as well, these variables of SS 2 are strictly smaller than those of SS 1. In SS 4, they increase with F_h and F_m from Propositions A1 (ii)(a) and 3 ($B=B^*(F_h,F_m)$). In SS 4, they are highest when $b^*(\widetilde{w_m})=e_h$ and $b^*(w_l)=e_m \Leftrightarrow P(F_h,F_m,B^*(F_h,F_m))A_T=\frac{1-\gamma_b(1+r)}{\gamma_b}e_m$, because they are highest on $b^*(w_l)=e_m$ from Figure 5 and increase with F_h among steady states on the locus from (25) and their expressions in the proof of Proposition A1 (ii)(a). (Note that the absolute value of the slope of the locus is less than 1.) The highest NI and average utility of SS 4 are strictly lower than those of SS 3, since the latter coincide with those when $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{hm}$ and $b^*(w_l)=e_m$. They are also strictly lower than those of SS 2, since they are highest at $b^*(\widetilde{w_m})=e_h$ in both SSs. They are at the infinimum when $F_h\to 0$ in SS 3, and when $\frac{F_h}{F_m}=\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m]$ and $F_h\to 0$ in SS 4, hence the infinima equal 0. The infinima of SS 2 are strictly higher than the ones in SS 3 and SS 4, since the former coincide with the NI and average utility at the intersection of $b^*(\widetilde{w_m})=e_m$ and $b^*(w_l)=e_m$ of SS 4.

(ii) In SS 3, Y increases with F_h from Propositions A2 (i) and 3 ($B=\widehat{B}^*(F_h)$), and $\frac{Y_M}{Y}$ is constant from the proof of Proposition A2 (i) and (30). Y is strictly lower than in SS 1, since it increases with F_h when $b^*(w_l)>e_m$ too. In SS 2, when $F_h<F_h^\dagger$, Y increases with F_h from Propositions A2 (ii)(b) and 3 ($B=\overline{B}^*(F_h)$). From the proof of Proposition A2 (ii)(b) and (38), $Y=A_M(\phi(F_h,\overline{B}^*(F_h)))^{1-\alpha}F_h+\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}[A_M(\phi(F_h,\overline{B}^*(F_h)))^{1-\alpha}F_h-(1+r)(e_h+\phi(F_h,\overline{B}^*(F_h))e_m)F_h]$(the first term is Y_M). Hence, $\frac{Y_M}{Y}=\{1+\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}[1-\frac{1+r}{A_M}(\frac{e_h}{(\phi(F_h,\overline{B}^*(F_h)))^{1-\alpha}}+e_m(\phi(F_h,\overline{B}^*(F_h)))^{\alpha})]\}^{-1}$ and $\frac{Y_M}{Y}$ increases (decreases) with $[\phi(F_h,\overline{B}^*(F_h))]^{-1}$ for $[\phi(F_h,\overline{B}^*(F_h))]^{-1}>(<)\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$, where $\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}>\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m]$ can be proved as follows. First, Assumption 2 implies $\alpha A_M((\frac{F_h}{F_m})_{hm})^{-(1-\alpha)}>\frac{e_h}{\gamma_b}\Leftrightarrow \alpha A_M(\frac{F_h}{F_m})^{-(1-\alpha)}-(1+r)e_h<(1-\alpha)A_M(\frac{F_h}{F_m})^{\alpha}-(1+r)e_m$ at $\frac{F_h}{F_m}=(\frac{\gamma_b\alpha A_M}{e_h})^{\frac{1}{1-\alpha}}\Leftrightarrow A_M\alpha^\alpha(1-\alpha)^{1-\alpha}>\frac{e_h^\alpha}{\gamma_b}[e_h-\gamma_b(1+r)(e_h-e_m)]^{1-\alpha}$. Then, the last equation proves $\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}>\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_m]\Leftrightarrow\gamma_b(1-\alpha)A_M(\frac{\alpha}{1-\alpha}\frac{e_m}{e_h})^\alpha>e_m\Leftrightarrow A_M\alpha^\alpha(1-\alpha)^{1-\alpha}>\frac{e_h^\alpha e_m^{1-\alpha}}{\gamma_b}$. When $F_h\geq F_h^\dagger$ and $\frac{F_h}{1-F_h}\leq(\frac{F_h}{F_m})_{ml,\theta}$, Y, $\frac{Y_M}{Y}$, and $\frac{C_{BM}}{PC_B}$ increase with F_h from Propositions A2 (ii)(b) and 3 ($B=\overline{B}^*(F_h)$). When $\frac{F_h}{1-F_h}>(\frac{F_h}{F_m})_{ml,\theta}$, Y increases with F_h from Proposition 3 ($F_m=1-F_h$ and $P=\theta$) and the proof of Proposition A2 (ii)(a) ($Y=A_M(F_h)^\alpha(1-F_h)^{1-\alpha}$), and $\frac{Y_M}{Y}=1$ and $\frac{C_{BM}}{PC_B}=1$ from Proposition 3 ($Y_T=0$). The highest Y of SS 2 (at $b^*(\widetilde{w_m})=e_h$) is strictly lower than Y of SS 1, because the latter coincides with Y when $\frac{F_h}{F_m}=(\frac{F_h}{F_m})_{hm}$ and $F_m=1-F_h$, and the above proof of Y increasing with F_h applies when $\frac{F_h}{1-F_h}\in(\widetilde{w_m}^{-1}[\frac{1-\gamma_b(1+r)}{\gamma_b}e_h],(\frac{F_h}{F_m})_{hm}]$ as well. In SS 4, Y increases with F_h and F_M from Propositions A2 (ii)(a) and 3 ($B=B^*(F_h,F_m)$). Since $Y=A_M(F_h)^\alpha(F_m)^{1-\alpha}+\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}[A_M(F_h)^\alpha(F_m)^{1-\alpha}-(1+r)(e_hF_h+e_mF_m)]$ from the proof of Proposition A2 (ii)(a) and (34), $\frac{Y_M}{Y}=\{1+\frac{\gamma_B}{1-\gamma_B-\gamma_b(1+r)}[1-\frac{1+r}{A_M}(e_h(\frac{F_h}{F_m})^{1-\alpha}+e_m(\frac{F_h}{F_m})^{-\alpha})]\}^{-1}$ and thus $\frac{Y_M}{Y}$ increases (decreases) with $\frac{F_h}{F_m}$ for $\frac{F_h}{F_m}>(<)\frac{\alpha}{1-\alpha}\frac{e_m}{e_h}$. From Figure 5, for given $\frac{F_h}{F_m}$, Y in SS 4 is strictly lower than in SS 2. Thus, the highest Y in SS 4 is strictly lower than in SS 2. The infinimum in SS 2 is proved to be strictly higher than in SS 3 and SS 4 in the same way as (i). ■