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CHILD LABOUR, FERTILITY, AND ECONOMIC GROWTH*

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This paper explores the evolution of child labour, fertility and human capital in the process of development. In early stages of development, the economy is in a development trap where child labour is abundant, fertility is high and output per capita is low. Technological progress, however, gradually increases the wage differential between parental and child labour, thereby inducing parents to substitute child education for child labour and reduce fertility. The economy takes off to a sustained growth steady-state equilibrium where child labour is abolished and fertility is low. Prohibition of child labour expedites the transition process and generates a Pareto dominating outcome.

Child labour is a mass phenomenon in today's world. According to the ILO Bureau of Statistics, 250 million children aged 5–14 were economically active in 1995, almost a quarter of the children in this age group world-wide.[1] The phenomenon is most widespread in the poorest continent, Africa, but was not always the sole province of the less developed countries: child labour was once common in Europe and in the US, too. In 1851 England and Wales, 36.6% of all boys aged 10–14 and 19.9% of girls in the same age group worked. The historical evidence suggests that child labour has been part of the labour scene since time immemorial.[2]

Although the empirical literature on modern-day child labour is abundant, a theoretical examination of the phenomenon is rather scarce. Recent theoretical studies are Basu and Van (1998) and Baland and Robinson (2000). Basu and Van demonstrate the feasibility of multiple equilibria in the labour market: one equilibrium where children work; and another where the adult wage is high and children do not work. Baland and Robinson (2000) study the implications of child labour for welfare. However, despite evidence about the positive relationship between child labour and fertility and a negative effect of income on child labour, existing theories have abstracted from the important dynamic interrelationship between child labour and the process of development.[3]

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[1] See Ashagrie (1998). Many definitions of child labour are available. See Ashagrie (1993) for a discussion of the definitions, classifications and the data available today on child labour. See also Basu (1999) and Morand (1999*b*) for data on contemporary child labour.

[2] These figures are from Cunningham (1990) who provides data on child employment in England and Wales from the 1851 census and evidence on earlier eras. An historical discussion of child labour in Europe, the United States and Japan appears in Weiner (1991).

[3] See Rosenzweig and Evenson (1977), Cain and Mozumder (1981), Levy (1985) and Grootaert and Kanbur (1995) for the positive relation between child labour and fertility. See Goldin (1979) and Levy (1985) for the negative relation between child labour and income, and Barro (1991) for the negative relation between fertility and income.

This paper explores the dynamic evolution of child labour, fertility and human capital in the process of development.[4] In early stages of development, the economy is in a development trap where child labour is abundant, fertility is high and output per capita is low. Technological progress, however, increases the wage differential between parental and child labour gradually, decreasing the benefit from child labour and ultimately permitting a take-off from the development trap. Parents find it optimal to substitute child education for child labour and reduce fertility. The economy converges to a sustained growth steady-state equilibrium where child labour is abolished and fertility is low.[5] Prohibition of child labour expedites the transition process and generates a Pareto dominating outcome.

The analysis is based on four fundamental elements. First, we assume that parents control their children's time and allocate it between child labour and human capital formation. Second, we assume that parents care about their descendants' future earnings. Third, we assume that the income generated by children is accrued to parents and, fourth, that child rearing is time intensive. As a result, an increase in the wage differential between parental and child labour increases the cost of child rearing and decreases the cost of schooling, which is the child's forgone earning in the labour market. Thus, the increase in the wage differential (between parental and child labour) decreases fertility and child labour and increases children's education and, therefore, the wage differential between adults and children increases further in the next period.[6] Consequently, along the dynamic path to steady state, families become smaller and better educated. We thus show that, consistent with the empirical evidence, child labour tends to decrease as the household's dependency on child labour's income diminishes.

Since child labour abounds in today's world, the question whether policy should be applied to combat this phenomenon is of particular interest. Baland and Robinson (2000) show that child labour may be inefficiently high when bequests are zero or when capital markets are imperfect. In our model, child labour is inefficiently high as well. To see why, consider the following contract: parents allow their children to study their entire childhood and, in exchange, children promise to compensate their parents in the next period, when adults. As long as the potential income of an individual who invests in human capital her entire childhood is greater than the sum of incomes of a child and an uneducated adult, this contract Pareto dominates the competitive equilibrium. However, Baland and Robinson (2000) claim that it is impossible to enforce such intergenerational contracts. Here we show that a government can solve this market failure by

[4] Although the literature presents several theoretical studies of the joint dynamics of income and fertility, so far, no theoretical analysis of child labour dynamics exists. Most of the literature which presents theoretical studies of the joint dynamics of income and fertility tends to explore the negative relation between income and fertility that has prevailed in developed countries since the mid-19th century, eg, Becker *et al.* (1990) and Galor and Weil (1996). Exceptions are Galor and Weil (1999, 2000) and Morand (1999*a*) who model a non-monotonic relation between income and fertility, namely that, at first, fertility increased with income and only at some stage this relation reversed.

[5] This take-off out of the 'pseudo steady state' resembles the endogenous demographic transition in Galor and Weil (1996) and Morand (1999*a*).

[6] Section 2 shows that the wage differential between adults and children may not increase when technology is constant, but when technological progress is introduced, this wage differential *must* increase.

introducing compulsory schooling in the current period and a redistributive taxation from educated adults to the elders in the next period, a policy that needs to prevail for one generation only.[7] We show that this policy not only Pareto dominates the competitive outcome, but also that it can immediately launch the economy out of the poverty trap towards the high output steady-state equilibrium. This take-off out of the poverty trap to a growth path toward the high output steady state is similar to the implication of policy in growth models that study income inequality in the face of capital market imperfection such as Galor and Zeira (1993)and Maoz and Moav (1999).

The paper is organised as follows: Section 1 presents the basic model of child labour and fertility with constant technology and derives the dynamic system implied by the model. Section 2 introduces technological progress and analyses the resultant dynamics. Section 3 discusses policy implications of the model and Section 4 concludes.

1. The Basic Structure of the Model

Consider a small, open, overlapping-generations economy that operates in a perfectly competitive world and faces a given world rate of interest. Time is infinite and discrete. In every period, the economy produces a single good that can be used for either consumption or investment. Three factors of production exist in the economy: physical capital, raw units of labour and efficiency units of labour.

1.1. *Production*

In each period, there are two potential sectors. Production can take place in either one of them or in both. It is important to emphasise that the existence of one sector is independent of the existence of the other, and, as will become clearer later, the existence of each sector is determined by individuals' optimal choices. In both sectors, technology has constant returns to scale, but employs different factors: one technology employs only raw labour; the other employs physical capital and efficiency units of labour. We refer to the former as 'traditional' and to the later as 'modern'.[8]

The production function of the traditional sector is[9]

$$Y_{1,t} = w^c L_t \tag{1}$$

The modern production function satisfies all the neoclassical assumptions and is given by

[7] This policy scheme formalises the idea suggested by Becker and Murphy (1988) though their discussion ignores the dynamic applications.

[8] The existence of these two sectors can represent the process of urbanisation. Thus, the traditional sector can represent rural production and the modern sector can represent industrial production. The set up of two sectors that produce the same output but employ different factors of production is in the spirit of Galor and Zeira (1993).

[9] For the sake of simplicity, we assume that the marginal productivity in the traditional sector is constant. As long as income in the traditional sector would grow at a lower rate than income in the modern sector, the qualitative results of the paper would not change.

$$Y_{2,t} = F(K_t, \lambda_t H_t) \tag{2}$$

where L_t, H_t, K_t, and λ_t are the quantities of raw labour, efficiency labour, physical capital and the level of technology (which we set in this Section to equal 1) respectively, employed at time t, and $w^c > 0$ is the marginal productivity in the traditional sector. Given the production technology, the competitiveness of markets and the world interest rate, $\bar{r}$, firms' inverse demand function for capital is

$$\bar{r} = f'(k_t) \tag{3}$$

where $k_t \equiv (K_t/\lambda_t H_t)$, and therefore,

$$k_t = f'^{-1}(\bar{r}) \equiv \bar{k}. \tag{4}$$

The return to one unit of raw labour is w^c and the return to one unit of efficiency labour, w_t, is

$$w_t = f(\bar{k}) - f'(\bar{k})\bar{k} \equiv \bar{w}. \tag{5}$$

1.2. *Individuals*

In each period, t, a generation of L_t individuals joins the labour force. Each individual has a single parent. Individuals within a generation are identical in their preferences and levels of human capital. Members of generation t live for three periods. In the first period (childhood), $t-1$, individuals are endowed with single unit of time that is allocated by their parent between schooling and labour-force participation. Children can offer only $\theta \in (0,1)$ units of raw labour due to their (purportedly) inferior physical ability and can work only in the traditional sector.[10,11] Their earnings accrue to the parent.[12] In the second period of life (parenthood), t, individuals save their income and allocate their single unit of time between childrearing and labour-force participation. They choose the number of children and the children's time allocation between schooling and labour; they then direct their own remaining time to the labour market. They decide whether to supply raw labour (and to work in the traditional sector), or to supply efficiency units of labour (and to work in the modern sector).[13] The decision is made

[10] 'Children rarely receive an income even approaching the minimum wage, and their earnings are consistently lower than those of adults, even where the two groups are engaged in the same tasks' (Bequele and Boyden, 1988, pp. 4–5). Thus, θ can also be interpreted as discrimination against children in the labour market in the sense that they are paid less than their marginal productivity. For evidence see, for example, Bequele and Boyden (1988, ch. 5).

[11] The literature on child labour suggests that children are usually employed in industries where technologies are simple and production labour-intensive. Many studies show that the development of capital-intensive production has the effect of displacing child labour. See, for example Bequele and Boyden (1988). Galbi (1994) shows the same impact for the industrial revolution. Hence, we assume that children can be employed in the traditional sector only.

[12] The role of children as assets is important in developing economies. See Dasgupta (1993) and Razin and Sadka (1995). Morand (1999*a*) introduces the old-age support motive when modelling the demographic transition.

[13] Canagarajah and Coulombe (1997), Jensen and Nielsen (1997) and Psacharopoulos (1997) support the assumption of a trade-off between child labour and their human capital formation.

according to the number of efficiency units of labour, h_t, they have. Specifically, they will choose the sector that maximises their income

$$I_t = \max(\bar{w}h_t, w^c) \tag{6}$$

where I_t is potential income.[14] In the third period, this generation consumes its savings with the accrued interest.

1.2.1. *Preferences*

We assume that individuals derive utility from consumption and from the potential income of their offspring in period $t+1$. For the sake of simplicity, we assume that individuals consume only in the third period. Thus, the utility function of an individual who is a member of generation t is[15]

$$u^t = \alpha \ln(c_{t+1}) + (1-\alpha)\ln(n_t I_{t+1}) \tag{7}$$

where c_{t+1} is consumption in period $t+1$, n_t is the number of children of individual t and I_{t+1} is the potential income of each child in period $t+1$, determined by the rule given in (6).

1.2.2. *The budget constraint*

As in Galor and Weil (1996, 2000), we follow the standard demand model of household fertility behaviour. We assume that a parent faces a time constraint when choosing how many children to have. More specifically, we assume that time is the *only* input required in raising children. We denote by $z \in (0,1)$ the amount of time needed to raise one child, implying that $1/z$ is the maximum number of children that can be raised.

As mentioned earlier, it is the parent who allocates the time endowment of children between schooling and labour-force participation.[16] Let $\tau_t \in [0,1]$ be the fraction of time allocated to schooling and $(1-\tau_t)$ the fraction of time allocated to labour-force participation of each child in period t. Thus, given the assumption on the physical ability of a child, each child supplies $\theta(1-\tau_t)$ units of raw labour to labour-force participation.

Schooling is free and hence the only cost of schooling is the opportunity cost, ie the forgone earnings of the child.[17] Therefore, the budget constraint of the household is

$$(1-zn_t)I_t + \theta(1-\tau_t)n_t w^c = s_t. \tag{8}$$

In the third period, individuals consume their savings with accrued interest:

$$c_{t+1} = s_t(1+\bar{r}). \tag{9}$$

[14] I_t is potential income because it is the income per one unit of time. However, parents devote some of their time to childrearing and hence earn an income equal to $(1-zn_t)I_t$.

[15] This form of preferences and utility function follows Galor and Weil (2000).

[16] Parents do not discriminate between children: each child receives the same schooling as its siblings.

[17] Introducing direct schooling costs does not change the qualitative result of the model, as long as they are constant. Kanbargi (1988) shows that, in some Indian states, where education (and even books and meals) are provided free of charge, enrolment is low due to the indirect costs of schooling, namely, the child's forgone earnings.

1.2.3. *The production of human capital*

The level of human capital of member of generation $t+1$, h_{t+1}, is predetermined in period t through schooling. We assume that an individual is born with some basic human capital and can achieve more by attending school. As in Galor and Weil (2000), we assume that the level of human capital is an increasing, strictly concave function of the time devoted to schooling. To simplify, we assume that the production function of human capital is

$$h_{t+1} = h(\tau_t) = a(b + \tau_t)^{\beta} \quad (10)$$

where $a,b > 0$ are constants and $\beta \in (0, 1)$ is the 'adjusted' elasticity of human capital with respect to schooling.[18] Note that, since $\tau_t \in [0, 1]$, the level of human capital is bounded from below by ab^{β}, the level of human capital that the child is born with, and from above by $a(b + 1)^{\beta}$, the maximum level of human capital that can be achieved if the child's time is allocated entirely to schooling.[19]

1.2.4. *Optimisation*

A member of generation t chooses the number of her children, the time allocation of her children between schooling and labour-force participation, and consumption, so as to maximise her utility function (7) subject to her budget constraint (8) and the constraints on τ_t and n_t, that is, $\tau_t \in [0, 1]$ and $n_t \in [0, 1/z]$.[20] Substituting (8) and (9) into (7), the optimisation problem facing the individual of generation t is

$$(n_t, \tau_t) = \arg\max\left(\alpha \ln\{(1 + \bar{r})[(1 - zn_t)I_t + \theta(1 - \tau_t)n_t w^c]\} + (1 - \alpha)\ln(n_t I_{t+1})\right) \quad (11)$$

$$\text{s.t.:} \quad 0 \le \tau_t \le 1$$
$$0 \le n_t \le 1/z.$$

Assumption 1 is needed to ensure the existence of child labour and that parents devote some of their time to labour force participation.

ASSUMPTION 1

- $\alpha z > \theta$
- $w^c < a\bar{w}(b + 1)^{\beta} < [z/(z - \theta)]w^c$

$\alpha z > \theta$ is needed to ensure that $(1 - \alpha)/(z - \theta) < 1/z$, i.e. that the parent devotes positive amount of time to labour-force participation.[21] The second part of Assumption 1 is needed to ensure that, if parental income is at its lowest possible

[18] By 'adjusted', we mean that β includes not only schooling but also innate ability, b. Note that, if $b = 0$, β would be exactly the elasticity of human capital with respect to schooling.

[19] Salazar and Glasinovitch (1996) and Schiefelbein (1997) point out that child labour adversely affects children's schooling performance. If we take this finding into account, we should specify the human capital production function as $h_{t+1} = h(\tau_t) = a(b + \eta\tau_t)^{\beta}$ where $\eta = 1$ if the child does not work at all and $0 < \eta_0 < 1$ if the child spends some time working. For simplicity, we ignore this finding since adding this element will only strengthen our results.

[20] We ignore integer problems and allow the number of children per household to be in the segment $[0, 1/z]$.

[21] A less restrictive assumption, $z > \theta$ is needed to rule out an uninteresting case. We thank an anonymous referee for pointing this out.

level, the parent would choose a positive level of child labour. Note that the middle term is the maximum level of potential income in the modern sector and can be thought of as the gain from child schooling in terms of future potential income. The term on the right is the ratio between the cost (in terms of output) of child rearing when each child just goes to school and the cost of child rearing when each child just works. Thus, this term can be thought of as the relative cost of child schooling. The second part of Assumption 1 implies, therefore that, if household's income is the lowest possible one, the relative cost of child schooling is greater than the gain from child schooling.

Let us now describe the solution to the optimisation problem (11). Note that h_t is determined in period $t-1$ and hence the parent chooses the sector to which she supplies her labour independently of the optimal choice of the number of children and their time allocation to schooling, which we denote by $\left(n_t^*, \tau_t^*\right)$. The optimisation is done in two stages. In the first stage, the parent considers the possibility that her children will work in the modern sector in the next period, that is, she assumes $I_{t+1} = \bar{w}h_{t+1}$. She maximises (11) with respect to (n_t, τ_t), derives a solution denoted by $(\hat{n}_t, \hat{\tau}_t)$, substitutes $\hat{\tau}_t$ into the production function of human capital, (10), and obtains a solution to h_{t+1}, denoted by $\hat{h}_{t+1}$. In the second stage, she compares her children's potential income in the next period if they work in the modern sector, $\bar{w}\hat{h}_{t+1}$, to their potential income in the next period if they work in the traditional sector, w^c. If $\max\left(\bar{w}\hat{h}_{t+1}, w^c\right) = \bar{w}\hat{h}_{t+1}$, then $(\hat{n}_t, \hat{\tau}_t) = \left(n_t^*, \tau_t^*\right)$ is the solution to the problem. Otherwise, if $\max\left(\bar{w}\hat{h}_{t+1}, w^c\right) = w^c$, then the parent chooses $\tau_t^* = 0$ and differentiates (11) with respect to n_t.[22]

Depending on the parameters of the model, two cases can arise regarding the solution to the maximisation problem. The first case occurs when $\theta q < z$ where

$$q \equiv \left[\left(\frac{w^c}{a\bar{w}}\right)^{1/\beta}\frac{1-\beta}{\beta} + 1 + b\right]$$

In this case, τ_t^* is positive, regardless of h_t. In the second case, when $\theta q \geq z$, τ_t^* is equal to zero for sufficiently low levels of h_t and positive only for higher levels of h_t. Note that $\hat{\tau}_t$ and therefore $\hat{h}_{t+1}$ are monotonically increasing functions of parental income, $I_t(h_t)$. If the parameters of the model are such that some schooling is optimal even when the level of parental income is the lowest possible one, w^c, then it would be optimal to choose schooling when parental income is higher than w^c, ie for every h_t. Alternatively, if the parameters are such that, when the level of parental income is the lowest possible one, w^c, no schooling is optimal, then there exists a threshold level of parental human capital (and a corresponding parental income's threshold), denoted by $\tilde{h}$, such that whenever parental human capital is below it, zero schooling is optimal and *vice versa*.

Equation (12a) gives the optimal schooling for the case where τ_t^* is equal to zero for sufficiently low levels of h_t.

[22] Note that if max $(\bar{w}h_{t+1}, w^c) = w^c$ then $\tau_t = 0$ is optimal, because any fraction of time devoted to schooling is chosen only to maximise children's future potential income. If future potential income is w^c, then education is a waste of time. Unpalatable as it may seem, this is probably true. See Bequele and Boyden (1988), especially p. 6; Bonnet (1993); and Grootaert and Kanbur (1995, p. 193).

$$\tau_t^* = \begin{cases} 0 & \text{if } h_t < \tilde{h} \\ \frac{\beta z\bar{w}h_t - \beta w^c\theta - bw^c\theta}{w^c\theta(1-\beta)} & \text{if } \tilde{h} \le h_t \le w^c\theta(1+b)/\beta z\bar{w} \\ 1 & \text{if } w^c\theta(1+b)/\beta z\bar{w} \le h_t \end{cases} \tag{12a}$$

where $\tilde{h} \equiv q\theta w^c/z\bar{w}$.

The first line of (12a) shows that children do not receive any schooling when parental human capital below the threshold $\tilde{h}$. Only when parental human capital is above this threshold, do children receive positive level of schooling as can be seen from the second and the third lines of (12a).

Equation (12b) gives the optimal number of children for this case.

$$n_t^* = \begin{cases} \frac{1-\alpha}{z-\theta} & \text{if } h_t \le w^c/\bar{w} \\ \frac{(1-\alpha)\bar{w}h_t}{z\bar{w}h_t - w^c\theta} & \text{if } w^c/\bar{w} \le h_t < \tilde{h} \\ \frac{(1-\alpha)(1-\beta)\bar{w}h_t}{z\bar{w}h_t - w^c\theta(1+b)} & \text{if } \tilde{h} \le h_t \le w^c\theta(1+b)/\beta z\bar{w} \\ \frac{1-\alpha}{z} & \text{if } w^c\theta(1+b)/\beta z\bar{w} \le h_t. \end{cases} \tag{12b}$$

The first two lines of (12b) are relevant for the case where τ_t^* is equal to zero; the third and the fourth lines are relevant for the case where some schooling is optimal.[23]

Equation (13a) gives the optimal schooling for case where τ_t^* is positive, regardless of h_t.

$$\tau_t^* = \begin{cases} \frac{\beta z - \beta\theta - b\theta}{\theta(1-\beta)} & \text{if } h_t \le w^c/\bar{w} \\ \frac{\beta z\bar{w}h_t - \beta w^c\theta - bw^c\theta}{w^c\theta(1-\beta)} & \text{if } w^c/\bar{w} \le h_t \le w^c\theta(1+b)/\beta z\bar{w} \\ 1 & \text{if } w^c\theta(1+b)/\beta z\bar{w} \le h_t. \end{cases} \tag{13a}$$

Equation (13b) gives the optimal number of children for that case.

$$n_t^* = \begin{cases} \frac{(1-\alpha)(1-\beta)}{z-\theta(1+b)} & \text{if } h_t \le w^c/\bar{w} \\ \frac{(1-\alpha)(1-\beta)\bar{w}h_t}{z\bar{w}h_t - w^c\theta(1+b)} & \text{if } w^c/\bar{w} \le h_t \le w^c\theta(1+b)/\beta z\bar{w} \\ \frac{1-\alpha}{z} & \text{if } w^c\theta(1+b)/\beta z\bar{w} \le h_t. \end{cases} \tag{13b}$$

[23] Note that, in (12b), n_t^* is continuous at $h_t = w^c/\bar{w}$ and, therefore, the distinction between the first line and the second merely reflects the fact that the parent switches from the traditional sector to the modern one. However, n_t^* is discontinuous at $h_t = \tilde{h}$. This happens because I_t is continuous at $h_t = \tilde{h}$ and the household's income is divided proportionally between consumption and the potential income of the children. Since schooling changes from zero to a positive level, child labour declines discontinuously and, therefore, the income generated by the children decreases discontinuously. To prevent a discrete fall in consumption, the parent has to supply more of her time to labour force participation. To do so, she has to rear fewer children and thus fertility decreases discontinuously.

In contrast to (12), the distinction between the first line and the second line of (13) merely represents the sector to which the parent supplies her labour and the solution for schooling as well as for fertility is continuous in parental income.

Note that, from (12*a*) and (13*a*), it follows that the optimal schooling time, τ_t^*, increases in time required to rear children, z; in the elasticity of human capital with respect to schooling time, β; and in the wage in the modern sector, $\bar{w}$. Also, τ_t^* decreases in the wage in the traditional sector, w^c; in the children's units of raw labour, θ; and in b, which represents part of their innate human capital. Similarly, from (12*b*) and (13*b*), it follows that the optimal number of children, n_t^*, decreases in z, β and $\bar{w}$ and increases in w^c, θ and b. Finally, it can be verified from (12) and (13), that optimal schooling is a non-decreasing function of parental income, I_t, and that fertility is a non-increasing function of I_t.[24]

Assumption 2 is needed to assure that, at the highest rate of fertility, the population does not contract.

Assumption 2

$$1-\alpha > z-\theta$$

It follows from the solution to the household's maximisation problem that, as long as child labour exists, the optimum number of children is greater than $(1-\alpha)/z$, which is the optimum number of children without child labour.[25] Hence, child labour increases fertility. Moreover, as the wage differential between parental and child labour increases, the optimum number of children declines. Along with the decline in the number of children, the time allocated to children's schooling increases because the relative importance of children's earnings declines. This result might explain a familiar feature of demographic transition: a rapid decline in fertility accompanied by higher rates of growth in output per capita. It also implies a trade-off between quantity and quality of children and that, as the economy develops, individuals prefer quality to quantity.

1.3. *The Dynamical System*

The level of human capital in period $t+1$, h_{t+1}, is uniquely determined by the time allocated to schooling in period t. Since τ_t^* is uniquely determined by the level of human capital in period t, h_t, the level of human capital in period $t+1$, h_{t+1}, is a real-valued function of h_t. Thus, the solution of the maximisation problem in each period generates a first-order nonlinear dynamical system in h_t, denoted here by $\Psi(h_t)$, which is given by substituting τ_t^* from (12*a*) or (13*a*) into (10).

[24] Child labour increases the family income for any level of parental income and weakens the income effect of the parent's wage relative to the substitution effect. Thus, the result that fertility decreases in parental income in a model with child labour, holds in any case where in the absence of child labour, the substitution effect dominates the income effect, equals it or is dominated by the income effect by less than the magnitude of weakening the income effect due to child labour.

[25] Note that, if the maximisation problem was formulated without child labour, ie with the same utility function, but a different budget constraint, $(1-zn_t)I_t = s_t$, the optimum number of children would be $(1-\alpha)/z$, regardless of I_t.

PROPOSITION 1

If $\theta q < z$, i.e. if τ_t^* is given by (13a), then the dynamical system, $\Psi(h_t)$, has a unique steady state equilibrium.

Proof. First, note that, for all $h_t \in [0, w^c/\bar{w}]$,

$$\Psi(h_t) = a\left[b + \frac{\beta z - \beta\theta - b\theta}{\theta(1-\beta)}\right]^{\beta} > \frac{w^c}{\bar{w}}$$

since

$$\bar{w}a\left[b + \frac{\beta z - \beta\theta - b\theta}{\theta(1-\beta)}\right]^{\beta} > w^c$$

must hold. Otherwise, choosing a positive level of schooling is not optimal. Thus $\Psi(h_t) > h_t$ for all $h_t \in [0, w^c/\bar{w}]$. Second, note that $\Psi(h_t)$ is continuous at $h_t = w^c/\bar{w}$ since

$$\lim_{h_t \to \left(\frac{w^c}{\bar{w}}\right)} a\left[b + \frac{\beta z\bar{w}h_t - \beta w^c\theta - bw^c\theta}{w^c\theta(1-\beta)}\right]^{\beta} = a\left[b + \frac{\beta z - \beta\theta - b\theta}{\theta(1-\beta)}\right]^{\beta}.$$

Third, note that for all $h_t \in (w^c/\bar{w}, w^c\theta(1+b)/\beta z\bar{w})$, $\Psi'(h_t) > 0$ and $\Psi''(h_t) < 0$ which implies that $\Psi(h_t)$ is strictly concave and strictly monotonically increasing in that range. Fourth, note that $\Psi(h_t)$ is continuous at $h_t = w^c\theta(1+b)/\beta z\bar{w}$ since

$$\lim_{h_t \to \left[\frac{w^c\theta(1+b)}{\beta z\bar{w}}\right]} a\left[b + \frac{\beta z\bar{w}h_t - \beta w^c\theta - bw^c\theta}{w^c\theta(1-\beta)}\right]^{\beta} = a(b+1)^{\beta}.$$

Finally, note that, for all $h_t \in [w^c\theta(1+b)/\beta z\bar{w}, \infty)]$, $\Psi(h_t) = a(b+1)^{\beta}$. Thus, there exists a unique $\bar{h}$ such that $\Psi(\bar{h}) = \bar{h}$. QED

PROPOSITION 2

If $\theta q \geq z$, ie if τ_t^* is given by (12a), then there can be either multiple equilibria or a unique equilibrium.

Proof. First, note that for $h_t \in [0, \tilde{h})$, $\Psi(h_t)$ is constant and equals ab^{β}. Second, note that $\tilde{h} > ab^{\beta}$ because $\theta q \geq z$ implies $\tilde{h} \geq w^c/\bar{w}$ and $\tau_t^* = 0$ implies $w^c/\bar{w} > ab^{\beta}$. Thus, the low stable steady-state equilibrium, $\bar{h}_l = ab^{\beta}$, exists. Third, note that $\Psi(h_t)$ is discontinuous at $\tilde{h}$ because τ_t^* changes from 0 to a positive value and $\lim \Psi(h_t)_{h_t \to \tilde{h}^+} > ab^{\beta}$. If $\Psi(\tilde{h}) > \tilde{h}$, the high stable steady-state equilibrium must exist because $\Psi(h_t)$ is bounded from above and thus $\Psi(h_t)$ has two stable steady-state equilibria (Figure 1*d*). If not, either $\Psi(h_t) < h_t$ for all $h_t > \tilde{h}$ and therefore only the low steady-state equilibrium exists (Figure 1*b*), or, $\Psi(h_t) > h_t$ for some $h_t > \tilde{h}$ and then an unstable steady-state and the high stable steady-state equilibria exist (Figure 1*c*). QED

Note that the existence of the development trap, ie the low steady-state equilibrium, depends positively on $\tilde{h}$ and thus, from the properties of $\tilde{h}$, the existence of the development trap depends negatively on the time required to rear children, z; on the elasticity of human capital with respect to schooling time, β; and on the

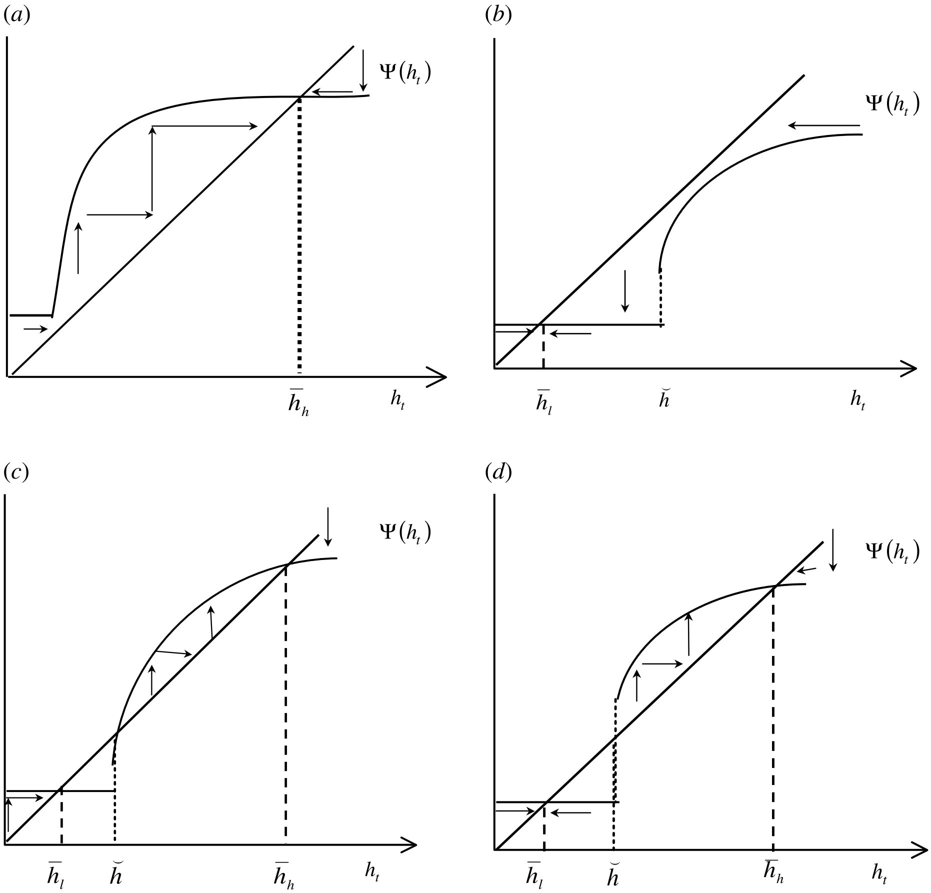

Fig. 1. (*a*) *The shape of* $\Psi(h_t)$ *when* $\theta q < z$. (*b*)–(*d*) *The possible shapes of* $\Psi(h_t)$ *when* $\theta q > z$

wage in the modern sector, $\bar{w}$. In contrast, it depends positively on the wage in the traditional sector, w^c; on the children's units of raw labour, θ; and on b, which represents part of their innate human capital.

The four possible shapes of $\Psi(h_t)$ are drawn in Figure 1 and can be divided into three groups:

(i) The dynamical system drawn in Figure 1*a* has a unique and stable equilibrium characterised by high income, a small number of children in each household, and almost no child labour.[26]

(ii) In Figure 1*b*, equilibrium is also unique and stable, but is characterised by low income, a large number of children in each household, and extensive child labour; we refer to this as a development trap.[27]

[26] The parameters can be adjusted so that child labour is abolished in the high equilibrium case.
[27] Actually, in this steady state, children work all the time and receive no education (Grootaert and Kanbur, 1995, p. 191).

(iii) The third group consists of the dynamical systems drawn in Figure 1*c* and 1*d*. In Figure 1*c*, there are three steady state equilibria: the low and the high ones are stable, and the 'middle' one is unstable; in Figure 1*d* only the low and high steady-state equilibria exist. For these two dynamical systems, the initial level of human capital is crucial because it determines the characteristics of the long-run equilibrium.

Note that, for the first two groups, the initial condition of the economy, i.e. the level of human capital at time 0, h_0, has no effect on the long-run equilibrium.

2. Technological Progress

In this Section, we extend the basic model to allow for technological progress. We show that, under this process, the poverty trap is only 'pseudo steady-state equilibrium', that is, child labour, fertility and output per capita are constant at their development trap levels for long periods. However, at some period, it becomes optimal to launch the modern sector and begin the process of investing in more advanced technology. At this stage, the wage differential between parental and child labour starts to increase and the process of development as described in the introduction 'kicks in'.

Our modelling of technological progress is rather abstract. Since the focus of this section is the effect of technological progress on child labour and fertility dynamics (and not technological progress *per se*) we do not model an R&D sector explicitly. Nonetheless, firms choose the level of technology to be employed in each period optimally. We rely on the non-rivalry property of technology as emphasised by Romer (1990), resulting in increasing returns to technological progress. The dynamic implication implied by this assumption is similar to the Goodfriend and McDermott (1995) model where, in the first stage, development is driven by population growth and, in later stages, development is driven by human capital accumulation.[28]

Consider the production function described in (2) and define x_t as the increment to the level of the technology employed in the modern sector from period $t-1$ to period t, ie $x_t \equiv \lambda_t - \lambda_{t-1}$. We assume that the process of upgrading the technology level incurred costs to the firms, which are represented by the cost function

$$P = x_t^{\phi} \tag{14}$$

where $\phi > 1$. In each period, firms choose (K_t, H_t, x_t) as to maximise their profits. The solution is characterised by the equations

[28] The process of development in the Goodfriend and McDermott (1995) model is driven, in its first stage, by increasing population size, which allows for specialisation and, in the second stage, by human capital accumulation. In our model, development is driven by the stock of human capital. However, in the first stage, this stock is increasing over time due to population growth while, in the second stage, this stock is increasing (mainly) due to direct investment in human capital through schooling.

$$\begin{aligned} k_t &= f'^{-1}(\bar{r}) \equiv \bar{k} \\ w_t &= (\lambda_{t-1} + x_t)\bar{w} \\ x_t &= \left(\frac{1}{\phi}\bar{w}H_t\right)^{\frac{1}{\phi-1}} \end{aligned} \tag{15}$$

where $\bar{k}$ and $\bar{w}$ are defined by (4) and (5). Note that the increment of the technology level, x_t, is positively related to the aggregate level of human capital. This is due to our assumption that the cost of technology change is independent of the size of the economy.[29] Note also that the existence of the modern sector still depends on the optimal choice made by the individuals as given by (6) where the modification needed in (6) is that the potential income in the modern sector now becomes $\lambda_t \bar{w} h_t$. Thus, firms invest in more advanced technology (i.e. $x_t > 0$) only if the modern sector is launch, ie only if

$$\max\ [(\lambda_{t-1} + x_t)\bar{w}h_t, w^c] = (\lambda_{t-1} + x_t)\bar{w}h_t.$$

Let us now describe the evolution of the economy under this specification of technological progress. Suppose that, at date $t = 0$, λ_0, x_0 and H_0 are such that $I_o = w^c$.[30] It follows that as long as $I_t = w^c$, ie as long as

$$\left\{\lambda_0 + [(1/\phi)\bar{w}H_t]^{1/(\phi-1)}\right\}\bar{w}h_t < w^c$$

the economy behaves as if it is trapped in poverty: fertility is at its highest level, child labour is extensive and consumption is at its lowest level. Note, however, that the potential income in the modern sector is increasing due to the growth of the population over time.[31] Hence, there exists a period t such that upgrading the technology level to $\lambda_0 + x_t$ and launching the modern sector is optimal. Denote this t by $\tilde{t}$ and suppose that the economy is at period $\tilde{t} - 1$. An individual who supplies raw labour and works in the traditional sector solves the maximisation problem (the first line of (13) gives the solution). She finds it optimal to provide her children with some schooling. From this period on, the level of technology employed in the economy is increasing in every period and thus potential income is increasing over time too. Consequently, fertility declines as well as child labour while consumption increases over time. At a certain level of potential income, the economy reaches its new steady state: child labour is abolished while fertility reaches its lowest level. However, consumption (and output) continues to grow forever since the investment in more advanced technology continues in every period. The evolution of the economy is described in Figure 2.

[29] This qualitative result would not change as long as we assume that the average cost of technology progress is decreasing in the population size. Formally, if we assume that $P = P(L_t, x_t)$, where P is increasing and strictly concave in L, the economy would follow the same qualitative dynamic path.

[30] In period $t = 0$, x_0 is normalised to zero and, hence, the optimal level of feasible technology to be employed in the modern sector is λ_0.

[31] Galor and Weil (2000) assume that the rate of technological progress is positively related to the population size. Kremer (1993) argues that regions that started with larger initial populations experienced faster technological progress.

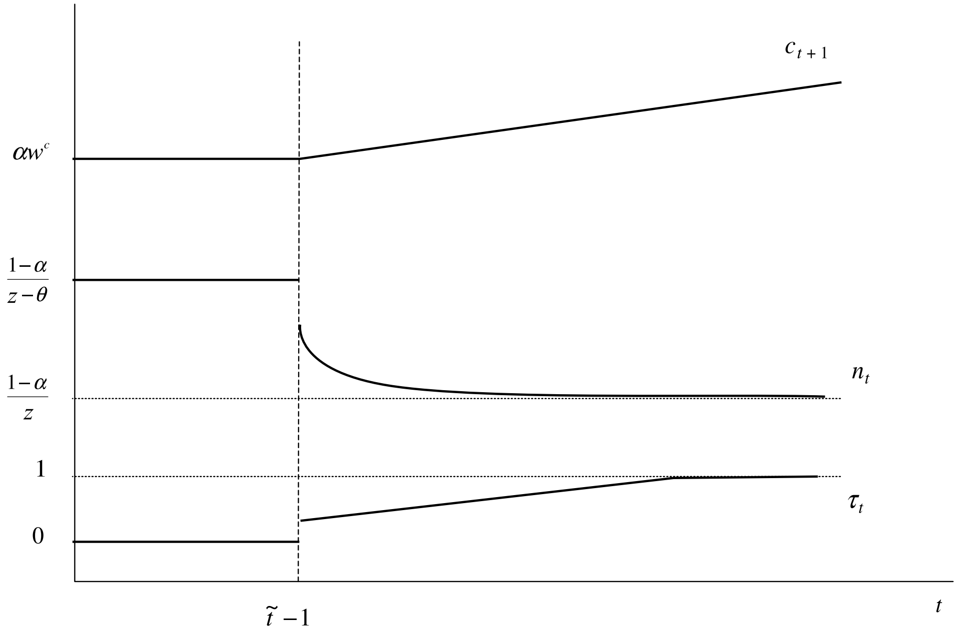

Fig. 2. *Consumption, Fertility and Schooling Over Time under Technological Progress*

3. Pareto Improving and Policy Implications

As explained in the introduction, the equilibrium of the model presented in Section 2 is not Pareto efficient.[32] This suggests that a government policy may enhance the welfare in the economy. Moreover, in the context of this model, we are more interested in the long-run consequences of such a policy, namely, we are interested in the question whether such a policy can immediately launch the economy out of the low steady state towards the high steady-state equilibrium.

Consider then an economy, which is characterised by two stable steady-state equilibria and is trapped in poverty (Figures 1*c*, *d*) and, for simplicity, ignore technological progress. We demonstrate the existence of a government policy that induces an allocation, which Pareto dominates the competitive one and pulls the economy out of its trap by formalising the idea of Becker and Murphy (1988) into a dynamic setting.[33] We assume that there exists a government in the economy, one that can execute a policy if it is Pareto improving.[34] Suppose that, at some period t, the government declares the following two period policy (for period t and $t+1$) before individuals allocate their resources. In the current period,

[32] Even if individuals were two-sided altruistic, it might be that the compensation from children when adults to parents would be too small and thus parents would find it optimal to send their children to work. Baland and Robinson (2000) provide a comprehensive discussion on the issue of two-sided altruism.

[33] Becker and Murphy (1988) suggest a policy of subsidies to education and redistributive taxation from educated children, when adults, to their parents through a social security system.

[34] A more realistic assumption would be that the government could execute policies that take into consideration the welfare of the current generation alone. We take this restrictive assumption because our objective is to examine whether government intervention can affect the long-run equilibrium.

compulsory schooling is introduced at a certain amount. In the following period, the government collects a lump-sum tax from workers in the modern sector and transfers the revenues to compensate the elders for the foregone earnings of their children in the previous period. Denote the policy by $\left(\tau_t^{cs}, \rho_{t+1}, \sigma_{t+1}\right)$ where τ_t^{cs} is the minimum time that must be allocated to schooling of each child in period t, and ρ_{t+1} and σ_{t+1} are the lump-sum tax levied on each worker in the modern sector and the compensation each elder receives in period $t+1$, respectively.[35] Note that the individuals observe the government policy and then choose the optimal number of descendants.[36] It is important to emphasise that, when the government picks the policy $\left(\tau_t^{cs}, \rho_{t+1}, \sigma_{t+1}\right)$, it takes into consideration the optimal number of descendants for each feasible policy it chooses. Given the compulsory schooling τ_t^{cs} and the compensation σ_{t+1}, consumption (in period $t+1$) and the optimal number of children are uniquely determined. Let $n_t\left(\tau_t^{cs}, \sigma_{t+1}\right)$ be the optimal number of descendants for each $\left(\tau_t^{cs}, \sigma_{t+1}\right)$.

The government scheme $\left(\tau_t^{cs}, \rho_{t+1}, \sigma_{t+1}\right)$ is Pareto improving and pulls the economy from its development trap if it meets three sufficient conditions:

1 $n_t\left(\tau_t^{cs}, \sigma_{t+1}\right)\rho_{t+1} = \sigma_{t+1}$
2 $\bar{w}h_{t+1} - \rho_{t+1} > \bar{w}\breve{h}$
3 (i) $\alpha w^c(1+\bar{r}) \leq \{[1 - zn_t(\tau_t^{cs}, \sigma_{t+1})]w^c + n_t(\tau_t^{cs}, \sigma_{t+1})(1-\tau_t^{cs})\theta w^c\}(1+\bar{r}) + \sigma_{t+1}$
(ii) $\dfrac{1-\alpha}{z-\theta}w^c \leq n_t(\tau_t^{cs}, \sigma_{t+1})\left(\bar{w}h_{t+1} - \rho_{t+1}\right)$
where $\breve{h}$ is the level of the unstable equilibrium level of human capital (Figures 1*c*, *d*).

Condition 1 implies a balanced government budget in period $t+1$. Condition 2 ensures that each child, when adult in period $t+1$, can earn in the modern sector a net income, larger than the minimum income, which ensures that her dynasty will converge to the high steady state. Condition 3 is a sufficient condition for (weak) improving of parent's welfare. The left-hand side of (i) is parent's consumption in the low steady state (without government intervention) while the right-hand side is parent's consumption when the government policy is introduced. The left-hand side of (ii) is potential income of children at $t+1$ in the low steady state, whereas the right-hand side is the potential income of children at $t+1$ net of taxes when government scheme is executed.[37]

PROPOSITION 3

Suppose that the government decides on compulsory schooling $\tau_t^{cs} = 1$. *Then, for a certain domain of the parameters* $(\theta, \bar{w}, w^c, \alpha)$, *there exists* $\left(\rho_{t+1}, \sigma_{t+1}\right)$ *such that the generated allocation Pareto dominates the competitive one, and takes off the economy out of its poverty trap.*

(See the proof in the Appendix)

[35] It is possible that the policy takes place over more than two periods. If it does, it can be denoted by $\left[\left(\tau_t^{cs}, \rho_{t+1}, \sigma_{t+1}\right)\right]_{t=0}^{\infty}$. However, we show that a two-period policy is sufficient.

[36] Note that, under this policy, the number of descendants and consumption are the only choice variables since compulsory schooling is binding.

[37] For the sake of simplicity, we choose to (weakly) increase both components of the parent's utility function.

The rationale behind this proposition is straightforward. The introduction of compulsory schooling solves the under investment of parents in their children's human capital. On the other hand, the redistributive taxation solves the compensation problem from children, when adults, to their parents. To achieve an allocation that Pareto dominates the competitive one, we only need to assume that the potential income of an individual who studies for her entire childhood is greater than the sum of incomes of a child and an uneducated adult.[38] The more restrictive assumptions on the parameters are imposed to assure that the induced allocation would not only Pareto dominate the competitive one, but would enable the immediate take-off of the economy out of its poverty trap towards the high steady-state equilibrium.

4. Concluding Remarks

In this paper, we have explored the dynamic evolution of child labour fertility and human capital in the process of development. In early stages of development, the economy is in a development trap where child labour is abundant, fertility is high and output per capita is low. Technological progress, however, increases the wage differential between parental and child labour, decreases the benefit from child labour and ultimately permits a take-off out of the development trap. Parents find it optimal to substitute child education for child labour and reduce fertility. The economy converges to a sustained growth steady-state equilibrium where child labour is abolished and fertility is low. We have also argued that the competitive equilibrium is not Pareto efficient due to the fact that children do not have access to capital markets and the lack of enforcement of intergenerational contracts. We have suggested a policy that not only Pareto dominates the competitive outcome but also expedites the take-off out of the poverty trap towards the high steady state.

Our result regarding the negative relation between fertility and income is well established in the literature (Becker *et al.*, 1990; Galor and Weil, 1996). However, we have shown that it still holds when child labour is introduced into the household's decision.

As for policy, we suggested the introduction of compulsory schooling in a given period and a redistributive taxation from the adults to the elders in the following period. The need for such a policy arises since, as Baland and Robinson (2000) claim, the intergenerational contract where the parent allows her children to study their entire childhood and, in exchange, children promise to compensate their parent in the next period, when adults, cannot be enforced. Basu and Van (1998) find that a ban on child labour is not Pareto improving since, in the equilibrium without child labour, firms' profits are lower. In contrast, Baland and Robinson (2000) show that a ban on child labour can be Pareto improving if it induces certain changes in children's wages in the current and next period and in the supply of efficiency units of labour in the next period. In their model, a ban on child labour is equivalent to compulsory schooling since schooling is given for free (in terms of output) as in our model. However, unlike in their model, we have assumed an open economy and thus a change in the supply of labour has no effect

[38] Formally, the condition is: $\bar{w}a(b+1)^{\beta} > \theta w^{c}(1+r) + w^{c}$.

on wages. We therefore suggested a redistributive taxation to compensate parents for the foregone earnings of their children. Nonetheless, our policy suggestion captures the essence of the intergenerational contract discussed in Baland and Robinson (2000) and in this paper.

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Appendix: Proof of Proposition 3

Suppose that individuals observe $(\tau_t^{cs},\ \sigma_{t+1})$. From the solution to the optimisation problem (11) it follows that

$$n_t\left(\tau_t^{cs},\sigma_{t+1}\right)=\frac{(1-\alpha)I_{t+1}(\tau_t^{cs})(1+\bar{r})w^c+(1-\alpha)I_{t+1}(\tau_t^{cs})\sigma_{t+1}+\alpha(1+\bar{r})w^c[z-\left(1-\tau_t^{cs}\right)\theta]\sigma_{t+1}}{\alpha(1+\bar{r})w^c\left[z-\left(1-\tau_t^{cs}\right)\theta\right]I_{t+1}(\tau_t^{cs})}.$$

Substituting $\tau_t^{cs}=1$ into $n_t(\tau_t^{cs},\sigma_{t+1})$ gives

$$n_t(\tau_t^{cs}=1,\sigma_{t+1})=\frac{1-\alpha}{z}+\frac{(1-\alpha)}{(1+\bar{r})w^c z}\sigma_{t+1}+\frac{\alpha}{\bar{w}a(b+1)^\beta}\sigma_{t+1}. \tag{A.1}$$

Condition 3(i) holds with strict inequality for all $\sigma_{t+1}>0$. Substituting (A.1) into condition 3(ii) gives

$$\sigma_{t+1}\geq\frac{\dfrac{1-\alpha}{z-\theta}w^c-\dfrac{1-\alpha}{z}\bar{w}a(b+1)^\beta}{\dfrac{\bar{w}a(b+1)^\beta}{w^c}\dfrac{1-\alpha}{(1+\bar{r})z}-(1-\alpha)}$$

and the time restriction of the parent $n_t\leq 1/z$ gives

$$\sigma_{t+1}\leq\frac{\dfrac{\alpha}{z}}{\dfrac{1-\alpha}{(1+\bar{r})w^c z}+\dfrac{\alpha}{\bar{w}a(b+1)^\beta}}.$$

Thus condition 3(ii) implies the inequality

$$\frac{\dfrac{1-\alpha}{z-\theta}w^c-\dfrac{1-\alpha}{z}\bar{w}a(b+1)^\beta}{\dfrac{\bar{w}a(b+1)^\beta}{w^c}\dfrac{1-\alpha}{(1+\bar{r})z}-(1-\alpha)}\leq\sigma_{t+1}\leq\frac{\dfrac{\alpha}{z}}{\dfrac{1-\alpha}{(1+\bar{r})w^c z}+\dfrac{\alpha}{\bar{w}a(b+1)^\beta}}. \tag{A.2}$$

Note that the right-hand side of (A.2) is strictly positive. Note also that the left-hand side of (A.2) is positive and continuous in θ (see Assumption 1), and as θ approaches to

$$\frac{z[\bar{w}a(b+1)^\beta-w^c]}{\bar{w}a(b+1)^\beta}$$

the left-hand side converges to zero. Thus, from continuity, there is a sufficiently small θ for which there exists σ_{t+1} satisfying inequality (A.2).

Substituting (A.1) into condition 1 and condition 1 into condition 2 gives

$$\bar{w}\Big[a(b+1)^{\beta}-\breve{h}\Big]\frac{1-\alpha}{z} \geq \left\{1-\bar{w}\big[a\big(b+1^{\beta}\big)-\breve{h}\big]\left[\frac{(1-\alpha)\bar{w}a(b+1)^{\beta}+\alpha(1+\bar{r})w^{c}z}{(1+\bar{r})w^{c}z\bar{w}a(b+1)^{\beta}}\right]\right\}\sigma_{t+1}. \tag{A.3}$$

Note that the left-hand side of (A.3) is strictly positive while the sign of the right hand-side is negative if

$$(1-\alpha)\frac{\bar{w}\lfloor a(b+1)^{\beta}\breve{h}\rfloor}{(1+\bar{r})w^{c}z}+\alpha\frac{\bar{w}\lfloor a(b+1)^{\beta}-\breve{h}\rfloor}{\bar{w}a(b+1)^{\beta}}>1$$

for all $\sigma_{t+1} > 0$. This is sufficient for conditions 1 and 2 to hold.

Thus, for a certain domain of $\theta, \bar{w}, w^c, \alpha$, the desired σ_{t+1} exists.[39] QED

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[39] Note that the choice of θ does not affect inequality (21).

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