# UNIVERSIDAD DE A CORUÑA
FACULTAD DE C. ECONÓMICAS

# HEALTH STATUS AND LEARNING CAPACITY: EFFECTS ON HUMAN CAPITAL ACCUMULATION AND ECONOMIC GROWTH

TESIS DOCTORAL PRESENTADA POR:
PAOLO RUNGO

DIRECTORES

PROF. DR. LUIS CLAUDIO CURRAIS NUNES

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# HEALTH STATUS AND LEARNING CAPACITY: EFFECTS ON HUMAN CAPITAL ACCUMULATION AND ECONOMIC GROWTH

**by Paolo Rungo**

**Submitted to the Department of Economic Analysis in partial fulfilment of the requirements for the degree of European Doctor at Universidad de La Coruña**

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Signature of Author

Department of Economic Analysis and Business Administration, March 2008

Certified by

Luis Currais and Berta Rivera
Professors of Economics
Thesis supervisors

*To my mother, my father*
*and my brother*

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Since I left home and my country, my family has been making a special effort to demonstrate that love is uncorrelated with distance. To my mother, my father and my brother I dedicate this thesis.

# Abstract

The importance of health improvements for economic growth has been underlined by a growing number of theoretical and empirical papers. This thesis contributes to the literature by analysing a specific mechanism that underlies this relationship, namely the complementarity of child health and learning ability. Health status is a constitutive component of human capital and, in addition, has a significant multiplier effect on its accumulation. Favourable health status affects practically all of the abilities and skills that children are capable of developing positively. As a direct result, school-based human capital investment provides an optimal channel for enhancing economic growth. Conversely, poor physical health constitutes a major constraint, that only serves to exacerbate deprivation.

The analysis carried out in this thesis is both empirical and theoretical. Most of the empirical exercises, which explore the relationship between health and education, have required the use of instrumental variable techniques in order to assess the question of endogeneity that arises when considering the two variables simultaneously. Theoretical models rely on the OLG framework, which allows for considering intergenerational linkages and the temporal evolution of the interest variables.

Throughout this thesis it is shown that parents tend to be the agents that transmit child health status, i.e. it is parents that are responsible for the investment of child-health human capital. This dynamic is instrumental in dictating both child learning capacity and the level of schooling investments. These findings have been included in a theoretical

model in order to explain the possible emergence of multiple equilibria in the temporal evolution of human capital. In addition, the consequences of a particular policy aimed at improving the condition of the poor, namely balanced school meals as a means of ensuring basic alimentation, have been investigated by means of a numerical simulation. If poor health causes poverty traps to emerge, substantial health improvements are needed to escape from the bear-pit of deprivation. In copying some of the processes that led the currently developed countries to escape from the Malthusian poverty trap to the Modern Growth regime, a renewed effort to enhance health conditions is required in order to break the cycle of poverty.

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# I. Introduction

Poor health conditions are a major barrier to the real opportunities that people enjoy. In low-income countries less than a quarter of people reach the age of 70, and nearly a third of all deaths are among children under the age of 14 (WHO, 2007). Although cardiovascular diseases are the principal cause of death, infectious diseases (HIV/AIDS, lung infections, tuberculosis, diarrhoeal diseases and malaria) together, claim more lives. Among children under 5 years of age, about 20 million suffer severe acute malnutrition, and current estimates suggest that this causes the death of nearly 1 million children every year (WHO *et al.*, 2007). If acute and chronic malnutrition are taken into account, these figures dramatically increase. In 2005, in all developing countries 32% of children under 5 years of age (about 178 million children) were estimated to be stunted (defined as height –2 standard deviations below the median height-for-age of the reference population, a measure of chronic malnutrition). In that year, more than 40% of stunting was found in the WHO regions of Africa and South-East Asia; of the 39 countries with a stunting prevalence of 40% or higher, 22 are in the region of Africa and 7 in South-East Asia. Wasting (defined as being –2 standard deviations below the median of weight-for-height) is a sign of acute malnutrition and a strong predictor of mortality among children. The global estimate of wasting occurring among children under 5 years of age based on WHO's new standards is 10%, or 55 million (WHO, 2007). These figures are an example of the motivation that encourages a large number of international and national institutions, as well as non-governmental organizations, to fight daily against the global endemic of malnutrition, which evidently constitutes a development objective in its own right.

The economic insights provided in this thesis offer only a partial perspective of the problem by focusing on the relationship across child health status, education and economic growth. Indeed, poor health is one of the many dimensions of poverty, and is a relationship that runs in both directions. Since Fogel (1991, 1994a 1994b, 2002) and Fogel and Wimmer (2002), a growing number of theoretical and empirical papers have underlined the importance of health improvements for long-term economic growth. Fogel (2004) cited, what he called, a historical technophysio evolution, the synergistic interaction between advances in production-technology and improvements in human physiology, and concluded that the increase in the amount of available energy and improved physical status has accounted for about 50 percent of British economic growth since 1790. Arora (2001), investigating the growth path of 10 industrialized countries over 100 to 120 years, provides further historical evidence of the importance of health for economic growth. According to this analysis, health increased the pace of growth of the countries analyzed by 30 to 40 percent, permanently altering the slope of the growth path. Conversely, the lack of health improvements may constitute a relevant barrier for the development of economies.

In consonance with Fogel's pioneering work, researchers have highlighted the direct link between physical condition and worker productivity in order to explain the relationship between health and economic growth (e.g. Sahn and Alderman, 1988; Beherman, 1993; Beherman and Deolalikar, 1998; Currais and Rivera, 2005; Case and et al., 2005). Currais and Rivera (2005), for instance, examine the relationship between wages and health indicators at different levels of earnings distribution by carrying out quantile regressions. They conclude that health has a significant influence on worker productivity, which is measured as a function of salary, and its impact is greater at the lowest wage level, decreasing as one moves up the wage distribution ranking. Though the existence of a direct causal effect of health on productivity has been amply demonstrated, results might hide other indirect channels related to the influence of health status on human capital accumulation.

The complementarity of child health status and education is another interesting mechanism that can help to better understand the relationship between health and economic growth. The impact of health status on cognitive capacity has received some attention in the literature; though causality has not always being clearly assessed (e.g. Aylward et al., 1989; Martorell, 1995; Grantham-McGregor et al., 1999; Alderman et al., 2006). The existence of this relationship, however, is extremely important because it implies that children endowed with unfavourable health status are likely to accumulate a lower amount of intellectual human capital, which in turn will influence their future well-being. In other words, unhealthy children have a lower ability to respond to educational *stimuli* and thus, they achieve a lower level of education even when they dedicate the same amount of time to schooling as healthy children. Another important feature is the correlation between poor health and the socio-economic status of the family of origin, provided that lower learning capacity exacerbates the economic constraints to human capital investments for the family. Children from rich families, on the other hand, enjoy potentially longer periods of schooling, and are more receptive and have better concentration spans and hence, higher learning capacities.

Differential ability due to variations in child health status may also influence the level of schooling-based human capital investments, since a lower return to education is likely to discourage educational efforts. Rosenzweig and Schultz (1982) and Behrman (1988), for instance, have shown that when it is assumed that children look after parents, and when returns to male labour are higher, favouring boys appears to be efficient from the parents' perspective. A similar process may apply when considering that the return to schooling is affected by the health status of children and therefore, it would be reasonable to invest more resources in the development of healthy students. The effect of health on the return to schooling considered here aggravates the negative effect of reduced life spans on earnings expectations (e.g. Chakraborty, 2004), and the complementarity of these two mechanisms may further depress returns to investments in human capital. Thus, considering the channels of influence across child health, schooling performance and human capital accumulation provides useful insights for understanding the role of health in the persistence of deprivation.

Yet this mechanism alone cannot explain the causal relationship between poor health conditions and persistent poverty, which is a significant characteristic of undeveloped countries (e.g. Mayer-Foulkes, 2003). In fact, it is necessary to consider the intergenerational transmission of health status across generations within the same family. When children inherit poor health status from parents, they are likely to face the same constraints that hold back their parents relative to the accumulation of human capital. Health mobility is an interesting feature, which has embraced different fields of research within medicine, including the genetic transmission of diseases such as Alzheimer's or, alternatively, there are more economicly-oriented studies, such as those of Currie and Moretti (2005), or works on behavioural economics (e.g. Johnson, Chase, and Breslau, 2002). In general, these studies find a positive correlation between parental and child health status; for instance, Currie and Moretti find that the probability that a child's birth weight is low is 50% higher if the mother similarly had a low birth weight. While this topic is receiving increasing attention, the analysis of high income countries has severe drawbacks in that it does not permit the generalization of these results to less-developed countries, which is our main concern.

Provided that poor health has an influence on the ability to learn, and that it is a factor that may be transmitted across generations within the same family, a health poverty trap can be identified. Multiple equilibria and bimodality in distribution functions have initially been discussed by considering income levels (e.g. Durlauf and Johnson, 1995; Bianchi, 1997; Quah, 1996, 1997). However, bimodal distribution functions are not exclusively related to income, and poverty traps have been empirically demonstrated when considering the cross-country distribution of health status. Mayer-Foulkes (2003), for instance, demonstrates that certain countries are characterised by low levels of longevity by considering the cross distribution of 159 countries between 1962 and 1997. The consideration of the mechanisms mentioned above sheds light on the underlying causes of this phenomenon, and they provide a theoretical advancement in the modelling of health poverty traps. In particular, parental opportunities for influencing child ability, either indirectly or through deliberate investments in nourishing, is a key factor for a better understanding of persistent poverty. Parents endowed with an unfavourable health status tend to transmit this to their children, both directly and by making it more likely for them to have lower incomes. Given the poor socio-economic status of the family of origin, children tend to receive low levels of education investment. In addition, their health status reduces the productivity of learning and might constitutes a further disincentive to schooling investment. Scant human capital accumulation leads then to low levels of income and poor health status during adulthood, which constraints the development of new generations. The analysis of this health poverty trap constitutes one of our main objectives.

But how are poverty traps to be eradicated? Health status and education are twin components of human capital and have inspired policies aimed at enhancing the two factors simultaneously. International agencies such as the World Food Programme (WFP) and national governments have dedicated a large amount of resources to school feeding programmes. For instance, 21.7 million children in 74 countries received WFP school meals in 2005. The basic idea is that the promise of one meal attracts children to school and, thus, this policy has the advantage of boosting education. The nutritional status of children and their school performance, moreover, are expected to improve. However, intra-household allocation may frustrate any potential positive results, should parents, in an attempt to be equitable, redistribute the benefits that a child receives in terms of extra-feeding to other members of the family (e.g. Simeon, 1998). In this situation, school meals may fail to accomplish one of their main objectives, enhancing deficient educational productivity. The analysis of this policy is extremely interesting given the growing emphasis on school meals as a channel for improving child health and educational outcomes, and refocuses the debate on unconditional versus conditional transfers as a means of alleviating poverty. For example, a common feature of conditional transfers, considered within this analysis, is that they generate a distortion in individual choices, which may negatively affect the accumulation of human capital.

If poor health can cause poverty traps to emerge by constraining the accumulation of intellectual human capital and, conversely, enhancing health status may generate growth, developed countries would still be poor if substantial health improvements had not taken place. The above considerations would seem to suggest that a threshold health status level for a population is a precondition for sustained economic growth. In particular, health improvements may be necessary for undertaking schooling-based human capital investments, which are the main force that drives growth in the modern regime. Literature that deals with this generally places education at the heart of the growth machine while improved health is merely conceived of as a by-product of income growth (e.g. Lucas, 2002; Galor and Weil, 1999, 2000). However, as mentioned above, health improvements seem to account for a large part of economic growth and this should be taken into account in order to understand the Transition that some economies have experienced during their recent history. In other words, the explicit consideration of the health status of a population and health improvements may shed light both on the persistence of deprivation and the possible "push" to a modern regime of growth. When people have low levels of education, human capital is more directly dependent on health status, which may improve thanks to the progressive adaptation of individuals to their environment. A phase of transition during which the health status of the population improves while intellectual human capital is stuck at its minimum level, can be viewed as a precondition to the subsequent passage to the modern regime of growth. In fact, only when the amount of resources dedicated to nourishing and the efficiency of human capital technology are sufficiently high, do parents have compelling incentives for choosing positive lengths of schooling, thus leading to a permanent change in the slope of the growth path. The following part of the analysis which is contained in the subsequent chapters aims to underline the necessity of health improvements for sustained growth or, conversely, the impossibility of escaping from deprivation when poor health status is wedged within the very structure of deprivation.

The results presented in this thesis rely on the assumption that rational economic decision making is the driver of concurrent events in fertility, health and education decision-taking at the micro level. This assumption allows the analyst to pose the questions mooted above simply, but, this also constitutes one of the limitations of the work. In particular, rational decision making in a reproductive setting overcomes many complications and is a useful instrument for explaining certain stylised facts. The economic approach to fertility adopted here dates from the work of Leibenstein (1957) and Beker (1960), who contributed to the understanding of the turning point in the process of the demographic transition. Becker, in particular, formulated the basic framework of completed fertility based on a familiar neo-classical assumption of fixed preferences and maximizing behaviour, which constitutes the basic Becker/Chicago demand theory of fertility. The economic decision making approach, however, omits many of the considerations that dictate fertility behaviour. Robinson (1997), for instance, underlines some difficulties. The exclusion of biology, Love or other psychological considerations from the demand for children, and the failure or unwillingness to consider the inability to control the number of children raised by a family, are in fact a limitation. Thus, results should always be considered bearing in mind the drawbacks of an economic decision making approach in this setting.

The following chapters look at the ideas mentioned above. The analysis begins by empirically studying two hypotheses, namely the intergenerational transmission of health status and the causal relationship between health and learning ability, which constitute the basis of the subsequent analysis. Chapter II assesses these questions by making use of a Brazilian data set, which facilitates an extrapolation capable of explaining certain elements of the growth dynamic in certain developing countries. In addition, the large number of variables included in the database, in particular with regard to health outcomes and historical educational attainments, has favoured the construction of an education indicator, which aims to measure children's ability to benefit from the educational process. Chapter III investigates the consequences of the relationship between health and learning ability on the level of schooling-based human capital investments. In particular, it is shown that unhealthy individuals dedicate less time to learning on average. Chapter IV deals with the possible emergence of poverty traps when results of the previous chapters are taken into account. Moreover, in the same chapter school feeding is considered in order to assess its effects and to draw some policy implications. Chapter V further broadens the analysis horizon and considers the role of health improvements in the transition of economies to the modern regime of growth. In particular, it is shown how health improvements may result in a permanent change in the growth path. Finally, the last chapter summarizes the main conclusions.

## 1.1 Resumen en castellano

Un estado de salud no favorable puede constituir un importante límite para las oportunidades reales de las personas. Menos de un cuarto de la población en los países de baja renta llega a la edad de 70 años y aproximadamente un tercio de todas las defunciones son de niños de edad inferior a los 14 años (WHO, 2007). A pesar de que las enfermedades cardiovasculares constituyen globalmente la principal causa de muerte, las enfermedades infecciosas en su conjunto (HIV/SIDA, infecciones pulmonares, tuberculosis, diarrea y malaria) generan una mayor cantidad de bajas. Aproximadamente 20 millones de niños de edad inferior a los 5 años sufren de malnutrición aguda severa y las estimaciones más recientes sugieren que esta condición causa la muerte de casi un millón de niños cada año (WHO et al., 2007). Considerando exclusivamente la malnutrición aguda o crónica, estos datos crecen de forma dramática. Se estima que en el 2005, el 32% de los niños de edad inferior a 5 años en los países en desarrollo (alrededor de 178 millones) sufrían de malnutrición crónica.[1] En el mismo año, más del 40% de los niños en esta condición se encontraba en las regiones WHO de África y Sur-Este Asiático; de los 39 países con una prevalencia del 40% o superior, 22 pertenecen a la región Africana y 7 al Sur-Este Asiático. La malnutrición aguda es otra potente variable explicativa de la mortalidad infantil.[2] Las estimaciones a nivel global, considerando los niños de edad inferior a los 5 años basadas en los nuevos estándares WHO, son iguales al 10%, o 55 millones de niños (WHO, 2007). Estos datos son un ejemplo de las motivaciones que animan un gran número de instituciones nacionales e internacionales,

[1] El indicador correspondiente, "stunting", se define como – 2 desviaciones estándar por debajo de la mediana de altura por edad del grupo de referencia.

[2] El indicador de malnutrición aguda utilizado por la WHO es "wasting", definido como – 2 desviaciones estándar por debajo de la mediana del peso por altura del grupo de referencia.

así como de organizaciones no gubernamentales, a luchar diariamente contra la endemia global de la malnutrición, que construye evidentemente un objetivo de desarrollo por sí misma.

Las consideraciones de carácter económico que se presentan en esta tesis ofrecen un punto de vista parcial a estos problemas, a través del estudio de las relaciones entre el estado de salud de los niños, la educación y el crecimiento económico. Evidentemente, la malnutrición y la alta prevalencia de enfermedades son sólo algunas de las múltiples dimensiones de la pobreza, a la cual se unen por relaciones causales no unidireccionales. A partir de Fogel (1991, 1994a, 1994b, 2002) y Fogel y Wimmer (2002), un número creciente de trabajos empíricos y teóricos han evidenciado la importancia de las mejoras en el estado de salud para el crecimiento económico a largo plazo. Fogel (2004), considerando lo que ha denominado la evolución tecnofisiológica, la interacción sinérgica entre avances en la tecnología de producción y mejoras en la fisiología humana, concluye que el incremento en la cantidad de energía disponible y el mejor estado físico de las personas explican aproximadamente un 50% del crecimiento económico en el Reino Unido a partir del 1790. Arora (2001), investigando la senda de crecimiento de 10 países industrializados en un arco temporal de 100 a 120 años, ofrece ulterior evidencia histórica de la importancia de la salud para el crecimiento económico. Según su análisis, la salud ha determinado un incremento del ritmo de crecimiento del 30-40%, alterando permanentemente la pendiente de la trayectoria de crecimiento de los países considerados. Al contrario, la falta de mejoras relacionadas con la salud puede constituir una importante barrera para el desarrollo de las economías.

En consonancia con los trabajos pioneros de Fogel, algunos investigadores han subrayado la relación directa entre condición física y productividad de los trabajadores para explicar el efecto de la salud sobre el crecimiento económico (e.g. Sahn y Alderman, 1988; Beherman, 1993; Beherman y Deolalikar, 1998; Currais y Rivera, 2005; Case et al., 2005). Currais y Rivera (2005), por ejemplo, examinan la relación entre salarios e indicadores de salud a distintos niveles de la distribución de la renta usando regresiones quantílicas y concluyen que la salud tiene una influencia significativa sobre la productividad de los trabajadores, medida esta como función de los salarios. Además, el impacto es mayor al nivel mínimo de salario y decrece a medida de que se sube la distribución de la renta. A pesar de que la existencia de un efecto causal directo de la salud sobre la productividad ha sido ampliamente demostrado, estos resultados podrían esconder otros canales indirectos, relacionados con la influencia de la salud sobre la acumulación de capital humano.

La complementariedad entre estado de salud de los niños y educación es otro mecanismo que puede ayudar a comprender la relación entre salud y crecimiento económico. El efecto de la salud sobre las capacidades cognitivas ha recibido cierta atención en la literatura, aunque la cuestión de la causalidad no haya sido siempre debidamente estudiada (e.g Aylward et al., 1989; Martorell, 1995; Grantham-McGregor et al., 1999; Alderman et al., 2006). La existencia de tal relación, sin embargo, es extremadamente importante porque implica que los niños dotados de un estado de salud no favorable tienden a acumular un nivel inferior de capital humano intelectual, lo cual puede afectar a su bienestar futuro. En otras palabras, los niños menos sanos tienen una capacidad inferior de aprovecharse de los estímulos educativos y, por lo tanto, consiguen un nivel inferior de capital humano dedicando el mismo tiempo a la educación que los niños sanos.

Otra cuestión relevante es que hay una correlación significativa entre estado de salud y estado socioeconómico de las familias y la reducida capacidad cognitiva puede agravar las restricciones presupuestarias a las inversiones en capital humano. Al contrario, los hijos de padres relativamente más ricos no sólo tienen los medios económicos para aprovecharse de períodos más largos de educación, sino que también gozan de una mayor capacidad de aprendizaje.

El diferencial de habilidad resultante de las diferencias en salud puede además afectar a los niveles de inversión en educación, puesto que un menor rendimiento de la educación tiende a desincentivar los esfuerzos educativos. Rosenzweig and Schultz (1982) and Behrman (1988), por ejemplo, demuestran que cuando se asume que los niños cuidarán de sus padres y cuando los hombres están favorecidos en el mercado laboral, una mayor preferencia para los hijos de sexo masculino parece eficiente desde la perspectiva de los padres. Un proceso similar podría aplicarse cuando el rendimiento de la educación depende del estado de salud de los niños y, por lo tanto, sería racional investir más recursos en el desarrollo de los estudiantes más sanos. Esta circunstancia tendría el efecto negativo de deteriorar ulteriormente las expectativas de bienestar de los pobres, que tienden a crecer en familias con menos recursos y gozan de un estado de salud no favorable, que constituye una barrera importante para su desarrollo y, al mismo tiempo, puede causar inferior inversiones en educación. Estas consideraciones implican que el efecto depresivo de un pobre estado de salud sobre las inversiones en educación puede ser aún mayor de lo que ya se ha evidenciado en la literatura considerando las consecuencias de una reducida esperanza de vida (e.g. Chakraborty, 2004). En consecuencia, el análisis de estos canales de influencia entre salud de los niños, *performance* educativa y acumulación de capital humano ofrece instrumentos útiles para la comprensión del papel de la salud en la persistencia de la pobreza.

Sin embargo, este mecanismo por sí solo no puede explicar la relación causal existente entre salud mala y persistencia de bajos niveles de ingresos, característica típica de los países en desarrollo (e.g. Mayer-Foulkes, 2003). El siguiente paso es la consideración de la transmisión intergeneracional del estado de salud entre generaciones de la misma familia. En otras palabras, si los niños tienden a heredar de los padres su estado de salud no favorable, también se enfrentarán a las mismas barreras relativas a la acumulación de capital humano.

El análisis de la movilidad del estado de salud constituye, por lo tanto, un interesante campo de estudio, extendido por distintas áreas de investigación, desde la medicina, cuya preocupación fundamental ha sido la transmisión genética de las enfermedades, hasta estudios de carácter más económico, como Currie y Moretti (2005), o trabajos sobre los comportamientos individuales (e.g. Johnson, Chase y Breslau, 2002). Estos estudios encuentran normalmente una correlación positiva entre estado de salud de padres e hijos, siendo la influencia de la madre más potente; por ejemplo, Currie y Moretti demuestran que la probabilidad que un niño nazca con bajo-peso es 50% mas alta si la madre nació con bajo-peso. Este tema está despertando un interés creciente pero hay que observar que los estudios existentes consideran datos de países desarrollados, básicamente a causa de su disponibilidad. Puesto que nuestra principal preocupación es la persistencia de la pobreza en los países en desarrollo, sería útil extender el análisis utilizando una base de datos que recoja información de alguno de estos países.

Si la salud afecta a la capacidad de aprendizaje de los niños y si es un factor transmisible entre generaciones de la misma familia, entonces es posible identificar una trampa de pobreza relacionada con la salud. Equilibrios múltiples y bimodalidad en las funciones de distribución han sido inicialmente estudiadas considerando los niveles de ingresos (e.g. Durlauf and Johnson, 1995; Bianchi, 1997; Quah, 1996, 1997). Sin embargo, funciones de distribución bimodales no están exclusivamente relacionadas con los ingresos y también se han identificado empíricamente trampas de pobreza considerando la distribución del estado de salud entre países. Mayer-Foulkes (2003), por ejemplo, considerando la distribución de 159 países entre el 1962 y el 1997 demuestra que algunos países están atrapados en una condición desfavorable de corta longevidad. Los mecanismos mencionados arriba pueden aclarar las causas subyacentes de este fenómeno y ofrecen un avance teórico en la modelización de las trampas de pobreza relacionadas con la salud. En particular, la posibilidad de los padres de influenciar la habilidad de los niños, indirectamente o a través de inversiones deliberadas en nutrición, es un factor clave para comprender la persistencia de la pobreza. Padres dotados de un estado de salud poco favorable tienden a transmitir su condición a los hijos, directamente o a través de las reducidas capacidades económicas. Dada la pobre condición socioeconómica de la familia, los niños reciben un bajo nivel de inversiones en educación. Además, su estado de salud reduce la productividad del proceso de aprendizaje y, posiblemente, constituye un desincentivo a las inversiones. La escasa acumulación de capital humano se traduce pues en un reducido nivel de ingresos, un estado de salud pobre durante la edad adulta y, por lo tanto, la inicial condición desfavorable de los padres tiende a perdurar de generación en generación. El análisis de esta trampa de pobreza relacionada con la salud constituye uno de nuestros objetivos prioritarios.

El estudio de las trampas de pobreza es fundamental para analizar su posible erradicación. El valor constitutivo de la salud para el capital humano y la complementariedad entre esta variable y la educación han llevado al desarrollo de políticas destinadas a impulsar los dos factores simultáneamente. Por ejemplo, agencias internacionales como el World Food Programme (WFP) y gobiernos nacionales han dedicado una gran cantidad de recursos a programas de nutrición escolar: 21,7 millones de niños en 74 países han recibido comidas en la escuela a través del WFP en el año 2005. La idea principal es que la promesa de una comida atrae los niños a la escuela y, en consecuencia, esta política tiene la ventaja de fomentar la educación esperando, al mismo tiempo, mejorar el estado nutricional de los niños y su *performance* educativa. Sin embargo, una redistribución intra-familiar podría frustrar el intento de lograr el último objetivo, puesto que padres racionales redistribuirían los beneficios que un niño recibe en términos de nutrición escolar a los demás miembros de la familia (e.g. Simeon, 1998). En estas circunstancias, la nutrición escolar podría no lograr uno de sus objetivos principales, con la consecuencia implícita de fomentar la educación cuando su productividad es baja. El análisis de esta política es muy interesante dada su creciente popularidad y contribuye además a la discusión más amplia sobre transferencias condicionales e incondicionales. Por ejemplo, una característica común de las trasferencias condicionales que se considerarán es que tienden a generar una distorsión en las elecciones individuales que podría afectar negativamente a la acumulación de capital humano.

Si un pobre estado de salud puede causar la emergencia de trampas de pobreza limitando la acumulación de capital human o intelectual y, al contrario, mejorar el estado de salud individual a través de la nutrición puede generar crecimiento, el desarrollo de las economías hoy desarrolladas podría no haberse producido sin substanciales mejoras de salud. Las consideraciones anteriores permiten entender porqué un mínimo estado de salud de la población podría ser una precondición para el despegue de una economía, como evidenciado, entre otros, por Arora (2005). En particular, mejoras en el estado de salud podrían ser necesarias para emprender inversiones en educación, que constituyen la fuerza principal que fomenta el crecimiento en el régimen de crecimiento moderno. Normalmente, la literatura que trata esta cuestión atribuye a la educación un papel central mientras que la salud es un producto secundario del crecimiento de la renta (e.g. Lucas, 2002; Galor y Weil, 1999, 2000). Sin embargo, como mencionado anteriormente, mejoras en el estado de salud parecen explicar gran parte del crecimiento económico y sería apropiado considerar este factor para entender la Transición que han experimentado algunos países a lo largo de su historia reciente. En otras palabras, la consideración explícita del estado de salud de la población y de las mejoras en el estado de salud pueden aclarar tanto la persistencia de la pobreza como el posible impulso hacia el régimen de crecimiento moderno. Cuando las personan gozan de bajos o nulos niveles de educación, el capital humano es mas directamente dependiente del estado de salud, el cual puede mejorar gracias a la progresiva adaptación de los individuos a los factores ambientales.

Una fase de transición durante la cual el estado de salud de la población mejora mientras que el capital humano intelectual está estancado a su nivel mínimo, puede ser considerada una precondición para el subsiguiente pasaje al régimen moderno de crecimiento. De hecho, cuando el total de recursos dedicados a la nutrición y la productividad con la cual tales recursos se convierten en energía son suficientemente altos, los padres se enfrentan a incentivos relevantes para elegir una duración positiva del proceso escolar de sus hijos, y la trayectoria temporal del capital humano incrementa de forma sustancial. En la última parte del análisis que se presenta en esta tesis se evidencia la necesidad de las mejoras en el estado de salud para el crecimiento sostenido o, al contrario, la imposibilidad de escapar del círculo de pobreza cuando el estado de salud está estancado en niveles muy pobres.

Los capítulos siguientes desarrollan las ideas expuestas hasta el momento. En particular, en el capítulo II se analizan desde el punto de vista empírico las hipótesis de transmisión intergeneracional del estado de salud y la existencia de una relación causal positiva entre estado de salud de los niños y capacidad de aprendizaje. Los modelos estimados utilizando una base de datos de Brasil (Pesquisa sobre Padrões de Vida; IBGE, 2003) confirman la existencia de una influencia del estado de salud de los padres sobre la salud de los hijos. En las regresiones se consideran tanto medidas objetivas como subjetivas del estado de salud y los resultados son independientes del indicador utilizado. Los ejercicios empíricos, además, demuestran que el estado de salud afecta a la capacidad de los niños de superar con éxito los años que componen el proceso escolar. En otras palabras, los niños dotados con un estado de salud más favorable obtienen resultados mejores con respecto a sus compañeros de la misma edad.

Estos resultados implican ulteriores consecuencias negativas en términos de acumulación de capital humano para los niños dotados de un estado de salud no favorable. En particular, el estado de salud puede afectar a la cantidad de inversiones en educación: la reducida habilidad de aprendizaje reduce el rendimiento de la educación en términos de ingresos futuros esperados y, en consecuencia, resulta racional para los niños menos sanos dedicar menos tiempo a la educación. El capítulo III ofrece una simple explicación teórica de estos mecanismos y presenta evidencia empírica a favor de las conclusiones obtenidas. En primer lugar, para analizar el efecto del estado de salud sobre el tiempo dedicado a la educación, se demuestra que los niños dotados de un estado de salud más favorable se incorporan a la escuela a edades más tempranas, con el resultado de poder aprovecharse de períodos más largos de educación. Además, el análisis empírico permite concluir que el estado de salud de los adultos considerados en la muestra tiene un efecto positivo sobre el tiempo total dedicado a la formación reglada de capital humano.

En el capítulo IV se desarrolla un modelo de generaciones solapadas de tres períodos en dónde los padres eligen óptimamente su consumo (presente y futuro), el número de hijos, así como su educación y el nivel de recursos dedicados a nutrición. Además, se incorpora el efecto de la salud sobre el capital humano y se analiza su evolución temporal. El modelo predice la posible emergencia de equilibrios múltiples. En particular, para ciertos valores de los parámetros, el modelo sugiere que existe un nivel crítico de ingresos de los padres que determina el nivel de inversión en calidad de los hijos y la convergencia a distintos estados estacionarios. Las dinastías generadas por individuos con una dotación inicial de capital humano e ingresos por debajo de este nivel, se encuentran atrapadas en un círculo de bajo nivel de capital humano, pobre estado de salud y altas tasas de fertilidad. Hay que observar que, independientemente de los valores de los parámetros, un estado de salud pobre siempre determina una inferior acumulación de capital humano, es decir, el efecto multiplicador de la salud es independiente de la existencia de equilibrios múltiples.

La consideración de una política de nutrición en la escuela en este contexto teórico conlleva resultados interesantes. Los resultados confirman el efecto positivo de esta política sobre la cantidad de educación y, por lo tanto, sobre el nivel de capital humano de los pobres. Sin embargo, los resultados con respecto al nivel nutricional de los niños son distintos. La provisión de comida induce a frecuentar la escuela por períodos más largos pero el modelo sugiere que el nivel nutricional permanece inalterado, coherentemente con lo que se ha encontrado en la literatura empírica (e.g. Simeon, 1998). Aunque no sea correcto concluir que los programas de nutrición escolar no tienen efectos positivos sobre el estado de salud de los niños, el análisis pone en evidencia un posible mecanismo que explicaría resultados inferiores a los esperados. Además, otro resultado es la existencia de efectos positivos sobre el estado nutricional cuando se consideran las generaciones siguientes a la afectada directamente por la política.

En el capítulo V se desarrolla un modelo teórico que pretende evidenciar la importancia de las mejoras en el estado de salud para la Transición desde un régimen de crecimiento maltusiano al crecimiento moderno. La teoría propuesta ilustra como a partir de una situación en la cual los niños reciben una cantidad mínima de recursos para la nutrición, suficiente para su subsistencia, y no reciben educación, la introducción de mejoras relacionadas con la salud (por ejemplos, aprendizaje de comportamientos saludables o adaptación de los individuos al ambiente) determina un acercamiento de la renta a los niveles críticos mínimos necesarios para la inversión en capital humano. Estas innovaciones, que determinan un lento cambio en la productividad con la que los recursos nutricionales se convierten en salud, dependen principalmente del nivel de capital humano de los agentes que las introducen en la economía. Sin embargo, durante la primera fase maltusiana de desarrollo los incrementos potenciales de ingresos generan un aumento de fertilidad y, por lo tanto, el nivel nutricional de los niños permanece constante. El aumento de productividad genera de todas formas un incremento gradual del nivel de capital humano y, cuando la productividad supera cierto nivel crítico, los agentes empiezan a emprender inversiones en nutrición de los niños. El incremento de capital humano genera una introducción de innovaciones más frecuente y, además, el estado de salud, siempre más favorable, determina una preferencia creciente por la inversión en educación. Esta fase durante la cual el estado de salud de la población mejora mientras que la educación es nula puede interpretarse como un período que precede la Transición propiamente dicha. Cuando los niveles de nutrición y el estado físico de los niños son suficientemente elevados, los padres eligen educar a sus niños y la trayectoria de crecimiento del capital humano experimenta un rápido cambio de pendiente. Un renovado impulso a las mejoras en el estado físico de las personas en los países en desarrollo, por lo tanto, puede favorecer un proceso de crecimiento parecido a la Transición experimentada por las economías occidentales.

# II. Health Status, educational adequacy and human capital accumulation

Since Becker and Tomes (1986) the analysis of intergenerational mobility has been a topic of great interest in both the theoretical and empirical literature. The degree of transmission of lifetime earnings across generations is extremely important in order to understand the persistence of deprivation, and recent empirical research have found that health status plays a central role in explaining this phenomenon. This result relies on two assumptions that should be made explicit and that constitute the starting point of the analysis carried out throughout the following chapters. Thus, the relationship across health, education and human capital accumulation is discussed here in order to set the basis of the succeeding analysis.

The first mechanism behind the role of health in human capital mobility that should be highlighted is the intergenerational transmission of health across generations of the same family. As it will be observed in the following sections, a growing number of empirical papers underlines the existence of a link between parents' and children's health condition. When parents endowed with a poor physical status transmit to their offspring their unfavourable condition, children's possibility of enjoying a healthy life is reduced, and they may face some constraint relative to the accumulation of human capital. The first objective of this chapter is to provide new empirical evidence on the intergenerational transmission of health status, using data from a developing country. As it will be observed in section 1, this is particularly important because the study of this topic has been generally focused on developed countries, due to data availability (e.g. Currie and Moretti, 2005).

The second assumption behind the importance of health status in the transmission of human capital and income is concerned with the influence of child health on human capital formation. A direct link across these variables can be found in the relatively lower productivity of unhealthy workers, as confirmed by Sahn and Alderman (1988), Beherman (1993), Beherman and Deolalikar (1998), and Currais and Rivera (2005), among others. In addition, another mechanism can help to explain the role of health in human capital accumulation, namely the complementarity of physical status and education, and the resulting consequences on income may be more important than the direct effect on labour productivity. Alderman et al. (2001), Glewwe et al. (2001), the Micronutrient Initiative and United Nations Children's Fund (2004) and Miguel (2005), among others, demonstrate the existence of a positive relationship between distinct measures of health status, school attendance, cognitive capacity of children and academic achievements. One implication of these studies, which will be discussed below more in detail, is that children with improved health status tend to receive larger benefits from the educational process, *ceteris paribus*. On the contrary, a child endowed with an unfavourable health status is likely to accumulate a low level of human capital. The analysis carried out in this chapter is an attempt to assess the effect of health on educational adequacy by using a number of health indicators, both subjective and objective measures. In addition, the study takes into account the possible emergence of double causation between health and education.

This chapter is organized as follows. Section 1 discusses the existing literature on the intergenerational transmission of health status and the relationship between child health and education. Section 2 presents the dataset used in the empirical exercises and a descriptive analysis. Section 3 provides new empirical evidence on the transmission of health status, while Section 4 treats about the impact of child health on learning ability. Finally, the last section summarizes the main conclusions.

## 1. An overview on intergenerational transmission of health status and learning ability

### 1.1 Intergenerational transmission of health

Epidemiologists have initially studied the intergenerational transmission of health status in order to find associations between genes and specific diseases such the Alzheimer disease. In addition, another pioneering line of research has focused on life spans, which may be considered as the final output of the health production function (e.g. Ahlburg, 1998). The basic idea behind the first estimations of the intergenerational transmission of life spans was simple: positive correlation between the life spans of relatives may reveal the genetic component of longevity (Yashine and Iachine, 1997). More recent, economic-oriented studies have also analysed this relationship, with the aim of finding a link between income mobility and health mobility. Currie and Moretti (2005), for instance, using confidential data of all Californian births from 1960 to 1974 and from 1982 to 2001, find that the probability that a child is low birth weight is 50% higher if the mother is low birth weight. Moreover, a positive independent effect of the socio-economic status (SES, henceforth) is found: the intergenerational transmission of low birth weight is stronger for poorer mothers. This result highlights that the inheritance of health status may be partially due to the economic conditions of families and in fact, a parent SES has a great impact on child health by determining the availability of resources dedicated to nutrition or the possibility of medical care, for example. The relationship between family income and overall child health status is confirmed, among others, by Case et al. (2005, 2002). Case et al. (2002) analyse the relationship between family income and child health using the US National Health Interview Survey, which is a cross-section dataset. They showed the existence of a positive effect of income, with children in poorer families having significantly worse health than children from richer families and they also found that the income gradient in child health increased with child age in the US, with the protective effect of income accumulating over the childhood years.

Cantarero and Pascual (2005) focus on intergenerational mobility in Spain using data from eight waves of the European Community Household Panel. In particular, they test the influence of parents' health on children's health using the self-assessed health status as an indicator of health. Their main finding is that the probability of reporting good or very good health is between 5 and 10 percent higher for individuals whose parents report good or very good health. In addition, this effect appears to be stronger when analysing the relationship between mothers and children respect to fathers and children. Maternal background is usually shown to be more important than paternal: for example, maternal factors can affect a wide range of child outcomes apart from health status, including educational choices (Simpson, 2003; Chevalier et al., 2005), and cognitive and social development (Menaghan and Pacel, 1991).

A different approach considers the transmission of health-related behaviours from parents to children. The main idea behind this line of research is that specific health-risk lifestyles are generally linked to risk for morbidity and shorter life expectancy (e.g. House et al., 1986; Wickrama, Conger, and Lorenz, 1994). Wickrama et al. (1999), provide evidence for the hypothesis that adolescents' health-risk behaviours associate with parents' health-risk behaviours, and work on smoking has highlighted this relationship across parents and children. Johnson, Chase, and Breslau (2002) find that smokers with a high proportion of relatives who were persistent smokers were at increased risk of persistent smoking themselves. In addition, they show that nicotine dependence modifies the association between family history of smoking and smoking persistence. Genetic influence is discussed in other papers such as Hopfer, Stallings, & Hewitt (2001), who find that heavy smoking is primarily affected by genetic effects, while Bantle and Haisken-DeNew (2002), using the German Socio-Economic Panel 1999, show that parental smoking significantly increases the probability that their children become smokers. In particular, children whose parents are both smokers are 3.3 times more likely to smoke themselves. As a general rule, studies on smoking conclude that both genetic and environmental factors influence the maintenance of cigarette smoking and the probability of ever starting smoking. Family influence and other environmental factors appear to affect smoking initiation, while genetic effects primarily explain smoking persistence, nicotine dependence, and the quantity of cigarettes smoked.

Health status therefore appears to be transmissible across generations of the same family due to a number of factors. It should be noted, however, that further evidence is needed in order to clearly assess this topic, provided that existing studies make use of data from developed countries while in our purpose, i.e. for analysing the persistence of deprivation in low-income countries, the consideration of a more appropriate dataset is required, and this circumstance constitutes the main motivation for the empirical analysis carried out here.

### 1.2 Child health and cognitive capacity

As pointed out in the introduction, the existence of a relationship between child health and education is a necessary condition for explaining the role of health in the persistence of deprivation. Firstly, poor health during early childhood may consist of different manifestations, such as low birth weight, growth faltering or micronutrient deficiency. Though these problems should be regarded as important development objectives in their own right, they also have implications for human capital accumulation and economic growth. One of the indicators of health status that has been broadly considered in the literature is low birth weight. Low birth weight (LBW) has been defined by the World Health Organization as weight at birth of less than 2,500 grams. This is based on epidemiological observations that infants weighing less than 2,500g are approximately 20 times more likely to die than heavier babies (e.g. UNICEF and WHO, 2004). More than 20 million infants are born with low birth-weight in the World, most of them in Asia and Africa, which account for ninety-four percent of total low birth-weight in the world. There are more than 1 million infants born with low birth-weight in China and nearly 8 million in India.

Aylward et al. (1989) review 80 studies on the consequences of low birth-weight and conclude that LBW children have poorer levels of development respect to normal birth-weight infants. In particular, there is evidence showing that IQ tends to be higher in children who were heavier at birth. In addition, neurological, behavioural and intellectual impairments at school age have been observed in children who were born low birth-weight (e.g. Saigal et al., 1999; Hille et al., 1994; Hille et al., 2001). Saigal et al. (2003), for instance, find that school difficulties are a severe outcome of extremely low birth-weight children. Grantham-McGregor et al. (1999) review several studies that concentrate on infant born at term but small for gestational age (SGA), and show that SGA infants have been found to suffer from more infections and higher mortality rates in the first year of life than normal birth-weight babies.

Malnutrition appears to be another relevant factor, which is related to both child health and school performance. The most common measures of malnutrition are height-for-age, weight-for-age, and weight-for-height. A growing number of studies analyse the relationship between child nutrition and subsequent human capital attainments. As reported by Grantham-McGregor et al. (1999), most cross-sectional studies have found significant associations between height-for-age and children's cognitive development. It has been found a significant association between height-for-age and IQ, cognitive function, or school achievement levels in school-aged children in many countries, including Jamaica (Grantham-McGregor et al., 1997), Guatemala (Johnston et al., 1987), Nepal (Moock and Leslie, 1986), and India (Agarwal et al., 1987). Only a few studies failed to find significant associations between height and measures of mental development or school achievement (e.g. Wachs et al, 1992; Church and Katigbak, 1991), though these studies make use of really small samples. Pollitt (1990) and Behrman (1996) are other examples of cross-sectional studies that document associations between nutritional status in early childhood and subsequent human capital attainments.

It should be noted that most of those studies do not clearly assess causality between those variables, and they do not consider that child health and educational attainments might reflect related household decisions regarding investments in children's human capital (Beherman, 1996). However, there are several studies that use longitudinal data in order to address this question. Alderman et al. (2006), using longitudinal data from rural Zimbabwe, show that improved health (measured as height-for-age) during early childhood results in increased height as young adult, higher educational attainment, and an earlier age at which the child starts school. The Institute for Nutrition in Central America and Panama Project (INCAP) developed in Guatemala (Martorell, 1995) leads to similar conclusions making use of an experimental setting with long-term data. In this project, four villages were randomly divided into two groups: in the first, children and expectant women received a high energy and high protein drink, while in the second group children received a low energy and no protein drink. Despite the small sample, the follow-up studies conducted at least a decade after the end of the intervention permitted to conclude that children of the first group presented a greater productive capacity (Haas et al., 1995), and showed improvements in cognitive capacity indexes related to school achievements (Pollit et al., 1993).

Miguel (2005) illustrates two projects that study the effects of the elimination of worm infections and have the advantage of a larger sample. However, conclusions about the relationship between health and learning performance are less strong. The Primary School Deworming Project (PSDP) in Busia, Kenya, included 75 primary schools with 32565 children, more than one third of which suffering from helmint infections. Schools were randomly divided into 3 groups of 25, creating treatment and comparison groups. The project, with duration of 4 years, permitted to conclude that the elimination of worms in primary schools reduces total school absenteeism by at least seven percentage points. Furthermore, the elimination of worms' infections produced an increase in school attendance among children that did not receive treatment in treatment schools and among children in neighbouring primary school, highlighting the externality benefits (Miguel and Kremer, 2003). The second project illustrated by Miguel (2005), the pre-school nutrition and health project conducted by the NGO PRATHAM in Delhi, India, finds similar results: a relationship is found between health and school attendance. A stronger link between health status and cognitive development may be found in non-experimental works, such as Glewwe et al. (2001). Glewwe et al. estimate the impact of nutrition on learning using a longitudinal data set collected in Cebu, Philippines over a period of 12 years, and they find that better early child nutrition raises academic achievement. Increases in test scores are partially due to the fact that well-nourished children enter the school earlier and, thus, they have more time to learn. The rest arise from a direct impact on learning productivity per year of schooling.

In summary, many researchers have analysed the association of child health and education, underlying the existence of a causal relationship. Two main effects have been identified in these studies. The first is concerned with the ability to learn and understand, which has been measured directly by cognitive tests, or indirectly by the observation of educational attainment. The second effect considered in the literature, which has the same consequences in terms of human capital accumulation, is inherent to the effect of child health on school attendance. In particular, it has been shown that poor health status is likely to result in the postponement of the age at which children start attending school, it determines higher absenteeism, and it might affect the probability of ever attending school. The important conclusion is that the initial endowment of health status appears to have an effect on the formation of human capital. Then, the correlation between human capital and earnings ensures that unhealthy children will tend to obtain low wages, which in turn results in low living standard and poor health when adults.

In the empirical analysis carried out in the next section, we make use of a cross-sectional dataset in order to assess the effects of health on education. A distinctiveness of this exercise is the use of a number of different indicators of health status from a large national survey and learning outcomes are measured with respect to the maximum feasible achievement of a child given the age, a methodology that allows for considering simultaneously a number of students with different ages. In addition, this variable permits to assess the effects of health on child ability even when considering a general household survey.

## 2. The database and sample

The analysis relies on data from a Brazilian survey, the Living Standards Measurement Survey (Pesquisa sobre Padrões de Vida - PPV), a household survey conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2003) in association with the World Bank. The survey collected data from 19,409 individuals in 4,800 households that were representative of the northeast and southeast regions of Brazil.[3] It has the advantage of including an extended set of variables related to the individual health status (both subjective and objective measures, which are not included in more recent surveys), as well as indicators on the historical outcomes of the educational process. In addition, it contains a great number of socio-economic variables. Another important characteristic, which is useful in intergenerational analysis, is that it allows for linking parents and children because each member of the family has been interviewed.

The Brazilian dataset being considered includes a very heterogeneous population in terms of health status, income and socio-economic conditions. In particular, about 25% of children suffer from the consequences of poor nutrition (measured as BMI-FOR-AGE), which is an interesting characteristic in order to analyse its impact on learning ability. In addition, the Gini index for income per capita is about 0.56, underlining enormous differences in the distribution of economic possibilities.

Considering the sampling design, the survey is based on a two-stage selection, with stratification of primary units and random selection of second-stage units. The primary unit is the 1991 Demographic Census geographic base sector, while the second-stage unit is the household. A 480-household sample size was determined for each geographic stratum. In urban areas, 60 sectors and 8 households per sector on each geographical stratum have been selected; in rural areas, the number of sectors has been fixed to be 30 and that of the selected households, 16.

In order to obtain a useful dataset in our purpose, individuals of the same family have been linked using children as reference. As a result, a total number of 4187 children have been extracted from the original dataset, in which full information about

[3] The metropolitan regions of Recife and Salvador, the rest of the urban area of the northeast, the rest of the rural area of the northeast, metropolitan regions of Belo Horizonte, Rio de Janeiro and Sao Paulo, the rest of the urban area of the southeast and the rest of the rural area of the southeast.

parents is available for each child. In other words, the 4187 observations used in the analysis include children that have been surveyed and whose parents have been surveyed, too. Children are defined as sons or daughters between 5 and 30 years of age, living with their parents. This definition is due to the possibility of comparison with the literature, and its main advantage consists of including higher levels of education such as postgraduate studies. It should be noted that the lower bound of 5 years is not arbitrarily but it corresponds to the lower age in the dataset. However, the sample has been restricted to children aged up to 20 years when considering BMI-for-age and height-for-age because this is the interval considered for WHO standards. In other words, the sample that includes children aged up to 30 years is used when subjective measures are considered, while children between 5 and 20 years old constitute the sample when the health proxies are objective measures.

### *Variables*

Variables used in the empirical analysis and the main descriptive statistics, are presented in Table 2.1. Both objective and subjective measures have been used as indicators of health status. The Body Mass Index (BMI) is defined, as usual, as the ratio between weight and height squared, and a relevant feature is that weight and height are not self-reported. This variable has been used when considering adults, since it is heavily dependent on age during the first period of life. When considering children, however, BMI-for-age and height-for-age have been used. BMI-for-age is defined as the ratio between child BMI and median BMI of the age group (2007 WHO standards).

**Table 2.1**: Variables and descriptive statistics. (Letters C, M and F appended to a variable's name stand for "child", "mother" and "father", respectively.

| Variable | Description | Children | Mothers | Fathers |
|---|---|---|---|---|
| **Health status Indicator** | | | **mean (sd)** | |
| BMI(M, F) | Body Mass Index | | 25.084 (4.895) | 24.815 (3.808) |
| BMIFA | BMI-for-age | 1.015 (.175) | | |
| HFA | Height-for-age | .988 (.060) | | |
| HEIGHT(M, F) | Height in meters | | 1.576 (.071) | 1.69 (.075) |
| SAHS(C, M, F) | Health status self-assessment | | | |
| | 1 = excellent | 24.49% | 11.86% | 15.30% |
| | 2 = very good | 31.57% | 21.10% | 24.22% |
| | 3 = good | 37.61% | 40.75% | 36.96% |
| | 4 = regular | 5.98% | 23.51% | 20.48% |
| | 5 = poor | 0.36% | 2.79% | 3.05% |
| GH(C, M, F) | 1 = values 1 or 2 in SAHS, 0 = otherwise | 55.71% | 32.82% | 39.07% |
| PROB(C, M, F) | 1 = reported health problems in 30 days prior to the interview 0 = otherwise | 20.87% | 23.85% | 20.53% |
| CHRON(C, M, F) | 1 = reported chronic illness, 0 = otherwise | 8.09% | 22.25% | 19.56% |
| **Education** | | | | |
| EAC | completed school years respect to feasible school years | .670 (.231) | | |
| EDU(M, F) | Completed years of education | | 6.200 (4.046) | 6.239 (4.340) |
| **Other individual characteristics** | | | | |
| AGE | age in years | 13.939 (5.833) | | |
| WHITE | 1 = if the individual is white, 0 = otherwise | 47.08% | | |
| MALE | 1 = if the individual is male, 0 = otherwise | 53.66% | | |
| **Household** | | | | |
| LOGRD | Log of total family income | 7.132 (1.02) | | |
| URBAN | 1 = if the family lives in an urban area, 0 = otherwise | 82.08% | | |
| NORTHEAST | 1 = if the family lives in the Northeast area, 0 = otherwise | 52.77% | | |

Another objective indicator of child health status related to child nutrition used in the analysis is height-for-age, which is defined as the ratio between height and the median height of the age group (WHO standards). Concerning subjective and self-reported measures, self-assessment of health status (SAHS) is a discrete variable varying between 1 and 5, representing 1 the self-perception of the best health status (excellent - excelente) and 5 the worst (very poor - ruim). Variable GH (good health) follows from the self-assessment; its value is equal to 1 if the individual reported an excellent or very good health status (values 1 or 2 in SAHS) and zero otherwise. In addition to these variables, other indicators used in the analysis are provided by responses to the survey questionnaires. Variable PROB follows from the question about the occurrence of health problems during the thirty days prior to the interview and, in addition, individual are asked if they have chronic health problems (CHRONIC).

Child education has been measured by the variable EAC (Educational Adequacy of Children), which is defined as the ratio between the number of school years successfully completed respect to the number of years that could have been completed by a child given the age. Concerning parents, learning has been measured by the number of years of education. Other control variables have been used in the analysis. In particular, as individual characteristics, age (AGE), racial group (WHITE), and sex (MALE). Family total income (LOGRD) and geographical localization (NORTHEAST, URBAN) characterize the household.

### 2.1 Descriptive analysis

Descriptive analysis may shed light on fundamental relationships that will be examined more in detail throughout this chapter. Firstly, it is interesting to observe the correlation between child health and ability. Figure 2.1 presents the distribution of SAHSC for the groups of children endowed with a level of EAC below and above ± 1 standard deviation respect to the mean. As it could be observed, a positive correlation between child health and education clearly emerges. As long as we consider higher levels of EAC, the self-assessed health status improves, particularly with respect to the first category, which corresponds to a self-reported "excellent" health status. While in the group of less able children only 15.41% report very good health and 30.16% report good health, these figures increase to 24.91% (very good health) and 31.38% (good health) when considering proficient student. The correlation between these variables may result from both a causal effect running from health to education, as well as the other way around.

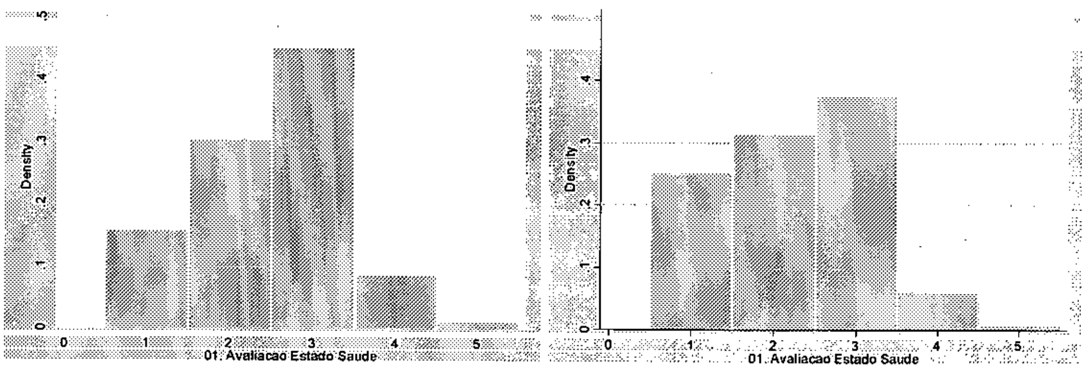


**Figure 2.1**. Distribution of SAHSC, for children endowed with EAC lower than –1 sd from the mean EAC (left), and above +1 sd from the mean EAC (right).

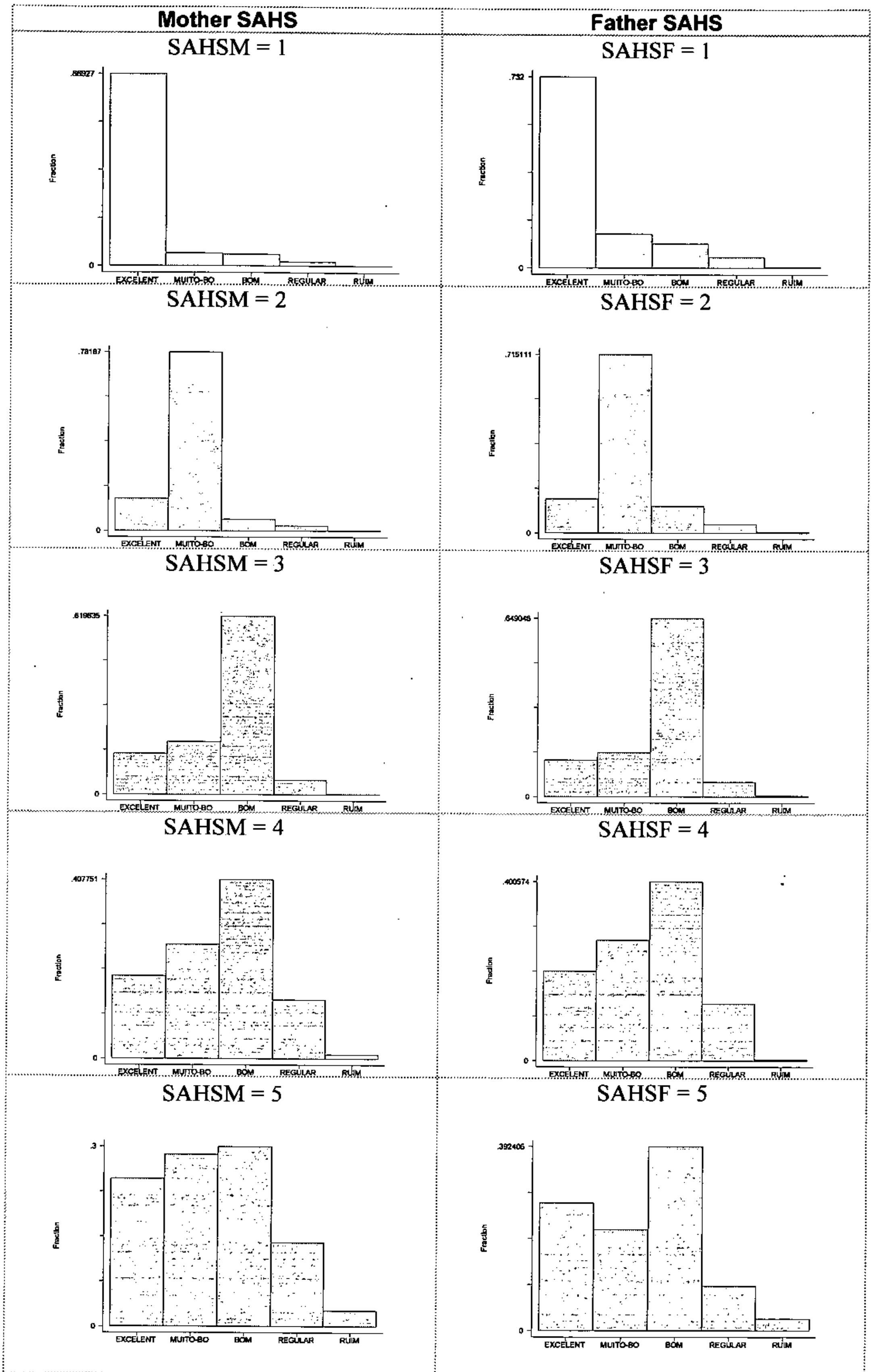


**Figure 2.2**. Distribution of SAHSC for each value of SAHSM (left) and SAHSF (right)

The distribution of health status of children conditional to the health status of parents is presented in Figure 2.2. Specifically, self-assessed health status has been considered and the values of the variable SAHSC has been related to each value of the same variable for fathers and mothers. The positive relationship between health status of parents and children is straightforward, particularly for high levels of self-assessed health status. As long as parents' health worsen, SAHSC concentrates more on intermediate values, though the decline in the self-assessment of health of children still remain relevant. By computing the mean values and variance for each situation, it is possible to assert that the relationship between mother's health and children's health is stronger than the relationship between father and children, a result in line with the literature presented above.

### 3. Transmission oh health status: estimates and results

In order to investigate parents' influence on the level of human capital of children through the transmission of their health status, the first logical step of the analysis consists of estimating the function

$$H^C = H(H^P; \bar{x}), \tag{1}$$

where $H^i$ is an indicator of health status of children ($i = C$) or parents ($i = P$) and $\bar{x}$ is a vector of control variables. It is worth noting that health status itself is a component of human capital and thus, (1) captures an essential aspect of human capital mobility. As discussed in the previous sections, child education may depend on health status,

$$E^C = E(H^C; \bar{z}), \tag{2}$$

where $E^C$ is a measure of the learning outcome and $\bar{z}$ a vector of other explicative variables. When it is true that $H^P$ has a significant explanatory power in (1) and child health affects learning outcomes, it can be asserted that the level of health status of parents has an indirect influence on child education. Evidently, the causal relationship expressed in (2) may run in the opposite direction, that is, child education may affect their health status. The presence of endogeneity in the estimation of (2) may reveal this circumstance and results would be consequently biased. In fact, reverse causality would cause a correlation of the health proxy in (2) with the error term. Should this be the relevant situation, equation (1) provides the means for assessing this question because the health status of parents could be used as instrument for child health, provided that the physical condition of adults is not directly related to child education.

Considering linear forms of (1) and (2),

$$H^C = \alpha_0 H^P + \bar{\beta}_0 \bar{x} + \varepsilon_0 \tag{3}$$

$$E^C = \alpha_1 H^C + \bar{\beta}_1 \bar{z} + \varepsilon_1, \tag{4}$$

which are the fundamental equations estimated in the empirical exercises. The choice of estimating (3) and (4) separately, instead of considering a reduced form, permits to assess the two logical steps that characterize the relationship.

On considering binary or categorical measures of health status, (1) will be estimated through probit or ordered probit models, that is,

$$\Pr(Y = 1 | X = \bar{x}) = \Phi(\bar{x}' \beta_0), \tag{5}$$

$$\Pr(Y_i = j) = \Phi(\mu_j - x_i \beta_1) - \Phi(\mu_{j-1} - x_i \beta_1), \tag{6}$$

where $Y$ is the outcome and $\Phi$ is the cumulative distribution function of the standard normal distribution. The categorical variable used in the estimation of (6) will be SAHS and thus, $j = 1,...5$. In other words, the observed ordinal variable takes on values 1 through 5 according to the scheme $y_i = j \Leftrightarrow \mu_{j-1} < y_i^* \leq \mu_j$, being $y_i^*$ the latent continuous variable that implicitly defines the model. Estimations have been carried out using STATA, version 9.

*Influence of parental health status on child health status*

The intergenerational transmission of health status is analysed in this section through the estimation of equation (3), and results of this exercise are presented in Table 2.2. Different indicators of child health status have been used as dependent variables and the methodology used in the empirical exercises varies according to their distribution functions. Columns 1-2 illustrate the results of regressions in which the dependent variables are the (continuous) indicators of child health, related to child nutrition, BMI-for-age (BMIFA) and HFA and thus, OLS have been used. In columns 3 to 5 results of the estimation of probit models are presented. Finally, an ordered probit model has been estimated when the dependent variable is the self-assessment of health status (column 6). The number of observations varies considerably between the first two columns and the rest of regressions due to the restricted sample used with BMIFA and HFA for the reasons mentioned above.

Considering indicators of malnutrition, it is possible to observe the positive and highly significant dependence on the corresponding indicators of parents' health. In particular, the health status of adults has been measured by the body mass index (column 1) and height (column 2), which is more appropriate when considering HFA due to a possible genetic influence in height. In fact, it is worth noting that while father's health appears to have a more significant and stronger effect on child's health when considering BMIFA, the impact of mother's height appears to be more important with child's HFA, confirming the existence of a more powerful link between mothers and children when using an indicator that is less dependent on environmental or socio-economic factors.

Main conclusions still apply when other indicators of health status are considered. In order to compare results of the estimations of Columns 3 – 5, marginal effects for selected variables are presented in Table 2.3. Children, whose parents report health problems during the 30 days prior to the survey, have a considerably higher probability of reporting problems (marginal effects: PROBM = 0.1979; PROBF = 0.1186), and suffering from chronic illness presents the same intergenerational link. It is interesting to observe that the relationship being analysed holds for this variable too, since only about 8% of children and about 20% of parents in the sample suffer from chronic illness.

**Table 2.2.** Intergenerational Transmission of Health Status.

| Dependent Variables | BMIFA | HFA | PROBC | GHC | CHRONC | SAHSC |
|---|---|---|---|---|---|---|
| Variables | (1) | (2) | (3) | (4) | (5) | (6) |
| BMIM | .0054* | | | | | |
| | (6.66) | | | | | |
| BMIF | .008* | | | | | |
| | (8.34) | | | | | |
| HEIGHTM | | .0021* | | | | |
| | | (10.15) | | | | |
| HEIGHTF | | .0013* | | | | |
| | | (8.18) | | | | |
| PROBM | | | .6334* | | | |
| | | | (11.72) | | | |
| PROBF | | | .3916* | | | |
| | | | (6.87) | | | |
| GHM | | | | 1.395* | | |
| | | | | (20.45) | | |
| GHF | | | | .8830* | | |
| | | | | (15.43) | | |
| CHRONM | | | | | .4150* | |
| | | | | | (5.64) | |
| CHRONF | | | | | .2986* | |
| | | | | | (3.95) | |
| SAHSM | | | | | | .3987* |
| | | | | | | (15.51) |
| SAHSF | | | | | | .2523* |
| | | | | | | (10.37) |
| **Control variables** | | | | | | |
| WHITE | .0029 | .0006 | -.0283 | .2923* | -.0209 | -.2743* |
| | (0.38) | (0.28) | (-0.55) | (5.58) | (-0.31) | (-6.98) |
| MALE | -.0000 | -.0081* | -.0656 | .0093 | -.0168 | -.0494 |
| | (-0.01) | (-3.54) | (-1.36) | (0.19) | (-0.27) | (-1.35) |
| AGE | -.0066 | -.0020 | -.0880* | .0690* | -.0538* | -.0598* |
| | (-1.07) | (-0.96) | (-4.56) | (3.37) | (-2.08) | (-3.88) |
| AGE^2 | -.0000 | .0020 | .0022* | -.0018* | .0013 | .0016* |
| | (-0.02) | (0.15) | (3.67) | (-2.80) | (1.57) | (3.30) |
| LOGRD | .0134* | .0067* | .0291 | .0636* | -.0224 | -.0639* |
| | (3.73) | (5.25) | (1.12) | (2.40) | (-0.67) | (-3.24) |
| NORTH | -.0412* | .0007 | .1838* | .1062* | .0590 | -.0698 |
| | (-5.51) | (0.31) | (3.56) | (2.03) | (0.90) | (-1.82) |
| URBAN | -.0008 | .0087* | .0340 | .0122 | .2403* | -.0166 |
| | (-0.11) | (3.35) | (0.53) | (0.20) | (2.64) | (-0.35) |
| **Model Statistic** | 27.44* | 48.14* | 290.29* | 994.02* | 75.70* | 772.78* |
| **R sq. / Pseudo-R** | .1127 | .1668 | .0776 | .3032 | .0367 | .1115 |
| **Obs** | 2365 | 2373 | 3711 | 3711 | 3711 | 3694 |

Note: Sample – children aged up to 30 years. Method: Column 1: Least Squares, Huber-White-Sandwich estimation of variances; Columns 2-4: Probit Regressions; Column 5: Ordered Probit Regression. Coefficients significant at confidence level 95% marked with "*".

**Table 2.3.** Probit regressions with dependent variables PROBC, GHC, CHRONC: marginal effects of selected variables.

| Variables<br>Dep. variable | Health M | Health F | WHITE | MALE | AGE | LOGRD |
|---|---|---|---|---|---|---|
| **PROBC** | **0.1979*** | **.1186*** | **-.0078** | **-.0182** | **-.0244*** | **.0080** |
| | (.0183) | (.0186) | (.0143) | (.0134) | (.0053) | (.0072) |
| **GHC** | **.4525*** | **.3150*** | **.1102*** | **.0035** | **.0261*** | **.0240*** |
| | (.0163) | (.0184) | (.0196) | (.0183) | (.0077) | (.0100) |
| **CHRONC** | **.0655*** | **.0452*** | **-.0027** | **-.0022** | **-.0071*** | **-.0029** |
| | (.0135) | (.0129) | (.0088) | (.0083) | (.0034) | (.0044) |

Reporting excellent of very good health status when the mother has reported excellent or very good health is very likely (the marginal effect of GHM is equal to 0.4525), and the results from the self-assessed health confirm this conclusion; see Table 2.4. As a general rule, mothers' health appears to have a greater impact on child health when considering subjective indicators, consistently with the existing literature.

Concerning control variables, the level of family income has a positive and significant effect on child health in all regressions but those reported in columns (3) and (5). In other words, reporting health problems of any type and chronic illness do not seem to be linked to income levels. The coefficient of the racial variable WHITE is positive and significant when considering GHC and SAHSC. White children tend thus to report better health status respect to non-white children, though this circumstance is not confirmed by objective measures. Gender is not a significant explanatory variable of child health status, except when considering HFA. Provided that HFA has been calculated respect to international WHO standards, the result suggests that Brazilian sons are relatively smaller, a circumstance that might reflect the poorer conditions that they enjoy. In other words, this result does not reflect a differential in health status between sons and daughters in the sample. People living in the northeast area of Brazil present poorer health status, consistently with the poorer economic performance of this region. Another interesting result is the significant impact of living in an urban area on chronic illness, underlining the poorer sanitary conditions of urban agglomerates.

Results presented above confirm the existence of a significant relationship between health status of parents and children, which may generate important consequences on the accumulation of human capital. Explicitly, if children inherit the level of health status from parents and if it has an effect on their learning capacity, a cycle of poor health, low human capital levels and deprivation may emerge.

**Table 2.4.** Ordered probit regression, dependent variable SAHSC: marginal effects.

| **SAHS** | SAHSC = 1 | SAHSC = 2 | SAHSC = 3 | SAHSC = 4 | SAHSC = 5 |
|---|---|---|---|---|---|
| **Prob at means** | **.2108** | **.3715** | **.3836** | **.03285** | **.0012** |
| **SAHSM** | **-.1151** | **-.0404** | **.1255** | **.0285** | **.0016** |
| | (.0070) | (.0043) | (.0086) | (.0025) | (.0005) |
| **SAHSP** | **-.0728** | **-.0256** | **.0794** | **.0180** | **.0010** |
| | (.0068) | (.0032) | (.0080) | .(0019) | (.0003) |
| **WHITE** | **.0791** | **.0276** | **-.0858** | **-.0197** | **-.0011** |
| | (.0113) | (0043) | (.0123) | (.0031) | (.0003) |
| **AGE** | **.0172** | **.0060** | **-.0188** | **-.0042** | **-.0002** |
| | (.0044) | (.0016) | (.0048) | (.0011) | (.0000) |
| **LOGRD** | **.0184** | **.0064** | **-.0201** | **-.0045** | **-.0002** |
| | (.0057) | (.0020) | (.0062) | (.0014) | (.0001) |

## 4. Health status and school performance

Equation (4) provides the basic framework for assessing the influence of child health on child education. In order to account for the possible correlation of the health proxy with the error term, we estimate a linear model using two-stage least squares, in which the indicators of parent's health status are the explicative variables of child health in the first regression. In particular, BMI of mothers and fathers have been used as instruments when BMIFA is the health proxy for children, while HEIGHTM and HEIGHTP have been used when considering HFA. All these variables are strongly related to the proxy of child health, in contrast to the dependent variable. It should be noted, however, that the Wu-Hausman test allows for not rejecting the null hypothesis of exogeneity of the health proxy and consequently, results presented in Table 2.5 follows from linear regressions. A discussion on the validity of instruments and some considerations on the absence of endogeneity are presented in Appendix A. Columns (1) and (4) present the results of regressions using the full sample, where health proxies are BMIFA and HFA, respectively. Columns (2) and (3), and (5) and (6) are referred to regression with the same explicative variables but using sub samples of poor households (LOGRD lower than the mean LOGRD) and rich households (LOGRD above the mean LOGRD). Considering those sub samples permits to draw some conclusion on the differential impact of child health depending on the economic condition of the family of origin.

As it can be observed, all the indicators of child health have a significant effect on learning ability, measured by the variable EAC. In other words, improved health status results in relatively higher capacity to successfully complete school years. On the contrary, these results permit to conclude that children who have inherited a poor health condition are likely to accumulate a lower level of intellectual human capital. Both child health and economic conditions are much more important for low-income families (columns 2 and 5). In other words, dependence on health status and socio-economic conditions tends to decrease with family well-being. For example, BMIFA is not significant when considering high-income households and child educational adequacy is thus high and independent from this attribute. The same feature is reflected in the impact of family income. Child capacity to complete with success school years increases with family income for poor households, while income turns out to be not significant when considering rich families. Therefore, results underline the effect family SES: the impact of health status on child learning ability is stronger for poorer families and it might disappear when family SES is sufficiently favourable. It should be noted, however, that HFA is significant in all sub-samples and the impact of health on EAC still varies depending on the income group.

Controls variables used in regressions have the expected sign and are significant. It is possible to observe a strong, direct effect of the educational level of parents on child ability. Moreover, mothers' education has a larger effect, which is independent from the explicative health proxy being used. Consistently with the conclusions about family SES, it can be observed that the level of parents' education is much more important for poorer families, thus suggesting a decreasing marginal effect on child ability. Results also permits to conclude that sons perform worse than daughters at school, being the coefficient of the variable MALE negative and significant in all regressions. Finally, living in the northeast regions of Brazil negatively affect child learning ability, especially for poorer children.

**Table 2.5:** Effects of health status on child educational adequacy.

| **Dependent Variable** | | EAC | | | EAC | |
|---|---|---|---|---|---|---|
| **Variable** | (1) | (2) | (3) | (4) | (5) | (6) |
| **BMIFA** | **.0834*** | **.1326*** | **.0327** | | | |
| | (3.63) | (3.52) | (1.19) | | | |
| **HFA** | | | | **.5205*** | **.6300*** | **.3389*** |
| | | | | (7.24) | (6.23) | (3.33) |
| **Control variables** | | | | | | |
| **EDUM** | **.0096*** | **.0152*** | **.0073*** | **.0090*** | **.0139*** | **.0070*** |
| | (6.80) | (6.53) | (4.25) | (6.38) | (6.01) | (4.10) |
| **EDUF** | **.0084*** | **.0124*** | **.0067*** | **.0081*** | **.0113*** | **.0067*** |
| | (6.35) | (5.75) | (4.06) | (6.12) | (5.26) | (4.09) |
| **LOGRD** | **.0218*** | **.0300*** | **-.0016** | **.0202*** | **.0315*** | **-.0032** |
| | (4.33) | (3.08) | (-.18) | (4.04) | (3.28) | (-.35) |
| **WHITE** | **.0306*** | **.0381*** | **.0242** | **.0316*** | **.0414*** | **.0232** |
| | (3.32) | (3.04) | (1.81) | (3.46) | (3.32) | (1.74) |
| **MALE** | **-.0473*** | **-.0422*** | **-.0522*** | **-.0449*** | **-.0401*** | **-.0509*** |
| | (-5.85) | (-3.67) | (-4.78) | (-5.60) | (-3.51) | (-4.70) |
| **NORTH** | **-.0318*** | **-.0295*** | **-.0242** | **-.0301*** | **-.0281*** | **-.0239** |
| | (-3.51) | (-2.39) | (-1.79) | (-3.36) | (-2.29) | (-1.79) |
| **URBAN** | **.0115** | **-.0000** | **-.0281** | **.0086** | **-.0044** | **-.0261** |
| | (1.00) | (-.00) | (-1.47) | (0.76) | (-.30) | (1.37) |
| **Wu-Hausman F test^** | 1.6234 | 0.2758 | 0.0776 | 3.6534 | 1.5989 | 3.1847 |
| **Model statistic** | 74.61 | 32.01 | 16.77 | 80.05 | 37.89 | 17.66 |
| **Cent-R2** | .1918 | .16 | .1047 | .2058 | .1742 | .1165 |
| **Obs** | 2639 | 1456 | 1183 | 2643 | 1459 | 1184 |

Note: Sample – children below 20 years of age. Method: linear regressions. *T* statistics in parenthesis. * significant at 95%. ^Results from auxiliary 2SLS estimates; instruments: BMIM, BMIP.

On considering these results, the role of health in the persistence of poverty can be assessed more clearly. Parents endowed with an unfavourable health status transmit to their offspring their condition. Poor health not only constrains children's possibility of enjoying a healthy life but it also negatively affects human capital accumulation. Low levels of human capital and, consequently, inadequate future income may then determine poor health conditions during adulthood, which in turn will be transmitted to the following generation. In addition, it should be noted that the negative effect of unfavourable health on learning ability might further depress human capital accumulation. Reduced returns to education, in fact, act as a disincentive for schooling investments, and poor and unhealthy children may thus dedicate less time to human capital formation. This question will be assessed in the next chapter.

## Conclusions

In this chapter a possible mechanism that link health status to the persistence of poverty has been highlighted. When health status is transmitted across generations of the same family, and health and education are complementary, children of "unhealthy" parents face constraints relative to the accumulation of human capital. The correlation between the level of human capital, income, and health status when adults, implies that the relationships being analysed may cause the emergence of a poverty trap, in which some families are stuck in an unfavourable condition of poor health and deprivation.

The analysis uses data from a Brazilian dataset, which permits to consider a very heterogeneous population in terms of income levels and health status. Firstly, the use of this particular dataset allows for extending conclusions about the intergenerational transmission of health status to developing countries. In addition, the large fraction of low-income households in the sample permits to assess more clearly the effect of health on learning ability, provided that the relationship between health and education is stronger for poorer families.

The empirical analysis carried out confirms that health status is a transmissible factor across generations. A number of objective and subjective measures of health status has been considered and all indicators suggest the existence of a relationship between the physical condition of parents and children. In addition, family income has an independent positive effect on child health, except for specific indicators such as reporting health problems or chronic conditions. These results constitute the first logical step in order to identify the role of health in the persistence of deprivation, and it is worth noting that data used in the analysis allows for claiming the existence of this fundamental intergenerational relationship in developing countries. Nevertheless, it can be asserted that health status plays a role in human capital mobility if it is possible to demonstrate that it influences human capital formation.

The empirical exercises also show that child health status affects the capacity of children to successfully complete school years. In other words, children endowed with improved health status tend to obtain better educational outcomes respect to schoolmates of the same age. The existence of a positive effect of child health on ability sheds light on the real opportunities of children of deprived families. Even when poor and unhealthy children dedicate the same time to education as healthy children, thanks, for example, to mandatory free schooling, they are likely to achieve a lower level of human capital. Therefore, filling the gap between the rich and the poor requires more than ensuring equal opportunities in the formal process of education.

Results suggest that the impact of child health on learning ability is stronger when the SES of the family of origin is less favourable. In fact, the health proxy BMIFA turns out to be not significant when considering families whose income is above the mean level (the other health proxy, HFA, remains significant but its impact is much lower for high-income families respect to low-income families). This result is consistent with a common lower dependence of learning ability on socio-economic factors for children living in rich households. For example, educational adequacy depends more heavily on income when low-income households are considered, and the influence of parents' education follows the same pattern. In other words, child health is much more important for children living in families with unfavourable SES.

In conclusion, the analysis carried out in this chapter has underlined the existence of a channel of influence from the health status of parents to human capital accumulation of children, via learning ability and education. In addition, the effect of child health on educational adequacy may further depress the scant accumulation of human capital for poor and unhealthy children. When the return to schooling affects decisions about human capital investments, lower ability due to poor health might act as a disincentive to dedicating much time to education.

# III. The impact of health status on human capital investments

When the ability to learn and understand depends on child health status, improved health may lead to greater schooling-based human capital accumulation. In fact, the complementarity of health and cognitive ability results in higher returns to schooling, which may act as an incentive for investing in human capital. Alderman et al. (2001) find a strong impact of nutritional status on school enrolment by using longitudinal data of rural Pakistan. Brown (2006) finds that making greater investments in both commodities and time depends both from higher expected returns to education for children and from different preferences among parents. Ayalew Belay (2005), by using a data set of rural Ethiopian household, finds that the allocations of educational inputs seem to favour the able and healthier children. Therefore, the length of schooling might be a non-decreasing function of child health.

There might be a number of reasons behind the positive correlation of child health and schooling-based human capital investments. Firstly, Blackburn and Cipriani (2002) point out that improved health has a positive effect on life spans. In particular, they develop a three periods OLG model, in which the probability of surviving from the second to the third period of life is endogenous. Provided that the probability of surviving depends on the health stock, investments in education are increasing with this factor. Accordingly, Basov (2002) proposes that the positive correlation between health and schooling investments arises from an insurance motive for health accumulation:

individuals invest in health to increase the probability of survival in order to enjoy the benefits of education. A healthy person, therefore, will have higher incentives to invest in schooling, provided that she is more likely to survive large enough to enjoy the results.

The objective of this chapter is to show that the impact of child health status on learning ability is an additional mechanism that should be considered for better understanding differences in schooling investments. In the theoretical framework considered here, agents choose the optimal length of schooling given their initial health stock, which is inherited from parents, and thus, their ability. Though some researcher uses a family utility function (Becker's common preference model), there is some recent evidence that support the individual preference model. Wilson, Wolfe & Haveman (2005), by constructing a choice model, find that youths' expected income returns to education are influential in their schooling choices, even when an extensive set of background, economic, family, and neighbourhood variables is introduced into the analysis. Botelho and Pinto (2004) present the results of an experiment explicitly designed for assessing students' expected returns to college education, and they conclude that students have realistic subjective beliefs about the economic returns to schooling.

The basic theoretical framework proposed here, in which educational attainments depend on both child health and time dedicated to learning, permits to conclude that the optimal length of schooling chosen by agents is increasing with the initial health stock. In addition, the impact of health on schooling is stronger for poorer families, while all rich children, who enjoy a favourable health status above a threshold level, attend school for the maximum feasible length. Conclusions have been empirically tested using the same dataset presented in the previous chapter. In particular, the empirical analysis has been separated in two sections and firstly, the effect of child health on the age of school initiation has been considered. School initiation is an interesting variable because it is an indirect predictor of school length, provided that beginning school in later ages reduces the total available time for human capital formation, and that the opportunity cost of learning is likely to increase with age. In addition, both mothers and fathers of children in the original dataset have been considered in order to investigate the effect of their health status on the total amount of time they dedicated to schooling.

The rest of the chapter is organized as follows. Section 1 presents the theoretical framework and highlights the relationship between health and school length. Section 2 treats about the effects of child health on school initiation. The impact of health status on the length of schooling is investigated in Section 3. Finally, the last section summarizes the main conclusions.

## 1. Theoretical framework

It is now considered a two periods, OLG economy, in which a new generation is born at each period $t$, each individual having only one parent. Both childhood and adulthood consist of one unit of time each. In the first period of life, children can dedicate a fraction of their available time to schooling, and their educational attainment $E_t$ depends both on the length of schooling $e_t$ and on the inherited endowment of health status, $P_t$,

$$E_t = E(e_t; P_t), \tag{1}$$

where $e_t \in [0;1]$ and

$$E_e^{'} > 0\,, E_e^{''} < 0\,, E_P^{'} > 0\,, E_P^{''} < 0\,, E_{e,P}^{'} > 0, \tag{2}$$

$$\lim_{e \to 0} E_e^{'} = 0,\ \lim_{e \to 1} E_e^{'} = +\infty,\ \lim_{e \to 0} E_t = 0,\ \lim_{P \to 0} E_t = 0.^4 \tag{3}$$

The initial endowment of health status enters the education formation function because it affects learning capacity, consistent with the empirical evidence presented in the previous chapter. Children's ability is determined during early childhood, that is, is inherited from parents through health status.

The educational attainment achieved during childhood is likely to influence future health status. For instance, Acemoglu, Johnson & Robinson (2003) argue for a reverse causality between education and health. Hence,

$$P_{t+1} = P(E_t)\,, \tag{4}$$

where it is assumed that

$$P_E^{'} > 0,\ P_E^{''} < 0, \tag{5}$$

---

[4] The following notation has been used: $x_y^{'} \equiv \partial x / \partial y$, $x_y^{''} \equiv \partial^2 x / \partial y^2$, $x_{y,z}^{'} \equiv \partial x / \partial y \partial z$.

$$\lim_{E \to 0} P_{t+1} = P^{MIN} > 0. \quad (6)$$

Lleras-Muney (2005), using the U.S. censuses of 1960, 1970, 1980, and compulsory education laws from 1915 to 1939 as instruments for education, shows that there is a large causal effect of education on health: one more year of compulsory schooling decreased mortality after age 35 by about 3%. Moreover, she calculated that one more year of education increased life expectancy at age 35 by as much as 1.7 years.

The level of human capital for which individuals are paid during adulthood is produced according to

$$h_{t+1} = h(E_t; P_{t+1}), \quad (7)$$

$$h_P^{'} > 0,\ h_P^{''} < 0,\ h_E^{'} > 0,\ h_E^{''} < 0, \quad (8)$$

$$\lim_{E \to 0} h_{t+1} = h^{MIN}(P^{MIN}) > 0. \quad (9)$$

*Optimal length of schooling*

The economy produces one consumption commodity according to a linear production function, which depends on the total amount of human capital, measured in efficiency units of labour, and on child labour. Adults are paid a fixed wage per efficiency unit of labour, normalized to one. The remuneration of children however, consists of a fixed quantity of consumption commodity, $k$. In other words, it is assumed that the level of human capital accumulated during the first period of life becomes effective, or it is recognised by employers, at the beginning of adulthood. The parameter $k$ may be also interpreted as a fixed cost of one unit of time of schooling, when children are not allowed to work. The expected level of lifetime earnings is thus equal to

$$z_t = (1 - e_t)k + \alpha \cdot h_{t+1}. \tag{10}$$

where the parameter $\alpha$ represents time preferences. Each individual chooses the length of schooling in order to maximize lifetime earnings (10). It should be noted that in the present framework it is equivalent to assume that either parents or children make educational decisions, being (10) the objective function. Parents may be very influential in schooling and other possible decisions about human capital investments for their children. The potential conflict of interest may result in different time preferences, which could alter the model predictions, though not qualitatively. Another feature of the maximization problem that should be considered is that by choosing the length of schooling, individuals also make a decision about their future health status and the overall level of health human capital during the adult age. Nevertheless, individuals have no opportunity to make health/nutritional decisions that complement educational choices. The assumption that schooling and nutrition are not a competing input into the human capital formation function is consistent with the observation that children cannot modify their health status during the first period of life and therefore, they have to accept passively the condition inherited from their parents.

It is assumed that each individual chooses $e_t$ in order to maximize (10), under assumptions $A \equiv \{(2), (3), (5), (6), (8), (9)\}$. The existence of one equilibrium simply follows from the concavity of the functions being considered.

**Proposition 1**. Under assumptions A, there exists a unique length of schooling $e^*$ that maximizes lifetime earnings (10).

*Proof.* The poof simply follows from the concavity of the functions being considered. For instance, consider the first derivative of $z_t$ respect to $e$,

$$\Omega \equiv z_e^{'} = -k + \alpha h_e^{'}. \tag{11}$$

Assumptions A ensure that

$$Z \equiv \lim_{e \to 0} \Omega = -k + \infty = +\infty \tag{12}$$

$$\Psi \equiv \lim_{e \to 1} \Omega = -k + 0 = -k < 0 \tag{13}$$

Hence, $\Omega$ takes positive values for $e \to 0$ and negative values for $e \to 1$, which ensures that there is at least one intersection of $\Omega$ with the horizontal axis. Explicitly, the first derivative of $z_t$ respect to $e$ is equal to zero at least for one $e$. Moreover, $\Omega$ is strictly decreasing in $e_t$, which ensures that the critical point is both unique and it is a maximum of the function $z_t$.

■

It should be noted that the initial health stock, $P_t$, is the main variable that determines lifetime earnings in this framework. In fact, $P_t$ affects the ability to learn and, thus, the return to education. Through this channel, it influences the optimal length of schooling and, finally, educational attainment. The effect of the inherited level of health status on the accumulation of human capital is made explicit in the following proposition.

**Proposition 2**. Under assumption A, the optimal length of schooling $e^*$ is an increasing function of $P_t$. In addition, $\exists P^* | (P_t > P^*) \Rightarrow z(1) > z(e_t), \forall e_t \in [0,1)$.

*Proof.* Firstly, function $\Omega$ is strictly increasing in $P_t$. In fact,

$$\Omega_P^{'} = \alpha h_{e,p}^{'} > 0, \tag{14}$$

since $h_{e,P}^{'} = h_E^{'} E_{e,P}^{'} > 0$, due to $E_{e,P}^{'} > 0$ under assumption A. Thus, the value of $e_t$ for which $\Omega = 0$ is increasing with $P_t$. The level $P^*$ for which $(e^* = 1)|\Omega = 0$, defines the corner solution. Provided that $e_P^{*'} > 0$ and $e_t \leq 1$ by definition, levels of $P_t > P^*$ do not result in higher levels of $e_t$.

■

Proposition 2 states that schooling decisions depend on the initial level of health status. In particular, this result follows from the consideration of the complementarity of child health status and child learning capacities, and their respective returns. What Proposition 2 highlights is that when it is assumed that child health influences child learning capacity and individuals take into account returns to schooling in their decisions, the length of schooling is a function of health status.

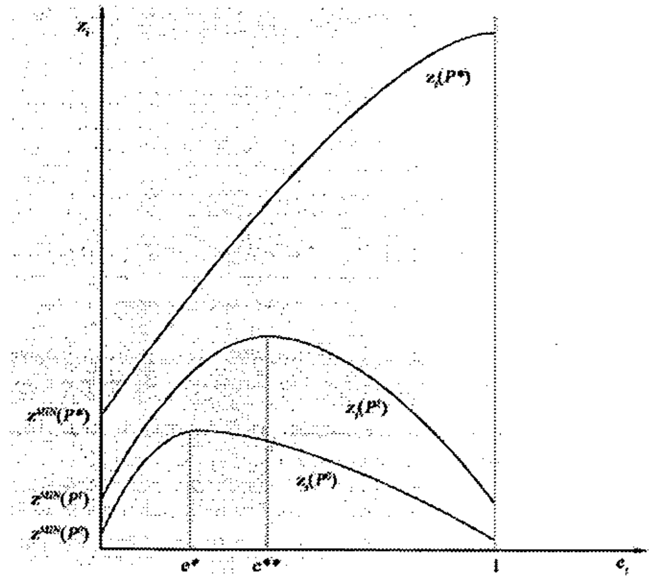


**Figure 3.1**. Effect of improved health status on the optimal length of schooling ($P^0 < P^1 < P^*$).

Figure 3.1 provides a graphical representation of this result. Expected lifetime earnings are a non-monotonic function of the length of schooling, due to the opportunity cost of education $k$ and decreasing returns. Income is maximised by choosing the length of schooling $e^*$, given the health stock $P$. Improved health status (in the graphical exercise, $P^0 < P^1 < P^*$) shifts up the earning function, determining increasing optimal lengths of schooling. Provided that the optimal length of schooling increases with health, the existence of a corner solution is straightforward. Children endowed with a level of health status above a threshold level $P^*$ in the graphical example of Figure 3.1, are sufficiently able to be profitable for them to dedicate the whole of their childhood to schooling. This conclusion is reflected in Figure 1 by the function $z_t(P^*)$, which provides a maximum for $e_t = 1$.

Hence, the length of schooling is a non-decreasing function of the health stock, and the next section provides some empirical evidence in favour of this conclusion. It should be observed, in addition, that the myopic and selfish agents considered here do not take into account the possible intergenerational effects of their decisions. In particular, though the total level of earnings may be lower, larger lengths of schooling enhance health status during adulthood and, therefore, the health status of children in the following generation. These considerations are exploited in Appendix B, which treats about the positive intergenerational effects of additional schooling on the next generation's health status and well-being.

## 2. Health status and school initiation

In order to provide some empirical evidence to support the conclusions of the previous section, the impact of child health on the age of school initiation is considered here. As mentioned above, this variable is a predictor of the length of schooling and thus, it may reveal the effect of health on schooling investments. Beginning school at later ages not only determines a reduction of the amount of time available for studying, but it is also related with increasing opportunity costs, provide that labour remuneration is likely to increase with age. In addition, the analysis of school initiation with our dataset allows for comparing results with the existing literature on the same topic (e.g. Alderman et al., 2006; Miguel, 2005). Section 3 will then discuss the relationship between health status and the total amount of time dedicated to schooling. The Brazilian survey presented in the previous chapter is the source of data for the analysis carried out here.

Before proceeding with the empirical analysis, new variables used throughout this chapter have to be defined. Table 3.1 presents those variables and sample means.

The analysis uses data of both parents and children in order to take full advantage of information provided by the dataset. Mothers and fathers have been considered separately because partner's height has been used as instrument for individual body height. The validity of this instrument, proved by different tests, and the high correlation between partners' height, might result from individuals' preference for living with a companion of the same nature (at least physically). On the other hand, the correlation between body height and the age of school initiation of the partner is weak. Moreover, the choice of parents' height as health proxy appears to be more appropriate for adults, provided that height is less dependent on contingent factors and it thus reflects health status during childhood.

**Table 3.1**. Additional variables and sample means.

| Variable | Description | Children | Mothers | Fathers |
|---|---|---|---|---|
| **Health status Indicator** | | | **mean (sd)** | |
| **SSTART(C, M, F)** | **Age of school initiation** | **5.248 (1.632)** | **7.293 (1.891)** | **7.584 (2.153)** |
| **SL (M, F)** | **Time dedicated to schooling (years)** | | **7.574 (4.687)** | **7.595 (5.144)** |
| **GMEDU-P** | **1 = if the grandmother has completed primary school or less**, 0 = otherwise | | 79.94% | 79.47% |
| **GFEDU-P** | **1 = if the grandfather has completed primary school or less**, 0 = otherwise | | 80.92% | 79.87% |
| **GMEDU-H** | **1 = if the grandmother has completed high education or more**, 0 = otherwise | | 7.45% | 9.25% |
| **GFEDU-H** | **1 = if the grandfather has completed high education or more**, 0 = otherwise | | 3.80% | 8.85% |

Variables GMEDU and GFEDU are indicators of grandparents' education, which is a significant explanatory variable of educational choices relevant for mothers and fathers in the sample.

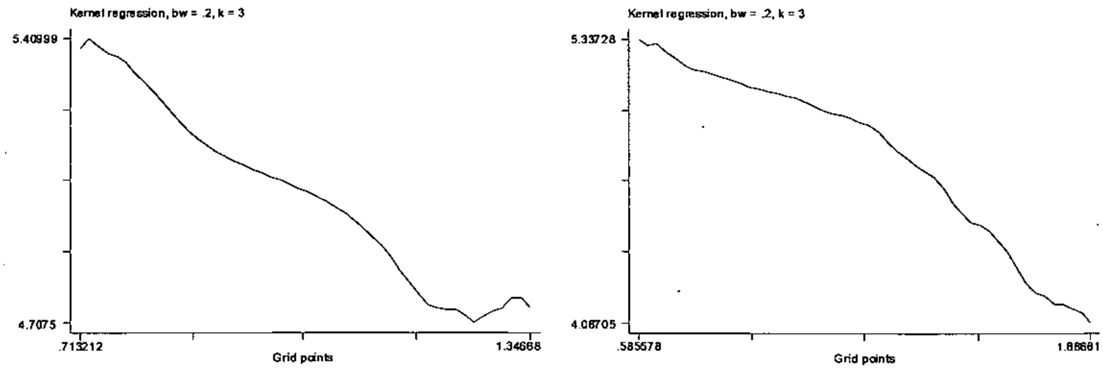


**Figure 3.2**. School initiation and health status: kernel regressions of SSTART on HFA (right) and BMIFA (left). Note: Kernel: Epanechnikov, bandwidth: 0.2.

Figure 3.2 provides a graphical representation of a kernel regression in which the dependent variable is the age of school initiation and the explicative variables are height-for-age (right) and BMI-for-age (left). As it can be observed, there is clear negative relationship between school initiation and the health proxy, consistently with our previous observations.

In order to assess the causal effect of health on school entrance, the model being considered is

$$SSTART^i = \alpha + \beta H^i + \chi \bar{z} + \varepsilon\,, \tag{15}$$

where $\bar{z}$ is a vector of exogenous control variables, $SSTART$ is the age of school initiation and $H$ has been already defined. As when considering the effects of health on educational adequacy, the health proxy may be endogenous and instrumental variables will be used in order to avoid the possible bias. Though the existence of a causal effect running from health outcomes to school entrance is not likely, endogeneity may reflect household decisions regarding human capital investments, and exogeneity tests confirm the relevance of this problem when children are considered. The detection of endogeneity in this situation can be interestingly compared to the exogeneity of the health proxy in the analysis of the effects of health on learning capacity; see chapter II. A possible source of omitted variables bias in this situation is related to parents' common decisions about human capital investments. School initiation, in fact, is likely to be affected by the same parents' behaviour that influences health-related decisions. On the contrary, school attendance is compulsory for a very large proportion of children in the sample.

Table 3.2 presents the results of the empirical analysis. As it can be observed, all coefficients of health proxies are negative and significant, highlighting that improved health status determines an early incorporation at school, and results are valid for both parents and children. As expected, parents' preferences and SES play an important role in the decision of school initiation, as underlined by the coefficients of parents' education and family income.

On considering columns 2 and 3, it can be observed that the impact of health on school initiation is larger for men than for women. At the same time, parents' education and environmental factors have a larger influence on the dependent variable for mothers. These results suggest that educational choices depend more heavily on health and ability for men, while parents' preferences and social conditions might be more influential for women. This seems to point to the institutional arrangement how people conduct their lives where men have to work to earn a living, and women are relatively dependent on men and their education, therefore, becomes a residual.

Therefore, the empirical analysis permits to conclude that the age of school initiation depends on health status. Thought this variable can be regarded as a proxy of the total length of schooling, as mentioned above, some limitations should be taken into account.

**Table 3.2**: Effects of health status on the age of school initiation.

| Dependent Variable<br>Variable | SSTARTC<br>(1) | SSTARTM<br>(2) | SSTARTF<br>(3) |
|---|---|---|---|
| **BMIFA** | **-1.928***<br>(-3.01) | | |
| **HEIGHTM** | | **-.0120***<br>(-2.02) | |
| **HEIGHTF** | | | **-.0368***<br>(-5.47) |
| **Control variables** | | | |
| **EDUM** | **-.0727***<br>(-7.46) | - | - |
| **EDUP** | **-.0584***<br>(-6.24) | - | - |
| **LOGRD** | **-.1160***<br>(-3.28) | - | |
| **GMEDU-P** | - | **.7417***<br>(8.38) | **.9401***<br>(7.41) |
| **GFEDU-P** | - | **.3546***<br>(4.04) | **.1328**<br>(1.08) |
| **MALE** | **.0945**<br>(1.72) | - | - |
| **URBAN** | **-.4422***<br>(-6.07) | **-.6909***<br>(-4.63) | **-.6698***<br>(-4.95) |
| **NORTH** | **-.8111***<br>(-12.70) | **-.1497**<br>(1.96) | **.0728**<br>(0.76) |
| **Wu-Hausman F test** | 4.74* | 0.55 | 3.76 |
| **Model statistic** | 119.82* | 40.34 * | 38.56* |
| **Cent-R2** | .2475 | .1141 | .1219 |
| **Obs** | 2363 | 1576 | 1395 |

Note: Sample – Column 1: children living with their parents; column 2: mothers; column 3: fathers. Method: Column 1: Instrumental Variables (2SLS) regression. Instruments: BMIM, BMIP. Method columns 2 and 3: Linear regression. * significant at 95%. Wu-Hausman F test, columns 2 and 3. performed after ancillary 2SLS estimates, instruments: HEIGHTM and HEIGHTF.

Literature on school initiation focused on developed countries, for example, shows that delaying school entrance boosts test score and implies a steeper test score trajectory during the first years of schooling. Datar (2006) demonstrates that a 1-year delay in kindergarten entrance increases math and reading scores by 6 and 5.2 points. One interesting result is that poor and disabled children benefit significantly more from delaying kindergarten entrance. A negative relationship between health status and age at school entrance may thus reflect a rationale response to the dynamic of child development. If child ability increases with age in the first period of life and children endowed with an unfavourable health status may suffer from a delay in cognitive development, it is optimal to postpone school entrance. In this situation, school initiation might be not informative on the length of schooling, and the explicit consideration of this variable may help to assess this question.

### 3. Health status and the length of schooling

In order to assess the impact of health status on the total amount of time dedicated to schooling, the sample has been restricted to adults only, explicitly mothers and fathers in the sample, since most children do not have completed their educational period. On considering adults, however, caution should be exercised in choosing an appropriate health proxy. In fact, health status during adulthood is likely to be affected by present conditions and SES, and this might be misleading for investigating the effects on schooling during childhood. To this end, the health proxy being considered is adult height, provided that this physical characteristic is determined during the first period of life and it cannot be modified afterwards. In addition, individual height is a good predictor of life expectancy and mortality during both childhood and old age (e.g.

Waaler, 1984), and the indicator is thus consistent with the theoretical framework presented above.

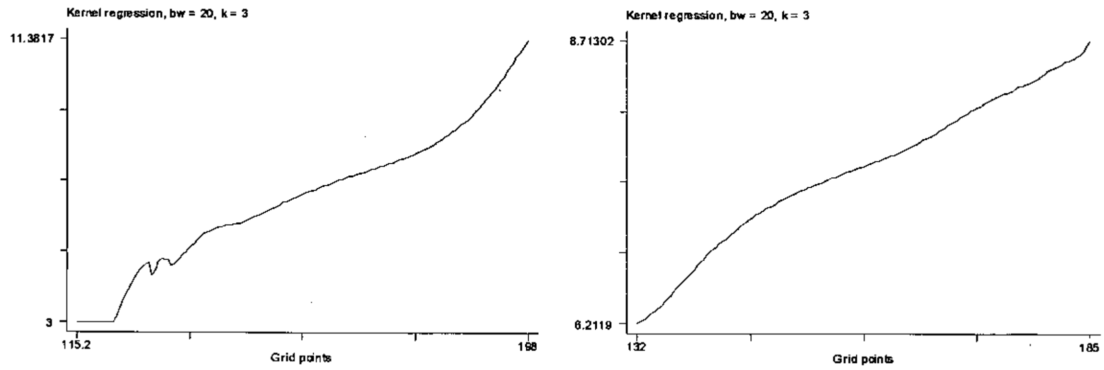


**Figure 3.3**. School length and individual height: kernel regression (kernel: Epanechnikov, bandwidth: 20)

Figure 3.3 provides the graphical representation of a kernel regression of SL on HEIGHTM (left) and HEIGHTF (right). As it can be observed, there is a positive correlation between the health proxy and school length, though this exercise is not informative about causality. In order to assess this question, another problem should be considered: the health proxy is likely to be endogenous, provided that parents' decisions about both health and schooling investments are usually consistent.

An instrumental variables approach has been used in order to assess this question, and partner's height is the instrument of adult height for the reasons discussed in the previous section. The Wu-Hausman test permits to reject the null hypothesis of exogeneity of the health proxy.

The model to be estimated directly follows from Proposition 2, which can be approximated by the linear function

$$e_t^i = \alpha + \beta H^i + \gamma z_t^i + \varepsilon_i \qquad (16)$$

where $z_t^i$ is a vector of control variables.

**Table 3.3**. Effects of health status on school length.

| Dependent Variable<br>Variable | SL-M<br>(1) | SL-M<br>(1a) | SL-F<br>(2) | SL -F<br>(2a) |
|---|---|---|---|---|
| **HEIGHTM** | **0.2328*** | **.2328*** | | |
| | (4.08) | (4.08) | | |
| **HEIGHTF** | | | **.3616*** | **.3533*** |
| | | | (5.89) | (6.19) |
| **Control variables** | | | | |
| **GMEDU-P** | **-2.5820** | | **-1.4241** | |
| | (-8.69) | | (-4.06) | |
| **GFEDU-P** | **-1.7035*** | | **-2.946*** | |
| | (-5.77) | | (-8.86) | |
| **GMEDU-H** | | **3.0839*** | | **1.6525*** |
| | | (6.06) | | (3.95) |
| **GFEDU-H** | | **2.9099*** | | **3.2784*** |
| | | (5.53) | | (6.79) |
| **WHITE** | **1.2623*** | **1.4050*** | **1.069*** | **1.1123*** |
| | (5.49) | (5.94) | (4.24) | (4.35) |
| **NORTH** | **2.7140*** | **2.6629*** | **2.0911*** | **1.9721*** |
| | (10.07) | (10.06) | (6.75) | (6.52) |
| **URBAN** | **3.0648*** | **3.373*** | **3.2952*** | **3.72*** |
| | (9.93) | (10.72) | (9.83) | (11.06) |
| **Wu-Hausman F test** | 5.65* | 8.82* | 12.75* | 13.61* |
| **Model statistic** | 100.84* | 76.10* | 102.78* | 91.07* |
| **Cent-R2** | .2536 | .1946 | .258 | .2307 |
| **Obs** | 1615 | 1534 | 1540 | 1573 |

**Note**: 2SLS estimates, instruments HEIGHTM (for HEIGHTF) and HEIGHTF (for HEIGHTM). Sample includes all mothers and fathers of the original dataset.

Table 3.3 presents the results of the empirical analysis. Columns 1 and 1a consider estimations in which the dependent variable is the length of schooling of mothers, while columns 2 and 2a show the results for parents' schooling. The difference between columns 1 and 2, and 1a and 2a relies in the grandparents' education proxies. The first relevant result is that health status has a significant and positive impact on the amount of time dedicated to schooling for both women and men. As it can be observed, the effect is larger for fathers, underlining the greater influence of ability for this group, while mothers' schooling depends more heavily on social characteristics. Grandparents' education plays an important role in schooling decisions, and results suggest that the positive influence of high-educated parents on the length of schooling is larger than the negative influence of living with uneducated parents.

As observed in the previous chapter, the intergenerational influence appears to be linked to gender: parent's education has a larger impact on children of the same sex. Racial characteristics also have a significant impact, and white individuals enjoy from larger schooling-based human capital investments. It is worth noting that being non-white has a larger negative effect for women than for men. Geographical localization has a significant effect on the length of schooling. Firstly, living in urban areas determines larger investments in education. The positive sign of the variable NORTH was initially unexpected, provided that this is the poorest area of Brazil. However, it permits to reflect on the meaning of the dependent variable being considered. School length, in fact, is a proxy of schooling investments but it is not fully informative about educational achievements. In other words, the difference between investments and results should be always taken into account. Obviously, dedicating more time to education is likely to result in higher outputs and investments depend on health status and other socio-economic characteristics as showed above. Nevertheless, many students do not complete school years with success. Results presented in this section only explain the differential across lengths of schooling. For example, population of the northeast area of Brazil dedicates more time to education respect to other individuals (11.81% on average), while the total number of school years that they successfully complete is slightly lower (about 3.35% less on average). The result found for the Northeast of Brazil might be caused by institutional arrangements (for instance, diplomas at the end of the school-curriculum), so that even if people have lower abilities, the length of their stay at school increases, simply because they need more time to get their diplomas.

## Conclusions

In the previous chapter, it has been shown that an unfavourable health status has a negative impact on child learning ability, and it thus influence the return to schooling. This result implies another negative consequences of poor health on human capital accumulation and in fact, unhealthy children may face a disincentive to undertake schooling-based investments. The theoretical framework proposed here underlines that the inheritance of an unfavourable health condition and the complementarity of child health and learning capacity have important effects of investments. Reduced ability lowers the return to the amount of time dedicated to education in terms of lifetime earnings and therefore, it might be optimal for "unhealthy" children to choose shorter length of schooling in order to maximize their income. In other words, it is shown that the length of schooling is increasing with the initial health stock.

This mechanism strengthens the conclusions of other researchers, who have investigated the influence of health on human capital accumulation through the channel of life expectancy (e.g. Blackburn and Cipriani, 2002). Following their approach, larger life spans result in higher expected lifetime earnings and therefore, healthy individuals are more likely to invest in education. The argument of health status and ability proposed in this chapter does not require individuals' capacity to predict their own probability of surviving. On considering that agents live for the same amount of time on average, the main focus is on ability, which has the advantage of being directly observable. Explicitly, this means that unhealthy children, who perform worse during the first school years, which are mandatory in most countries, might decide to reduce the length of schooling. The relationship between health status and learning ability is thus a key factor for better understanding differentials in human capital investments.

In order to assess the impact of health status on schooling investments, two different variables have been considered. Firstly, by considering both adult and children of the original dataset, it is shown that the age of school initiation is decreasing with health status, even after controlling for a number of social and economic characteristics. Parents' education, family income and other factors have in fact a significant impact on this decision but the empirical exercises highlight the independent effect of health status, consistently with the results of other researchers (e.g. Alderman et al. 2001). It should be noted that, though this result does not permit to draw explicit conclusions about the whole period of education, school initiation may be a reasonable proxy of this variable, provided that the opportunity cost of schooling increases with age, and that making up for lost school years is progressively less likely. Nevertheless, the dataset being considered provides unique information, which can be used to assess the impact of health status on the total amount of time dedicated to education independently from school achievement.

In order to investigate the relationship between health status and school length, children have been excluded from the original sample and the analysis uses data of fathers and mothers only. This methodology allows for considering individuals that have completed their educational period. Results clearly show that health status has a significant and positive effect on the amount of time dedicated to schooling, for both women and men. In addition, the effect is larger for fathers, underlining the greater influence of ability for this group, while mothers' schooling depends more heavily on social characteristics.

Finally, this chapter has shown that poor and unhealthy children not only suffer from their unfavourable condition, which in turn negatively affect their learning ability and possibility of human capital accumulation. This circumstance implies that they invest fewer resources in the formation of human capital, thus further reducing their future real possibilities. In other words, deprived children develop a lower capacity to generate income during adulthood and this situation is likely to affect their future SES and the SES of the following generations. The aim of the next chapter is to investigate the emergence of this health poverty trap.

# IV. Health human capital and poverty traps

The approach of multiple equilibria permits to explain why some countries are persistently poor while others are improving their favourable conditions. The mechanisms behind bimodality in distribution functions of income have been initially discussed by Quah (1996, 1997), who also reviews a body of empirical research that model directly the dynamics of the cross-section distribution of countries in order to provide evidence on stratification, formation of convergence clubs and polarization of the cross section distribution into twin peaks. Durlauf and Johnson (1995), for instance, provide evidence for a multi-modal behaviour of the evolution of income, and they interpret this result as multiple regimes. Bianchi (1997) estimates with non-parametric techniques the distribution function of income in different moments in time, ignoring the dynamics behind the observations. While he finds that the distribution is likely to be unimodal in the early 1960s, the data reject the null hypothesis of unimodality against bimodality in the late 1980s, confirming the occurrence of twin-peaknedness.

Those results suggest that feedbacks inherent to the process of growth may give rise to multiple equilibria. However, twin peaks may also result from differences in fundamental forces that affect productivity. If behind bimodal distributions of income there is the distribution of unobserved variables related to economic performance, twin peaks are not informative about the existence of multiple equilibria. This consideration has motivated the analysis of Bloom, Canning and Sevilla (2003), who readdress the question of bimodality by studying the distribution of income levels for countries with similar exogenous characteristics. Despite the use of a different approach, the main conclusion concerning the existence of multiple equilibria remains unchanged.

Multiple equilibria and bimodal distribution functions are not exclusively related to income, and poverty traps have been also empirically found when considering the cross-country distribution of health status. Mayer-Foulkes (2003), for instance, demonstrates that some countries are stuck in an unfavourable condition of short longevity, as shown in Figure 4.1, which represents life-expectancy histograms for 159 countries both in 1962 and 1997.

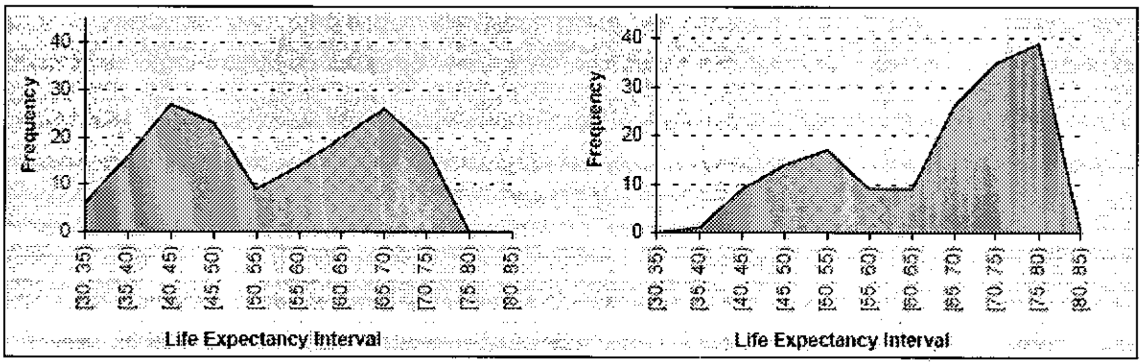


**Figure 4.1.** Cross Country life Expectancy Histograms (159 countries) in 1962 (left), and 1997 (right). Source: Mayer-Foulkes (2003)

As it can be observed, the distribution function appears to be twin-peaked in the two dates considered in the analysis. This suggests the existence of a group of countries for which health status has not improved during this period, and which are not experiencing convergence with healthier (and richer) countries.[5]

[5] Mayer-Foulkes (2003) analyses the trajectories of life expectancy between the periods been considered in order to state this conclusion.

The analysis carried out in chapter II showed that health human capital tends to be transmitted from parents to children and thus, children of poor parents are much more likely to suffer from poor nutrition and ill health. The complementarity of health status and education, then, explains the relationship between poor health during childhood and a low level of income during adulthood, which is in turn related to future unfavourable health conditions. These phenomena are closely linked to the persistence of deprivation in low-income countries.

The first aim of this chapter is to analyse those mechanisms in order to underline the role of health status in the emergence of poverty traps. To this end, the relationship across SES, health and nutritional status and the accumulation of human capital have been included in a three periods, overlapping generations model with endogenous fertility, in which adults choose their present and old age consumption, the number of children they have, the length of schooling of each of their children and the amount of resources dedicated to nutrition. It is assumed in the model developed in this chapter that children share their unit of available time between work and education, in accordance with the decision their parents make. Child labour, in fact, may be crucial in order to ensure a positive level of consumption and nutrition when the SES of the family of origin is particularly low. Hence, children of poor families dedicate less time to education in favour of labour and the resulting scant accumulation of human capital during childhood has a direct negative impact on future income. Children of the following generations therefore, are very likely to be facing the same economic problem and hence, poverty tends to characterize the whole dynasty.

In order to analyse the implications of the relationship between health and education, it is assumed in the model that cognitive capacities and the productivity of schooling depend on child nutrition, consistently with the conclusions obtained in the previous chapters. This generates a second effect that explains the persistence of poverty: the undernourished children of poor parents have a lower capacity to learn. As a consequence, malnourished children, on average, even when these dedicate the same amount of time to schooling as healthy children, accumulate less human capital. This has a knock-on-effect that aggravates the problems of financing the education of deprived families.

Though the consequences of the complementarity of child health and learning capacity have not been explicitly studied previously from a theoretical point of view, it should be noted that the model developed here is related to de la Croix and Doepke (2003), who analyse the relationship between inequality and growth and stress the interdependence between educational and fertility choices. In particular, the utility function considered here, and the *ad hoc* form of modelling intergenerational altruism follow from the framework used in their analysis. Another reference, which has been useful in the present analysis, is Berti Ceroni (2001), who also studies poverty traps related to the accumulation of human capital, though she does not explicitly consider health status and its effects on education, and the existence of multiple equilibria in her paper is closely related to the use of a non-homothetic utility function. In addition, conclusions concerning the positive effects of health on human capital investment are consistent with the approach of Chakraborty (2004). Chakraborty, in fact, considers the effect of life expectancy on expected lifetime earnings, which act as an incentive to educational investment. The influence of health status on the return to schooling considered in this chapter, however, passes through the channel of cognitive capacity and child ability to learn. To some extent, it can be asserted that these two mechanisms are complementary and operate in the same direction.

The second part of this chapter extends the basic OLG framework and considers heterogeneous agents in order to discuss a particular mechanism for escaping from deprivation, namely school feeding. The interest of this policy relies on its growing popularity and on the fact that it should enhance both health and education simultaneously. With the exception of van Zon and Kiiver (2006), who have studied food-coupons as an instrument in favouring the abilities of the new and the next generations using a modelling approach similar to that followed in this chapter, school feeding has been generally studied from an empirical point of view. International agencies such as the World Food Programme (WFP) and national governments have dedicated a large amount of resources to school feeding programmes. In 2005, for instance, 21.7 million children in 74 countries received WFP school meals. According to the WFP, the promise of one meal attracts children to school, promotes regular attendance and enhances student performance. On the other hand, empirical evidence suggests that providing food at school do not necessarily imply health gains for children. For instance, Simeon (1998) reviews two Jamaican studies that show that students receiving a meal at school during a program of school feeding did not experiment any weight gain. The standard interpretation of this result is that parents reallocate resources from children to other members of the family, redistributing the benefits of transfers across the whole family. Results of the numerical simulation suggest that school feeding tends to generate a significant improvement in educational levels while having a much lower effect on child nutrition. However, school feeding is shown to have positive intergenerational effects on child nutrition and human capital levels.[6]

The outline of the rest of the chapter is as follows. Section 1 and 2 describe the basic framework and results of the maximization problem. In addition, the question of club convergence is assessed trough a numerical simulation. Section 3 focuses on the intergenerational transmission of human capital and section 4 extends the basic framework in order to consider the effects of school feeding and presents a computational experiment, which allows for drawing the consequences of this policy. Finally, main conclusions are summarized in the last section.

## 1. The model economy

In the overlapping generations economy being considered, each individual has only one parent. Agents live for three periods, childhood, adulthood and old age, which are normalized to one unit of time each. In the first period of life, children dedicate their unit of time to the accumulation of human capital, measured in efficiency units of labour, and to child labour in accordance with what their parents decide. Hence, a child allocates the available time among education $e_{t+1}$ and work $(1-e_{t+1})$. It should be noted that a market for education has not been considered. Explicitly, the analysis has been simplified and presupposes the existence of a public, exogenously financed educational system, or

[6] School feeding has another consequence that is considered in this chapter as an "external" effect. By increasing the amount of time dedicated to schooling, in fact, the policy generates a reduction of child labour. However, on considering the diffusion and perception of this phenomenon in poor countries, the disutility of child labour to the parent and the child has not been taken into account here. As a consequence, the reduction of child labour is a positive external effects in this framework.

assumes that education is not a formal process and may consist of reading (free) books, for example.

The total amount of resources dedicated to child nutrition in terms of the consumption commodity, $N_t$, is equal to the amount of resources that parents dedicate to nourishing, $cn_t$, and on the level of income from child labour $zc_t$,

$$N_t = cn_t + zc_t . \tag{1}$$

In order to underline the mechanisms through which health affects the intergenerational transmission of poverty, it is assumed that human capital depends on both the amount of resources dedicated to nutrition and the length of schooling. The technology of formation of human capital is thus

$$h_{t+1} = (N_t)^{\mu}(\lambda_t e_{t+1})^{\eta}, \tag{2}$$

where $0 < \mu < 1$, $0 < \eta < 1$ and $\lambda_t$, which affects the productivity of schooling, is assumed to be a function of the level of nutrition,

$$\lambda_t = \lambda(N_t) = \lambda_0 N_t^{\kappa}, \tag{3}$$

where $0 < \kappa < 1$. The positive relationship between child nutrition and schooling productivity directly follows from the empirical analysis carried out in the previous chapters. Substituting (3) and (1) into (2),

$$h_{t+1} = (N_t)^{\psi} \cdot (\lambda_0 e_{t+1})^{\eta}, \tag{4}$$

where $\psi = \mu + \kappa\eta$ and it is assumed that $\psi + \eta \leq 1$. Hence, the formation of human capital depends on education and on child nutritional status, which enhances human capital both directly and indirectly through its effect on the productivity of schooling.

Children dedicate the fraction of childhood $(1-e_t)$ to work in order to increase their own level of consumption and nutrition. They participate in extra-market activities and they are paid a fixed amount of consumption commodity $\chi$ per unit of time dedicated to labour. A different interpretation of $\chi$, which is compatible with this framework, is that it represents the fixed cost of one unit of time of education when children are not allowed to work and $\chi$ represents thus the opportunity cost of schooling. The assumption on child labour income, though formally simpler, generates an effect similar to Hazan and Berdugo (2002), in that the increasing differential between child and parental labour leads to the progressive reduction of child labour.

In the second period of life, adulthood, individuals choose the level of personal consumption $c_t$, savings $s_t$, which determine the level of old age consumption, the number of children $n_{t+1}$ they have, the level of child consumption $cn_t$, and how to distribute their offspring's time between education and work. In addition, parents face a positive time cost of rearing a child, $\phi$. As is normally assumed in the literature, children are considered a consumption commodity since it is impossible to make a monetary profit by rearing a child. As follows from (1), in fact, income from child labour is entirely dedicated to child nutrition or, equivalently, children retain their earnings.

Consumption is the only feasible activity during the third period of life. Hence, agent *i*, born at $t-1$ and endowed with a level of human capital $h_t$ at $t$, is subject to the budget constraint

$$z_t(1-\phi n_{t+1}) = c_t + s_t + cn_t n_t, \tag{5}$$

$$R^e_{t+1} s_t = x_{t+1} \tag{5a}$$

where $z_t \equiv w_t h_t$ represents adult income ($w_t$ represents the wage per efficiency unit of labour), $R^e_{t+1}$ is the expected return on savings and $x_{t+1}$ old age consumption. Preferences of adults born at $t-1$ and endowed with $h_t$ efficiency units of labour are represented by the logarithmic utility function

$$U_t = \log(c_t) + \beta \cdot \log(x_{t+1}) + \gamma \cdot \log(n_t h_{t+1}), \tag{6}$$

which underlines that parents care about the quality and quantity of children. De la Croix and Doepke (2003) used this particular form of modelling parents' preferences and intergenerational altruism. The time-cost associated with children is only connected with the number of children, whereas in utility terms the contribution of the number of children and human capital per child is the same. Hence, for growing income, the opportunity cost of having more children goes up and one substitutes quality for quantity.

*Firms*

It is assumed that a representative firm produces at period $t$ by using human and physical capital as factors of production,

$$Y_t = AH_t^{\tau} K_t^{1-\tau}, \tag{7}$$

where $A$ is a productivity parameter, $H_t$ is the total amount of efficiency units of labour at $t$, and $0 < \tau < 1$. The capital stock at $t = 0$ is given and equal to $K_0$; for all $t > 0$, capital $K_t$, productive at $t$, is equal to the total amount of savings at $t - 1$,

$$K_t = P_{t-1} s_{t-1}, \tag{8}$$

where $P_{t-1}$ is the number of agents at $t - 1$. The initial amount of efficiency units of labour $H_0$ is also exogenous, and for all $t > 0$ its level depends on the decisions of adults concerning the number of children they have and their level of human capital. It is assumed that factors are paid their marginal productivity.

### 2. Individual behaviour

Parents choose $c_t$, $s_t$, $n_{t+1}$, $cn_t$ and $e_{t+1}$ in order to maximize (6) subject to (4), (5) and (7). The solution implied by the first order conditions of the maximization problem depend on the initial level of income of parents respect to the threshold levels $\check{z} \equiv \frac{\chi}{\phi(\eta+\psi)}$ and $\hat{z} \equiv \frac{\chi(1-\psi)}{\eta\phi}$. In terms of education, the maximization problem is solved for

$$e_{t+1} = \begin{cases} \dfrac{\eta}{\eta+\psi} & if \quad z_t \leq \check{z} \\ \dfrac{\eta(z_t\phi-\chi)}{1-\eta-\psi} & if \quad \check{z} < z_t < \hat{z} \\ 1 \quad if \quad z_t \geq \hat{z} \end{cases} \tag{9}$$

The threshold levels of adult income $\check{z}$ and $\hat{z}$ define three intervals. When $z_t \leq \check{z}$, parents decide that their children can attend school for the minimum (and constant) period $\frac{\eta}{\eta+\psi}$, and they dedicate the rest of available time to labour. Time dedicated to education begins to increase with parents' income when $z_t > \check{z}$. Finally, when $z_t \geq \hat{z}$, children dedicate the whole unit of available time to schooling. Provided that children dedicate the available time to either schooling or labour, (9) implicitly shows the negative relationship between parents' income and child labour.

Considering investments in the second component of human capital, i.e. resources dedicated to nutrition, the maximization problem is solved for

$$
cn_t = \begin{cases} 0 \quad if \quad z_t \leq \underline{z} \\ \dfrac{z_t \phi(\eta + \psi) - \chi}{1 - \eta - \psi} \quad if \quad \underline{z} < z_t < \tilde{z} \\ \dfrac{z_t \phi \psi}{1 - \psi} \quad if \quad z_t \geq \tilde{z} \end{cases} \tag{10}
$$

The fact that poor parents have not the possibility to offer resources to children for their nutrition does not imply that the overall level of nutrition is equal to zero. In fact, it is equal to the sum of resources offered by parents and the resources from child labour,

$$
N_t = \begin{cases} \dfrac{\chi \psi}{\eta + \psi} \quad if \quad z_t \leq \underline{z} \\ \dfrac{(z_t \phi - \chi) \psi}{1 - \eta - \psi} \quad if \quad \underline{z} < z_t < \tilde{z}\,. \\ \dfrac{z_t \phi \psi}{1 - \psi} \quad if \quad z_t \geq \tilde{z} \end{cases} \tag{11}
$$

In other words, children of deprived families work for their own subsistence. Finally, the number of children per adult varies with adult income according to

$$n_t = \begin{cases} \dfrac{\gamma}{(1+\beta+\gamma)\phi} & \text{if} \quad z_t \leq \check{z} \\ \dfrac{z_t \gamma (1-\eta-\psi)}{(1+\beta+\gamma)(z_t \phi - \chi)} & \text{if} \quad \check{z} < z_t < \hat{z} \\ \dfrac{\gamma(1-\psi)}{(1+\beta+\gamma)\phi} & \text{if} \quad z_t \geq \hat{z} \end{cases} \tag{12}$$

The model predicts that fertility is constant at its maximum level for $z_t \leq \check{z}$, then decreasing for $z_t \in (\check{z}, \hat{z})$, and constant at its minimum level elsewhere. It is worth noting that these results are consistent with the trade-off between quantity and quality of children faced by parents.

Equations 9–12 show that poor parents tend to rear a large number of uneducated and undernourished children. Conversely, adults substitute quantity for quality of children for growing income. The rationale behind this result is that the time cost of parenthood is lower for individuals endowed with a low level of human capital, who are likely to obtain lower wages in the labour market. Provided that increasing family size or the amount of human capital per child is the same in terms of parents' utility, poor individuals choose the cheapest solution, which consists of rearing more children. Conversely, when dedicating time to child rearing implies a high loss of remuneration, parents prefer to invest in children's human capital.

**3. Intergenerational transmission of human capital**

The level of human capital of children depends on choices that adults make with respect to the time those children dedicate to education and on child nutrition. The allocation of childhood time between work and education is a function of their parents' income and thus, human capital evolves according to the policy function

$$h_{t+1} = G(z_t) = [N_t(z_t)]^{\psi} \{\lambda_0 [e_{t+1}(z_t)]\}^{\mu}, \tag{13}$$

where $N_t(z_t)$ and $e_{t+1}(z_t)$ are functions of parental income, as follows from (9) and (10). The dynamic of income, however, also depends on adult savings and on the number of workers in the next period, which determine the capital-labour ratio. In particular, the wage per efficiency unit of labour at $t+1$, obtained by assuming that factors of production are paid their marginal productivity, is equal to

$$w_{t+1} = \tau A \left( \frac{K_{t+1}}{H_{t+1}} \right)^{1-\tau} = \tau A \left( \frac{s_t}{(P_t n_t)(h_{t+1})(1 - n_{t+1}^{e}\phi)} \right)^{1-\tau}. \tag{14}$$

The total amount of efficiency units of labour at $t+1$ is equal to the number of adults in the same period, $P_t n_t$, the level of human capital of each worker $h_{t+1}$ and the time they dedicate to labour net of child rearing $(1 - n_{t+1}^{e}\phi)$, where it is assumed that the firm has rational expectations on the level of fertility of the next generation, $n_{t+1}^{e} = n_t$. Equations (13) and (14) and the results of the maximization problem permit to analyse the dynamic of income. In order to simplify the exposition, we consider separately the situations in which the representative agent has a level of income $z_t \leq \underline{z}$, $\underline{z} < z_t < \bar{z}$, and $z_t \geq \bar{z}$. Firstly, when $z_t \leq \underline{z}$, the policy function, which represents the level of income of adults born at $t$ as a function of the level of income of adults born at $t-1$, reduces to

$$z_{t+1} = \tau\left(\frac{z_t \beta(1+\beta+\gamma)\phi}{(1+\beta)\gamma}\right)^{1-\tau}\left(\frac{\eta}{\eta+\psi}\right)^{\eta\tau}\left(\frac{\chi\psi}{\eta+\psi}\right)^{\eta\psi}, \tag{15}$$

where $\lim_{z\to 0} z_{t+1} = 0$, $\dfrac{\partial z_{t+1}}{\partial z_t} > 0$, $\dfrac{\partial^2 z_{t+1}}{\partial z_t^2} < 0$. Condition

$$h_{MIN} \equiv \left(\frac{\eta}{\eta+\psi}\right)^{\eta}\left(\frac{\chi\psi}{\eta+\psi}\right)^{\psi} < \frac{\beta(1+\beta+\gamma)\left[\beta\left(\frac{1}{1+\beta}+\frac{1}{\gamma}\right)\tau\phi\right]^{-1/\tau}}{(1+\beta)\gamma(\eta+\psi)} \tag{16}$$

ensures that the level of income

$$z^* = \frac{(1+\beta)\gamma\left[\beta\left(\frac{1}{1+\beta}+\frac{1}{\gamma}\right)\tau\phi\right]^{1/\tau}\left(\frac{\eta}{\eta+\psi}\right)^{\eta\tau}\left(\frac{\chi\psi}{\eta+\psi}\right)^{\tau\psi}}{\beta(1+\beta+\gamma)\phi} \tag{17}$$

is a steady state of the policy function in the interval being considered. In fact, when (16) holds, $z_t = z^* \Rightarrow z_{t+1} = z_t$ and $z^* < \underline{z}$. For $\underline{z} < z_t < \bar{z}$, the policy function takes the form

$$z_{t+1} = \tau\left(\frac{z_t\phi - \chi}{1-\eta-\psi}\right)^{2(1-\tau(1-\eta-\psi))}\left\{\frac{\beta(1+\beta+\gamma)(1-\eta-\psi)}{\gamma\left[z_t\phi(1+\beta+\gamma(\eta+\psi)) - \chi(1+\beta+\gamma)\right]}\right\}^{1-\tau}\psi^{\psi\tau}\left(\frac{\chi}{\eta}\right)^{-\eta\tau} \quad (18)$$

As in the previous situation, the first derivative of the policy function respect to $z_t$ is positive and the second derivative, negative. Given the functional form of (18), it is not possible to obtain the steady state level of income in this interval, though it should be noted that condition

$$h_{MIN} > \frac{\chi(1-\psi)(\chi\psi)^{\psi(1-\tau)}\eta^{\tau\psi}}{\eta^{1-\eta}\left[\dfrac{\beta(1+\beta+\gamma)\chi}{\gamma\eta(1+\beta+\gamma\psi)}\right]^{1-\tau}(\eta+\psi)^{\eta+\psi}\tau\phi} \quad (19)$$

ensures that $\lim\limits_{z\to\hat{z}} z_{t+1} > \hat{z}$. Hence, when (16) and (19) hold, the policy function provides an unstable steady state in the interval $[\underline{z}, \hat{z}]$. Finally, for $z \in [\hat{z}; \infty]$, the policy function takes the form

$$z_{t+1} = \tau\left(\frac{z_t\phi\psi}{1-\psi}\right)^{\psi}\left[\frac{\beta(1+\beta+\gamma)}{\gamma\psi(1+\beta+\gamma\psi)}\left(\frac{z_t\phi\psi}{1-\psi}\right)^{1-\psi}\right]^{1-\tau}. \quad (20)$$

In the interval being considered, (20) provides the steady state

$$z^{**} = \left\{ \frac{\gamma(1-\psi)(1+\beta+\gamma\psi)}{\beta(1+\beta+\gamma)\tau\phi} \left[ \frac{\beta(1+\beta+\gamma)\left(\frac{\phi\psi}{1-\psi}\right)^{1-\psi}}{(1+\beta+\gamma\psi)\gamma\psi} \right]^{\tau} \right\}^{\frac{1}{-\tau+\tau\psi}}, \tag{21}$$

under (19). Therefore, when (16) and (19) hold, the policy function provides exactly three steady states in the interval $[0;\infty]$, as depicted in figure 4.2.

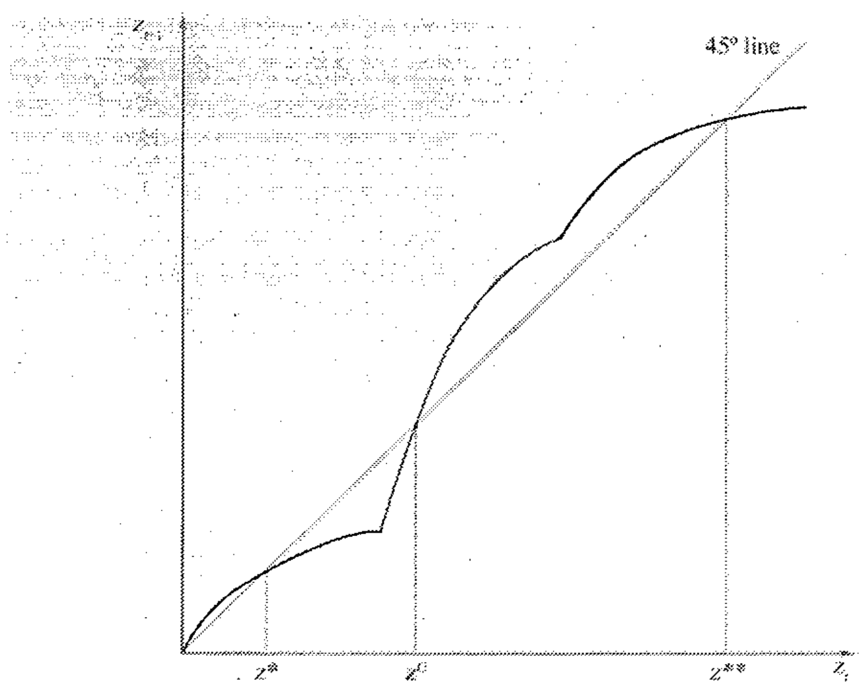


**Figure 4.2.** Temporal evolution of income per agent with multiple equilibria.

It is worth noting that, depending on the values of parameters, the policy function may provide up to 5 equilibria, three of which would be stable, and the others unstable. This result follows from the functional form of (13), which is concave in all three intervals considered in the analysis. Condition (16), however, is sufficient for the existence of a poverty trap. A level of adult income $z_t < z^U$ in the graphical exercise of figure 4.2 implies that the dynasty of the representative agent converges to the low nutrition, high fertility and low human capital equilibrium $z^*$. In contrast, when it is assumed that the initial level of human capital is greater than the threshold level $z^U$, the dynasty converges to the low fertility, high human capital equilibrium $z^{**}$. When several economies are considered, each of them characterized by a different initial level of income per agent, the model predicts club convergence (e.g. Galor, 1996).

When only condition (19) holds, however, the policy function provide a unique equilibrium, which is characterized by high levels of health human capital and low fertility. As stressed by Azariadis and Stachurski (2005), however, this situation should be regarded as a poverty trap, too. In fact, though the economy converges to the unique upper equilibrium independently from the initial level of income per capita, the degree of non-convexity of the policy function determines club convergence in the medium run.[7] Hence, unfavourable health conditions of the family of origin result in scant accumulation of human capital for children and, possibly, in the persistence of deprivation for the whole dynasty. The option of child labour and the necessity of nutrition force poor children to ensure their subsistence by reducing their future real opportunities. Only when it is feasible to offer an adequate amount of resources for nutrition to children, they can reallocate labour time to schooling. An effective policy aimed at enhancing the condition of the poor, therefore, should break the negative relationship between present survival and future development. This is the rationale

[7] Model predictions about club convergence are considered in Appendix C by means of a numerical simulation.

behind school feeding programmes, which are an attempt to improve education by offering free meals at school.

### 4. School feeding, improved human capital and growth

The consideration of health-related poverty traps naturally poses the question of their eradication. In a heterogeneous population only a fraction of agents may suffer from deprivation, while the rest of individuals enjoy from higher degrees of freedom. The existence of a group of individuals endowed with higher levels of income provides the opportunity of transfers from the rich to the poor in order to give all people the same chances and reduce the burden of inequality. In the present section this issue is considered and a particular mechanism of transfer to deprived children is analysed, namely school feeding. The objective of the analysis carried out here is to show a potential failure of this policy rather than assessing its impact on human capital.

It is now assumed that a Government agency raises funds exclusively by levying a tax on labour income, being the tax rate equal to $t_z$. It should be noted that this policy has an effect on the supply of labour, though indirectly through fertility. In fact, as it will be shown below, labour income taxation generate an increase in fertility, provided that it reduces the time-cost of rearing a child and, consequently, it causes a reduction of the total amount of time that parents dedicate to labour. The individual budget constraint at $t$ with labour income taxation is

$$c_t + s_t + cn_t n_t = z_t(1 - \phi n_{t+1})(1 - t_z)\,. \tag{22}$$

The Government agency transfers available resources to all children at each period $t$ in order to improve their level of human capital according to the following rule. A fixed quantity of consumption commodity $T$ per unit of time dedicated to education is transferred to each child. For example, free meals are offered to children at school. The level of child nutrition is thus equal to

$$N_t = cn_t + zc_t + T \cdot e_{t+1}, \tag{23}$$

and the human capital formation function (4) varies accordingly. Adults maximize their utility (6) subject to the modified budget constraint and the human capital formation function, which includes transfers from the Government agency. The solution of the maximization problem for a representative agent is summarized by the functions

$$e_{t+1} = \begin{cases} \dfrac{\eta\chi}{(\chi - T)(\eta + \psi)} & if \quad z_t \le z^* \\ \dfrac{\eta(z_t\phi(1 - t_z) - \chi)}{(\chi - T)(1 - \eta - \psi)} & if \quad z^* < z_t < z^{**} \\ 1 \quad if \quad z_t \ge z^{**} \end{cases} \tag{24}$$

$$cn_t = \begin{cases} 0 \quad if \quad z_t \le z^* \\ \dfrac{z_t(1 - t_z)\phi(\eta + \psi) - \chi}{1 - \eta - \psi} & if \quad z^* < z_t < z^{**} \\ \dfrac{z_t(1 - t_z)\phi\psi - T}{1 - \psi} & if \quad z_t \ge z^{**} \end{cases} \tag{25}$$

$$n_t = \begin{cases} \dfrac{\gamma}{(1+\beta+\gamma)\phi} & if \quad z_t \le z^* \\ \dfrac{z_t(1-t_z)\gamma(1-\eta-\psi)}{(1+\beta+\gamma)(z_t(1-t_z)\phi-\chi)} & if \quad z^* < z_t < \bar{z}^{**} \\ \dfrac{z_t(1-t_z)\gamma(1-\psi)}{(1+\beta+\gamma)(z_t(1-t_z)\phi-T)} & if \quad z_t \ge \bar{z}^{**} \end{cases}, \tag{26}$$

$$s_t = \frac{z_t(1-t_z)\beta}{1+\beta+\gamma} \tag{27}$$

where $z^* = \dfrac{\chi}{(\eta+\psi)(1-t_z)}$ and $\bar{z}^{**} = \dfrac{(1-\psi)(\chi-T)+T\eta}{\eta\phi(1-t_z)}$. The threshold levels of income, which define three intervals, are increasing in $t_z$, that is, the policy being considered alters the behaviour of agents with respect to fertility and human capital investments. This is particularly important because it implies that the level of $t_z$ and $T$ indirectly determines the number of children that enjoy form transfers, and this circumstance will be taken into account in the computational experiment. Firstly, school feeding has a positive effect on the length of schooling. This is always true for families with an initial level of income below the threshold level $z^*$, while children of richer adults might suffer from the negative effect of labour income taxation, provided that the length of schooling is proportional to income. The policy being considered does not affect the length of schooling only when the initial level of income is above $\bar{z}^{**}$, which ensures that children dedicate the available time to education.

Another interesting result is the effect of school feeding on child nutrition,

$$N_t = \begin{cases} \dfrac{\chi\psi}{\eta+\psi} & if \quad z_t \le z^* \\ \dfrac{\psi[z_t(1-t_z)\phi-\chi]}{1-\eta-\psi} & if \quad z^* < z_t < \bar{z}^{**} \\ \dfrac{\psi[z_t(1-t_z)\phi-T]}{1-\psi} & if \quad z_t \ge \bar{z}^{**} \end{cases} \tag{28}$$

As it can be observed, the level of nutrition of children of deprived families remains unchanged. This result does not follow from intra-household allocation as argued by some authors, since children retain their earnings and transfers and deprived parents do not allocate resources to child nutrition in this model. Education has a negative effect on child nutrition because it prevents children to work. School feeding programmes lower the opportunity cost of schooling by reducing the amount of time that young workers need in order to obtain a given quantity of resources, and the model predicts that the reduction of child labour is exactly equal to the amount of time that is required for obtaining the amount of resources offered at school. As a result, deprived children maintain their nutritional level and, at the same time, they allocate more time to education. Even when school feeding does not succeed in enhancing nutritional status, results might be desirable. Firstly, this policy causes a reduction of child labour and secondly, it results in improved human capital. In addition, improved human capital permits to offer better conditions to the next generation. In other words, school feeding may have positive intergenerational effects, which might result in enhanced nutritional status.

### 4.1 Computational experiment

In order to clarify the effects of school feeding programmes, a computational experiment is presented in this section. The model has been calibrated to match empirical features of the Brazilian economy by making use of the Brazilian Living Standards Measurement Survey (Pesquisa sobre Padrões de Vida - PPV) discussed in chapter II. In the computational experiment presented in this section, the base period does not represent a steady state and the model determines all endogenous variables. The procedure used here is similar to Malakellis (1994): the base year of his control scenario does not represent a steady state and the economy asymptotically converges to a balanced steady-growth path. The values of variables in the base year are observed from statistics and, beyond the base year, the model determines the levels of all endogenous variables. Hence, the control path for that experiment starts with year one, and it is not necessary to reproduce a base year's data set.

Firstly, the basic framework has to include heterogeneity in initial levels of income. It is assumed that the initial level of income is distributed across the adult population according to the distribution function $F_t(z)$. Heterogeneity in levels of income changes the aggregate level of savings, the total number of efficiency units of labour and the consequent level of wage per efficiency unit of labour. The maximization problem considered in the previous section and heterogeneity in income levels imply that the aggregate level of savings at $t$ is equal to

$$s_t = \int \frac{z_t(1-t_z)\beta}{1+\beta+\gamma} dF_t(z), \tag{29}$$

which is the total amount of physical capital in the next period. Additionally, the amount of efficiency units of labour at $t+1$, $eul_{t+1}$, depends on the evolution of both fertility and human capital,

$$
\begin{aligned}
eul_{t+1} = & \int_{z \le z^*} \frac{(1+\beta)\gamma}{(1+\beta+\gamma)^2 \phi} \left( \frac{\eta}{\eta+\psi} \right)^{\eta} \left( \frac{\chi\psi+\eta T}{\eta+\psi} \right)^{\psi} dF_t(z) + \\
& + \int_{z^* < z < z^*} \frac{z_t \gamma \left[ z_t (1-t_z) \phi (1+\beta+\gamma(\eta+\psi)) - (1+\beta+\gamma)\chi \right]}{(1+\beta+\gamma)^2 (1-\eta-\psi)} \left( \frac{\eta}{\chi - T} \right)^{\eta} \left( \frac{\psi (z_t (1-t_z)\phi - \chi)}{1-\eta-\psi} \right)^{\psi+\eta-2} dF_t(z) + \\
& + \int_{z \ge z^*} \frac{z_t (1-t_z) \gamma (1-\psi) \left[ \phi z_t (1-t_z)(1+\beta+\gamma\psi) - T(1+\gamma+\gamma) \right]}{(1+\beta+\gamma)^2 \left[ z\phi(1-t_z) - T \right]^2} \left( \frac{\psi (z_t (1-t_z)\phi - T)}{1-\psi} \right)^{\psi} dF_t(z).
\end{aligned}
\tag{30}
$$

From equations (29) and (30) it is possible to determine the level of the wage per efficiency unit of labour at $t+1$, $w_{t+1}$. Each adult in the model economy, thus, makes decisions according to the maximizing behaviour described in the previous section. Those decisions have an effect on the aggregate level of savings, and choices regarding human capital investments determine the particular level of human capital of children of each agent. Fertility and human capital levels subsequently determine the number of efficiency units of labour and the wage in the following period. The value of those variables finally allows for quantifying the level of income of adults of the new generation. However, analysing the behaviour of the dynamical system for every possible distribution of income at the initial period is difficult because it involves keeping track of all fertility and human capital levels simultaneously. However, a non-steady-state simulation is considered here and the initial distribution function of income fits the real distribution provided by the dataset while all endogenous variables vary according to the model.

*Static calibration*

Firstly, it is assumed that one period in the model corresponds to 23 years in order to match life expectancy estimates for Brazil in the three periods OLG economy. The distribution of income across families in our database appears to be close to a lognormal distribution, being the skewness of the variable *log*(*income*) equal to 0.1160 and the kurtosis close to 3 (3.3780). In addition, skewness and kurtosis tests for normality confirm this conclusion. Consequently, it is assumed that the initial level of income in our experiment is distributed according to a lognormal distribution, and this distribution function has been fitted to sample observations by maximum likelihood.[8] 10000 observations have been randomly obtained from the fitted distribution and the computation of inequality indexes confirms that data representing income levels reproduce the scenario of the original dataset (for instance, the Gini index for both sample observations and random observations from the lognormal distribution is equal to 0.56).

The parameter $\tau$ is the human capital share in the consumption good sector, which is set to the usual value of 2/3. This value is consistent with international evidence and, although it might be high when not considering a balanced growth path, it does not affect the conclusions in terms of human capital accumulation. The discount factor $\beta$ takes the value 0.99^92, 0.99 per quarter, which is a standard value in the real-business-cycle literature. In order to set the weight $\gamma$ of children in the utility function, we firstly consider the time cost of bearing a child. As in de la Croix and Doepke (2003), we take into account the implications of Haveman and Wolfe (1995) and Knowles (1999), which

[8] The command lognfit in STATA has been used for this purpose.

requires setting $\phi = 0.07$ in our model. In the dataset being considered, the total number of children per family varies between an average of 3.1176 for households in the first quintile of the distribution of income and 1.9444 for households in the last quintile. It is assumed that those levels represent the maximum and minimum number of children per family, although in the model each individual could be a parent, regardless of gender. Given those values and considering the equation that represents maximum fertility in the model, we can set the value of $\gamma$,

$$\frac{\gamma}{(1+\beta+\gamma)\phi} = 3.1176/2 \Rightarrow \gamma = 0.144109. \tag{31}$$

The value of $\psi$ can be obtained by considering the minimum level of the fertility rate, see (12),

$$\frac{\gamma(1-\psi)}{(\alpha+\beta+\gamma)\phi} = 1.9444/2 \Rightarrow \psi = 0.37631. \tag{32}$$

In order to set the value of the return to schooling, it should be observed that the average age of incorporation in the labour market of adults with the lowest income in the dataset being considered (first quintile of the distribution function of income per capita) is approximately equal to 12.2216. In addition, this age is consistent with the existence of compulsory schooling for children aged up to 14 years at the time of the survey. Thus, from (9) it is obtained the value of $\eta$,

$$\frac{\eta}{\eta+\psi}=0.53137 \Rightarrow \eta=0.426701. \tag{33}$$

The parameter $\chi$ represents the opportunity cost of schooling and its value affects fundamental dynamics of the model. In particular, it should be noted that threshold levels of income depend on it. In other words, the value of $\chi$ influences the optimal choices of adults about fertility, education and child consumption. It is difficult to provide a consistent calibration for this parameter and thus, the value of $\chi$ has been chosen in order to ensure that the average level of TFR (Total Fertility Rate) matches empirical evidence. We thus set the parameter equal to 0.066, being the implied average fertility rate 2.45. Finally, the scale parameter $A$, which characterizes the production function, is set to 7 in order to replicate the average annual growth rate of income per capita in Brazil during the last decade, about 1.5%. It should be noted that this value is arbitrarily and results in terms of income growth have to be interpreted with caution. In fact, our main concern is to analyse the relative effects of school feeding programmes respect to a situation of Government inactivity.

The values of parameters chosen for the simulation and summarized in Table 4.1 replicate the basic features of the Brazilian economy in the period being considered. The effects of parameter variations are considered in Appendix C.

**Table 4.1**. Baseline levels of parameters.

| | | | |
|---|---|---|---|
| $\chi$ | 0.066 | $\psi$ | 0.37631 |
| $\beta$ | .99^92 | $\phi$ | 0.07 |
| $\gamma$ | 0.144109 | $\tau$ | 2/3 |
| $\eta$ | 0.426701 | **A** | 7 |

The specific set of baseline values of parameters implies that the economy converges to a unique steady state, independently from the initial level of income. As observed above, however, this circumstance does not impede the existence of club convergence in the medium run. The model, in fact, generates twin-peaknedness despite the initial unimodality of the distribution function of income. It is interesting to observe that the model predicts that all children will dedicate the whole of their childhood to education starting from the fourth period, that is, after three generations or 69 years, and the distribution of income converges tends then to a unimodal distribution.

*Simulation*

It is now assumed that the parameters are set at their baseline level, and we compute the effects on child nutrition, length of schooling, level of human capital, income levels and growth rate of income per capita, resulting from the introduction of the policy discussed above. As pointed out in the previous section, transfers have an effect on both individual decisions and on the shares of population that adopt different behaviours. In other words, the threshold levels of income, which split the population in three groups with different behaviours, are a function of transfers. Hence, the number of beneficiaries of school feeding indirectly depends on the level of the tax rate. As a consequence, an approximation technique has been used in order to set the values of $T$ and $t_z$. The main assumption is that the Government agency transfers to students the entire amount of resources obtained by labour income taxation. The procedure that has been followed consists of three steps. Given arbitrarily values of $t_z$ and $T$, the response of adults is predicted by the model. Model predictions and the value of $t_z$, subsequently, permit to compute the real amount of resources that the Government obtains and the level of transfers that is able to offer, $T^R$. When $T \neq T^R$, the procedure is repeated by setting a new value of $T$ between the old value and $T^R$. When $T^R = T$, $t_z$ and $T$ ensure the equilibrium in the Government budget constraint.

Firstly, model predictions with different levels of transfers to students are computed in order to analyse the effects of school feeding on the interest variables. Secondly, we present a simulation in which the intergenerational effects of this policy are compared to the temporal evolution of the system in absence of transfers. In order to provide some conclusion on inequality, mean values of human capital and income variables for the whole population as well as for the poorer ten percent are presented. Main results of this computational exercise are reported in Table 4.2. Average levels of child consumption decrease with $t_z$, a result that naturally follows from the reduction of resources suffered by middle and high-income households. In other words, while the net effect in terms of nutrition for children of deprived families is null, as pointed out above, transfers through school feeding does not balance the reduction in the total amount of resources that more privileged families dedicate to nourishing. Though this result is not socially alarming, provided that children of rich families are endowed with satisfactory nutritional levels, a question of political feasibility might arise. In fact, when the rich are mostly in "control" of things, they have an incentive to provide food to their children by themselves and oppose to school feeding programmes. Although this question is not considered here, it should be considered as a potential limitation of this policy.

positive effects of this policy are concerned with improved education, a result consistent with the empirical analysis of Simeon (1998). In particular, the average length of schooling for the whole population and for the poorer ten percent of the population is increasing with the tax rate $t_z$ and the amount of transfers per student. Improved education has a positive influence on the level of human capital and, through this channel, on income per capita and the annualised growth rate of income per capita. This is an interesting result, which underlines that a policy aimed at favouring the poor and reducing inequality has a positive effect on economic growth. Explicitly, the model predicts a positive relationship between the reduction of inequality through school feeding and the growth rate of income per capita.

**Table 4.2.** Effects of school feeding: computational experiment.

| $t_z$ | $T$ | $\overline{N}_t$ | $\overline{N}_t^{10}$ | $\overline{N}_t^{10} / \overline{N}_t$ |
|---|---|---|---|---|
| 0 | 0 | 0.043504 | 0.030929 | 0.710956 |
| 0.005 | 0.036845 | 0.043252 | 0.030929 | 0.715088 |
| 0.01 | 0.00773 | 0.042991 | 0.030929 | 0.719433 |
| 0.015 | 0.011545 | 0.427198 | 0.030929 | 0.0724 |
| 0.02 | 0.015323 | 0.424367 | 0.030929 | 0.072883 |
| 0.025 | 0.019058 | 0.042141 | 0.030929 | 0.733947 |
| $t_z$ | $\overline{e}_{t+1}$ | $\overline{e}_{t+1}^{10}$ | $\overline{e}_{t+1}^{10} / \overline{e}_{t+1}$ | $\overline{h}_{t+1}$ |
| 0 | 0.598354 | 0.531376 | 0.888064 | 0.238476 |
| 0.005 | 0.628424 | 0.564572 | 0.898394 | 0.243017 |
| 0.01 | 0.661831 | 0.601869 | 0.9094 | 0.247888 |
| 0.015 | 0.699176 | 0.644037 | 0.921137 | 0.253137 |
| 0.02 | 0.741178 | 0.692042 | 0.933706 | 0.258812 |
| 0.025 | 0.788776 | 0.747113 | 0.94718 | 0.264976 |
| $t_z$ | $\overline{z}_{t+1}$ | $\overline{z}_{t+1}^{10}$ | $\overline{z}_{t+1}^{10} / \overline{z}_{t+1}$ | $g$ |
| 0 | 1.345977 | 1.165016 | 0.865554 | 1.49 |
| 0.005 | 1.360918 | 1.186217 | 0.87163 | 1.54 |
| 0.01 | 1.376948 | 1.209163 | 0.878147 | 1.59 |
| 0.015 | 1.394217 | 1.234089 | 0.885148 | 1.64 |
| 0.02 | 1.412876 | 1.261291 | 0.892712 | 1.7 |
| 0.025 | 1.433132 | 1.291114 | 0.900904 | 1.76 |

Positive effects of school feeding on the nutritional status of deprived children emerge when considering the intergenerational consequences of this policy. When a particular policy enhances the level of human capital of the poor, in fact, it should be expected that children of the following generations would benefit from the more favourable condition of their parents. Model predictions have been computed for a period of three generations (69 years) for assessing this question, and Table 4.3 presents the results of this experiment. In particular, the basic framework in absence of school feeding and the consequences of the introduction of a Government agency, which imposes a labour income tax with $t_z = 0.005$ in order to provide meals at school, have been considered. Effects after one period have been already discussed, and the lack of a positive influence of school feeding on the nutritional status of the poor has been underlined. We will concentrate thus on the effects of the policy after three generations compared to the evolution of the system in absence of transfers. The model predicts that, when the Government agency does not offer meals at school, the total amount of resources dedicated to nutrition of children of the poorer ten percent of population increases about 28.1% after three generations, in contrast to an average increase of about 6.6%. The same figure for the poorer fraction of population increases to about 38.8% when school feeding is introduced in the economy. In other words, improved education caused by this policy results in enhanced nutritional status in the following periods and thus, both components of human capital contribute to the development of the poor. Though offering free meals at school does not endow deprived children with more resources for their nutrition, it succeeds in enhancing nutrition and health in the following periods. In addition, the annualised growth rate of income per capita is always higher when the Government agency operates in the economy and therefore, school feeding results in faster economic growth.

**Table 4.3**. Effects of school feeding: Temporal evolution of human capital and income.

| $t_z$ | period | $\overline{N}_t$ | $\overline{N}_t^{10}$ | $\overline{N}_t^{10} / \overline{N}_t$ |
|---|---|---|---|---|
| 0 | 1 | 0.043504 | 0.030929 | 0.710956 |
| 0 | 2 | 0.037911 | 0.030929 | 0.815844 |
| 0 | 3 | 0.046491 | 0.041049 | 0.882937 |
| 0.005 | 1 | 0.043252 | 0.030929 | 0.715088 |
| 0.005 | 2 | 0.038571 | 0.031749 | 0.823137 |
| 0.005 | 3 | 0.051099 | 0.045826 | 0.896808 |
| period | $\overline{e}_{t+1}$ | $\overline{e}_{t+1}^{10}$ | $\overline{e}_{t+1}^{10} / \overline{e}_{t+1}$ | $\overline{h}_{t+1}$ |
| 1 | 0.598354 | 0.531376 | 0.888064 | 0.238476 |
| 2 | 0.580349 | 0.531376 | 0.915616 | 0.228089 |
| 3 | 0.730956 | 0.705237 | 0.964815 | 0.273549 |
| 1 | 0.628424 | 0.564572 | 0.898394 | 0.243017 |
| 2 | 0.626274 | 0.579543 | 0.925383 | 0.237427 |
| 3 | 0.853146 | 0.836493 | 0.980481 | 0.303203 |
| period | $z_{t+1}$ | $\overline{z}_{t+1}^{10}$ | $\overline{z}_{t+1}^{10} / \overline{z}_{t+1}$ | $g$ |
| 1 | 1.345977 | 1.165016 | 0.865554 | 1.49 |
| 2 | 1.38107 | 1.24983 | 0.904972 | 0.11 |
| 3 | 1.486502 | 1.40795 | 0.947156 | 0.32 |
| 1 | 1.360918 | 1.186217 | 0.87163 | 1.54 |
| 2 | 1.418079 | 1.292013 | 0.911101 | 0.18 |
| 3 | 1.617088 | 1.549091 | 0.957951 | 0.5 |

When the main objective is the enhancement of the condition of the poor, school feeding is an appropriate policy, provided that it boosts human capital and reduces inequality. However, when the main concern is child nutritional status, the short-run consequences of this policy should be considered. For example, when children suffer from acute malnutrition and improving their health status is the prime aim, the absence of immediate effects of school feeding on nutritional status predicted by the model implies the inefficiency of this policy. Caution should be exercised in drawing policy conclusions from the results presented above. Firstly, it has been observed that school feeding tend to enhance education while the level of child nutrition remains unchanged, a fact that is explained by the optimal response of agents to this particular policy. An important point is that schooling may have an effect on health status, though not directly on the level of resources dedicated to nutrition. In particular, education may help individuals to use their resources more efficiently by encouraging healthy behaviours, for example. Hence, the same amount of resources might be transformed into energy and cognitive output more efficiently if agents were properly educated to do so. The relevance of this argument however, is directly related to the level of child nutrition, since chronic malnutrition is not likely to disappear thanks to a highly efficient use of lacking resources. In addition, it could be argued that nutritional choices of children depend more on the decisions of their parents than on their own preferences and education. Another question, which is closely related, is that resources for nutrition are accounted as the total amount of a unique homogeneous consumption commodity. Some empirical research show that there may be a difference between food provided at home and at school because controls for nutritional quality are usually more effective in the second situation. Even when children withdrawn calories from their normal meals due to the reduction of child labour, the higher quality of food at school may generate a positive effect on the nutritional status of children. Nevertheless, what this model highlights is the existence of an incentive to dedicating the same amount of resources to nutrition when school feeding is introduced in the economy. Though this mechanism of resource might not work exactly as in the model economy considered here, policies aimed at enhancing health status should take this possibility into account.

Another positive effect of improved schooling, which has been underlined in this chapter, is the reduction of child labour. The social benefit arising from offering children the freedom to be educated and to enjoy their childhood may be more important than the overall effect on the accumulation of human capital. School feeding programmes should be then considered the best policy option when child labour is socially undesirable.

## Conclusions

Empirical evidence suggests that some countries are stuck in an unfortunate condition of poor health status and deprivation (e.g. Mayer-Foulkes, 2003). This paper analyses one particular mechanism that may explain this phenomenon, the complementarity of child health and child learning capacity. The educational process depends on the capacity of children to learn and understand, which is in turn affected by the level of child nutrition and overall physical condition. When it is assumed that child nutrition depends on family income through, for instance, resources dedicated to child consumption, the inherited child nutritional status is a key factor in determining the intergenerational transmission of human capital and income. Firstly, a poor economic condition of the family of origin results in greater need of income from child labour. Thus, children of low SES parents are less likely to be educated because of lower family income that cannot allow for long-term schooling-based human capital accumulation. In addition, reduced child consumption and nutritional status influence the cognitive capacities of children and the return to education. Poor health status, thus, has an independent effect on educational achievement. In fact, when the length of schooling is held constant, children suffering from ill health accumulate a lower amount of human capital due to their lower learning capacity.

On considering these factors, the model predicts the possible emergence of multiple equilibria in the evolution of health human capital and income per capita. The scant accumulation of human capital of children of deprived families results in lower future income and, consequently, children of the following generations are likely to face the same constraints with respect to the accumulation of human capital. In particular, under certain values of parameters, the model suggests that there is a threshold level of parents' income that determines investments in child human capital and the convergence to different equilibria. Dynasties that are generated by individuals with a sufficiently low endowment of human capital, find themselves trapped in vicious circle of low human capital, poor health status and high fertility rates. In absence of multiple equilibria for a particular set of parameters, the effects considered in this paper determine a lower accumulation of human capital, though this does not formally cause the emergence of a poverty trap. In other words, the multiplier effect of health status is independent from the existence of multiple equilibria.

The basic framework has been extended in order to analyse the consequences of a policy aimed at offering better conditions to the poor, namely school feeding. Poor health status and inadequate accumulation of human capital are an important source of inequality in every society. Policies aimed at reducing this problem by enhancing health and education, therefore, are likely to exert important effects. The analysis of school feeding in particular is interesting because this policy propose a mechanism for improving schooling while enhancing child nutrition. Results suggest that school feeding has a positive influence on the length of schooling and, thus, on the level of human capital of the poor. A source of concern however, is its outcome respect to child nutrition. The model predicts that school feeding induce children of low income families to attend school for longer periods while they maintain their nutritional status and cognitive ability at the initial level. This conclusion is consistent with the empirical literature, which show that children participating in school feeding programmes do not experiment weight gains (e.g. Simeon, 1998).

On considering the intergenerational effects of school feeding, however, this policy has a positive impact on child nutrition and human capital levels during the subsequent periods. Improved education, in fact, permits to offer better conditions and more educated (and rich) parents to newborns of the following generations. When the policy objective is the enhancement of the condition of the poor, school feeding can be regarded as a successful way to that end. In fact, it is shown that it results in improved health human capital, higher income levels as well as an increased growth rate respect to a situation in which no policy is adopted. However, the limitations of school feeding, particularly respect to its short-run effects on nutritional status, should be considered when the main aim is the improvement of health and nutritional status of deprived children.

# V. The role of health improvements in the Transition out of deprivation

The aim of this chapter is to analyse the relationship between improvements in health and a permanent change in an economy's growth path. It has been shown that poor health may cause poverty traps to emerge while improving the health status of individuals may constitute a successful way to escape from deprivation. The history of now developed countries is marked by long periods of poor health and quasi-absent growth, to which has recently followed a quite radical passage to what has been labelled "Modern Growth regime" (e.g. Galor and Weil, 2000). The analysis of health improvements for the evolution of economies provides an interesting benchmark for assessing possible development policies aimed at enhancing social and economic conditions of non-developed countries. In models of Transition, the central role is normally given to education while improved health is usually seen as a by-product of economic growth (e.g. Lucas, 2002; Galor and Weil, 1999, 2000). Improved health status, however, has been considered a key factor for the Transition in both the theories of the Epidemiological Transition (Omran, 1971; Arora, 2005) and that of the Techno-Physio Evolution (Fogel, 2004). Fogel (2004), for instance, concluded that the raise in the amount of available energy and improved physical status accounts for about 50 percent of British economic growth since 1790. Arora (2001), investigating the growth path of 10 industrialized countries over 100 to 120 years, provides further historical evidence of the importance of health for economic growth. According to this analysis, health increased the pace of growth of the considered countries by 30 to 40 percent, altering permanently the slope of the growth path. Many other papers underline the importance of health status for growth, e.g., Weil (2005), Doppelhofer et al. (2004), Bloom et al. (2004), Mayer-Foulkes (2001), and Schultz (1999), among others.

The theory developed in this chapter suggests that in order for an economy to make the leap out of stagnation into the Modern Growth regime, its population must first attain a given minimum level of health status. In particular, health improvements are a necessary condition for undertaking schooling-based human capital investments, which are the main force that drives growth in the modern regime. This approach is complementary with Chakraborty and Das (2005), among others, who point out that health improvements reduce infant mortality and increase longevity, increasing the return to human capital investments. In this chapter, however, it is assumed that individual live for a constant amount of time and improved health status generates higher returns to education through its effects on learning capacity, as stressed in the previous chapters.

If improved health may lead to higher educational levels, this may prove to be a two-way relationship (e.g. Grossman, 1972; Leig, 1983; Kendel, 1991; Arendt, 2005). Accordingly, in the model proposed here the level of human capital of the population affects the occurrence of health-related "innovations" and, through this channel, individual health status. Double causation between health and education, however, only emerges when individuals undertake positive schooling investments in order to improve their level of intellectual human capital. The correlation between the level of human capital and the introduction of novelties that influence health status may be viewed as a reflection of the importance of organization in societies for producing better health outcomes. When the level of human capital is related to the evolution of institutions, for example, the framework considered here is not at odds with the institutional approach. Another question is that some researcher have argued that much of the improvements in health can be attributed to the provision of public services such as immunization campaigns or targeted programs (e.g. Soares, 2007). Though this is an interesting approach, the aim of this chapter is to stress the importance of nutrition, or the constraints imposed by under-nutrition.

The model presented here is related to that of Galor and Weil (2000) but differs on several dimensions. Firstly, it is assumed that parents care about total human capital with which they endow their children, while they appropriate their total child labour income. In contrast, Galor and Weil (2000) consider the case where parents care for their children's income when adults. The form of intergenerational altruism considered here, however, is similar to that used in the previous chapter. Secondly, in Galor and Weil (2000) technological progress indirectly increases the return to education and, through this channel, increases the demand for human capital. In the model developed throughout this chapter, technological progress, which depends exclusively on the level of human capital and not on population size, takes the form of improvements in health and education's productivity. It is this factor that stimulates human capital investments in both nutrition and education.

The framework considered here can be considered an extension of the previous chapter. Nevertheless, there are a number of differences that should be highlighted. Firstly, it is assumed that three periods constitute childhood, namely schooling, child labour, and infancy, which is the novelty introduced here. During infancy individuals neither work nor dedicate time to education, but spending time with parents has a positive effect on their level of human capital. In other words, individuals accumulate a positive level of intellectual human capital regardless of schooling-based human capital investments. This assumption allows for isolating an interval, or a regime of growth, during which education is absent but the level of human capital can increase thanks to nutrition and health improvements. Secondly, the analysis has been simplified and assumes that individuals live for two periods, childhood and adulthood. In addition, it is assumed here that parents appropriate child labour income. Provided that parents must ensure a minimum level of child nutrition for the survival of their offspring, which is greater than the remuneration of child labour, this frameworks is equivalent to the previous chapter but for a relevant feature. In this chapter it is assumed that the cost of child rearing includes both the cost of time dedicated to children and a positive amount of resources for their nutrition. This assumption generates a characteristic feature of stagnant economies, i.e. the positive correlation between income and fertility for low levels of income.

The rest of the chapter is organized as follows. The subsequent section presents the model economy and the results of the maximization problem. The structure of the model economy and results in terms of individual decisions are presented in sections 1 and 2 section 3 treats about the evolution of human capital and income across the different regimes of growth. Section 4 introduces the process of innovation in behaviours related to health status and provides the means for assessing the evolution of income during the Malthusian Transition. Finally, the last section summarizes the main conclusions.

### 1. The structure of the model

The economy is characterized by two overlapping generations of adults and children. At each period $t$ a new generation is born, each individual having only one parent. In the early stages of their lives, children spend the available unit of time (minus a fraction $\phi$ that represents infancy) accumulating human capital and/or working, in accordance with the decision of the parent. The technology of production of human capital is assumed to be

$$h_{t+1} = \left[A_t(e_{t+1} + \phi)\right]^{\mu} \tag{1}$$

where human capital $h_{t+1}$ is measured in efficiency units of labour, $0 \leq e_{t+1} \leq 1 - \varphi$ represents time dedicated to schooling, $0 < \phi < 1$ and $0 < \mu < 1$. It is supposed that the productivity $A_t$ is related to the ability to learn and to the total amount of resources dedicated to child nutrition $cn_t$,

$$A_t = \left(B_t cn_t\right)^{\tau}, \tag{2}$$

where $0 < \tau < 1$ and $B$ is a productivity parameter that is assumed to influence the way in which consumption inputs are converted into nutritional and energy output.[9] In addition, child consumption cannot fall below the subsistence level $sl > 0$, in order to

[9] For the sake of simplicity, it is assumed that $B$ grows without bound. It should be noted however, that this is only to simplify notation, provided that the growth of $B$ is unlikely to be a long term source of economic growth.

ensure surviving of children to adulthood. In other words, $sl$ represents the minimum level of nutrition, which is necessary to survive, and the minimum investment in terms of consumption commodity that parents must undertake in order to bring up a child. Hence, substituting (2) in (1), the human capital formation function takes the functional form

$$h_{t+1} = \left[(B_t cn_t)^{\tau}(e_{t+1} + \phi)\right]^{\mu}, \tag{3}$$

where it is assumed that $\mu(1+\tau) \leq 1$.

During the fraction of childhood that is not dedicated to schooling, children contribute to family income by participating in the labour market. It is assumed that children are paid a fixed amount of consumption commodity per unit of time worked, $\chi$, as in the previous chapter. In addition, it is assumed that the maximum child remuneration is lower than the subsistence level of consumption commodity that young individuals need in order to survive, and children are thus a consumption commodity. Hence,

$$\chi(1-\phi) < sl, \tag{4}$$

where $(1-\phi)$ represents the maximum fraction of childhood dedicated to labour.

In the second period of life, adults optimally choose the number of children $n_{t+1}$, the time they will dedicate to schooling $e_{t+1}$, the level of child nutrition $cn_t$ and their present consumption $c_t$. Parents face a time-cost of rearing a child $\phi$ (related to infancy), in addition to expenses in child nutrition in terms of the consumption commodity. The cost of bringing up a child, regardless of education, is thus a positive function of the level of human capital of the parent. The cost of education does not depend on adult human capital, in that the only cost related to schooling is the opportunity cost of bringing up a student rather than a worker. The choice of an adult $i$, endowed with a level of human capital $h_t$, is thus subject to the budget constraint

$$h_t w_t (1 - n_{t+1}\phi) + \chi \cdot n_{t+1}(1-\phi) \geq c_t + cn_t n_{t+1} + n_{t+1} e_{t+1} \chi \,, \tag{5}$$

where $w$ is the wage per efficiency unit of labour at $t$.

Preferences of adults born at $t-1$ are represented by the utility function

$$U_t = \alpha \cdot [\log(c_t)] + \beta \cdot [\log(n_{t+1})] + \gamma \cdot [\log(h_{t+1})] \tag{6}$$

where it is assumed that $\beta > \gamma$. It should be noted that parents care about total human capital of children, while they appropriate their children's total remuneration.

**2. Individual decisions**

Adults choose $c_t$, $n_{t+1}$, $cn_t$ and $e_{t+1}$ to maximize (5) subject to (1), (4) and (6),

$$\underset{\{c,n,cn,e\}}{Max}\left\{\alpha\cdot[\log(c_t)]+\beta\cdot[\log(n_{t+1})]+\gamma\cdot\left[\log\left(\left[(B_t cc_t)^{\tau}(e_{t+1}+\phi)\right]^{\mu}\right)\right]\right\} \tag{7}$$
$$sub.to: h_t w_t(1-n_{t+1}\phi)+\chi\cdot n_{t+1}(1-\phi-e_{t+1})\geq c_t+cc_t n$$

Results implied by the first order conditions underline the existence of three threshold levels of adult human capital, which define four different situations respect to fertility choices and human capital investments,

$$\check{z}\equiv\frac{sl\beta-\gamma\mu[sl-\chi(1-\phi)]\tau}{\gamma\mu\tau\phi}, \tag{8a}$$

$$\hat{z}\equiv\frac{\{\beta\phi+\gamma\mu[1-\phi(1+\tau)]\}\chi}{\gamma\mu\phi}, \tag{8b}$$

$$\tilde{z}\equiv\frac{(\beta-\gamma\mu\tau)\chi}{\gamma\mu\phi}. \tag{8c}$$

Given the threshold levels of income, and letting $z_t\equiv wh_t$, the maximization problem is solved for

$$n_{t+1}=\begin{cases}\dfrac{z_t\beta}{(\alpha+\beta)[z_t\phi+sl-\chi(1-\phi)]}, & z_t\leq\check{z}\\ \dfrac{z_t(\beta-\gamma\mu\tau)}{(\alpha+\beta)[z_t\phi-\chi(1-\phi)]}, & \check{z}<z_t\leq\hat{z}\\ \dfrac{z_t[\beta-\gamma\mu(1+\tau)]}{(\alpha+\beta)[z_t\phi-\chi]}, & \hat{z}<z_t<\tilde{z}\\ \dfrac{\beta-\gamma\mu\tau}{(\alpha+\beta)\phi} & z_t\geq\tilde{z}\end{cases}, \tag{9}$$

$$e_{t+1} = \begin{cases} 0, \quad z_t \leq \bar{z} \\ \dfrac{\gamma\mu\left[z_t\phi - \chi(1-\phi(1+\tau))\right] - \beta\phi\chi}{\chi\left[\beta - \gamma\mu(1+\tau)\right]}, \quad \bar{z} < z_t < \bar{\bar{z}} \\ 1-\phi \quad h_t \geq \bar{\bar{z}} \end{cases} \tag{10}$$

$$cn_{t+1} = \begin{cases} sl, \quad z_t \leq \underline{z} \\ \dfrac{\left[z_t\phi - \chi(1-\phi)\right]\gamma\mu\tau}{\beta - \gamma\mu\tau}, \quad \underline{z} < z_t \leq \bar{z} \\ \dfrac{(z_t\phi - \chi)\gamma\mu\tau}{\beta - \gamma\mu(1+\tau)}, \quad \bar{z} < z_t < \bar{\bar{z}} \\ \dfrac{z_t\phi\gamma\mu\tau}{\beta - \gamma\mu\tau} \quad z_t \geq \bar{\bar{z}} \end{cases} . \tag{11}$$

Figure 5.1 provides a graphical representation of these results. For low levels of income, $z_t \leq \underline{z}$, children dedicate the whole available time to labour (the length of schooling is equal to zero), and the level of child nutrition is the subsistence level *sl*. The number of children per adult is initially increasing with income and reaches its maximum for $z_t \to \underline{z}$. This is an interesting prediction of the model, which shows that when the relative price of child quantity relative to the price of child quality is lower than the marginal rate of substitution (*MRS*), parents respond to a raise in income by rearing more children in order to increase their utility.

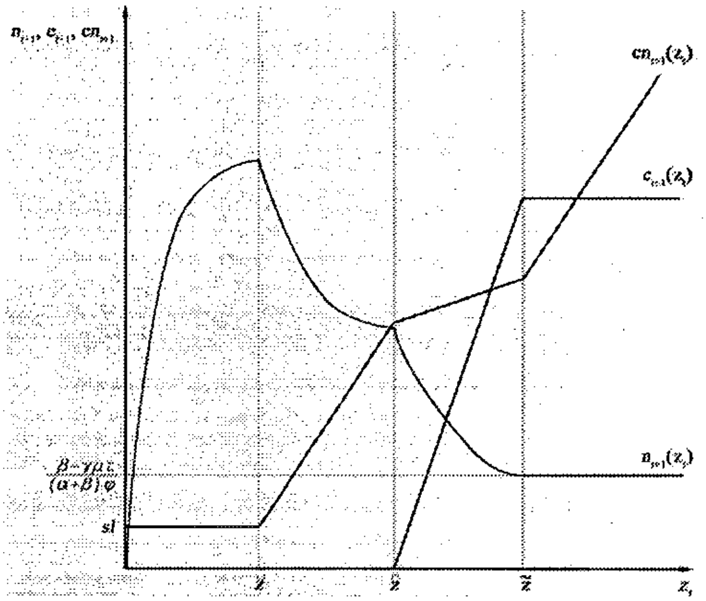


**Figure 5.1**. Income per capita, fertility, education and child consumption.

When $z_t > \breve{z}$ however, the amount of resources dedicated to nourishing begins to increase and fertility decreases. In fact, the cost of rearing a child, as discussed above, is a positive function of the level of human capital and income, while the cost of increasing child nutrition is constant. In other words, at the threshold level $\breve{z}$ the *MRS* between quantity and quality of children (in terms of nutrition only) is equal to the price ratio, and it is indifferent for parents to increase their utility by rearing more children or by better nourishing a lower number. The length of schooling becomes positive and increasing in the level of income when $z_t > \hat{z}$. It should be noted that the child nutrition function is less steep than in the previous situation, provided that education implies a loss in terms of consumption commodity for parents. Fertility continues to decrease up to the minimum level $\dfrac{\beta - \gamma\mu\tau}{(\alpha + \beta)\phi}$, which is achieved for $z_t > \tilde{z}$. The existence of this interval follows from the upper bound of the length of schooling, $e^{MAX} = 1-\phi$, and the fact that education does not further increase determines that income is devoted to child nutrition as when $z_t \in (\underline{z}, \hat{z})$.

### 3. Evolution of human capital and income

Given the results of the maximization problem, the policy function

$$z_{t+1} = \begin{cases} w\left[(B_t sl)^{\tau}\phi\right]^{\mu}, & z_t \le \underline{z} \\ w\left\{\left[\dfrac{B_t\gamma\mu\tau\left[z_t\phi-(1-\phi)\chi\right]}{\beta-\gamma\mu\tau}\right]^{\tau}\phi\right\}^{\mu}, & \underline{z} < z_t \le \hat{z} \\ w\left\{\left[\dfrac{B_t\gamma\mu\tau(z_t\phi-\chi)}{\beta-\gamma\mu(1+\tau)}\right]^{\tau}\dfrac{\gamma\mu(z_t\phi-\chi)}{\chi\left[\beta-\gamma\mu(1+\tau)\right]}\right\}^{\mu}, & \hat{z} < z_t < \tilde{z} \\ w\left(\dfrac{B_t z_t\gamma\mu\tau\phi}{\beta-\gamma\mu\tau}\right)^{\tau\mu} & z_t \ge \tilde{z} \end{cases} \tag{12}$$

represents the level of income of children as a function of the level of income of parents. In order to simplify the exposition, we will refer to the intervals defined by the thresholds levels of income as three different regimes, namely Malthusian regime $(z_t \in (0, \underline{z}])$, post-Malthusian regime $(z_t \in (\underline{z}, \hat{z}])$, and Modern Growth regime $(z_t \in (\hat{z}, \infty])$. Given its functional form, (12) could provide multiple steady states depending on the value of parameters. Firstly, it is considered the interval $(0, \underline{z}]$. Since the policy function does not depend on the initial level of income in this situation,

$z_t = \left[(B_t sl)^{\tau}\varphi\right]^{\mu} \Rightarrow z_{t+1} = z_t = z^1$. The level of income $z^1$ is a steady state of the policy function if

$$z^1 = \left[(B_t sl)^{\tau}\phi\right]^{\mu} < \frac{sl\beta - \gamma\mu[sl - \chi(1-\phi)]\tau}{\gamma\mu\tau\phi} \equiv z. \tag{13}$$

If $z^1$ is a steady state of (12), it is defined as "equilibrium of subsistence", because that level of income ensures that nourishing is stuck at the subsistence level. After some manipulation, (13) can be rewritten as,

$$\frac{\beta}{\gamma\mu\tau/sl} > \left[(B_t sl)^{\tau}\phi\right]^{\mu}\phi + sl - \chi(1-\phi), \tag{A1}$$

which underlines that $z^*$ is a stable steady state of the policy function if the ratio between the marginal utility of rearing an extra child and the marginal utility of child nutrition (*MRS*, left-side term) is greater than their relative price (right-side term) in equilibrium.

Since (12) is concave in the intervals $(z, \bar{z}]$, $(\bar{z}, \tilde{z}]$ and $(\tilde{z}, \infty]$, the policy function might provide up to seven equilibria, four of which would be stable. Nevertheless, I will concentrate only on the interval $(z, \bar{z}]$, which is interesting to our end, while the same considerations will apply to the remaining situations. Firstly, consider the *MRS* between child nutrition and education,

$$MRS_{cn,e} = \frac{\gamma\mu\tau / cn_{t+1}}{\gamma\mu / \phi}. \tag{14}$$

For $z_t \to \bar{z}$,

$$MRS_{cn,e} \to \frac{1}{\chi}, \tag{15}$$

which is the price ratio of the two substitutes. In other words, the maximization problem implies that at $z_t = \bar{z}$ it is indifferent for parents to increase their level of utility through child nutrition or child education. For $z_t < \bar{z}$ however, it can be observed that nourishing is preferred,

$$\frac{\phi(\beta - \gamma\mu\tau)}{\gamma\mu[z_t\phi - \chi(1-\phi)]} < \frac{1}{\chi}. \tag{A2}$$

Condition (A2) defines the policy function in the interval $(z, \bar{z}]$.

**Assumption A3**

There is at least one $z^i \middle| z^i = \left\{ \left[ \frac{B_t \gamma\mu\tau [z^i\phi - (1-\phi)\chi]}{\beta - \gamma\mu\tau} \right]^{\tau} \phi \right\}$, where i = 2, 3 and $z^2 \leq z^3$.

**Proposition.**

Under A2-A3,

i) Under A1, either $z^2 < z^3$ and $z^2$, $z^3$ are steady states of the policy function (12), the first of which is unstable and the second stable, or $z^2 = z^3$ and $z^2$ is the unique (unstable) steady state of (12) in $(\underline{z}, \bar{z}]$.

ii) When A1 does not hold, then $z^2 = z^3$ and $z^2$ is the unique (stable) steady state of (12) in $(\underline{z}, \bar{z}]$.

*Proof.* See appendix D.

Different scenarios described in the previous proposition and the existence of other equilibria provided by (12) crucially depend on the value of parameters, which affects both the marginal utility and the cost of each policy. In our purpose, it is interesting to underline the role of the productivity term $B$ in the dynamic of human capital and income. In fact, the consideration of technological or behavioural improvements in the health status production function will allow for assessing the transition to the modern growth regime.

### 3.1 Effects of variations of *B*

The aim of this subsection is simply to address the effects of variations in the productivity term $B$ on the policy function (12), while this parameter will be made endogenous in the next section. In order to underline the role of health status in the temporal evolution of human capital, conditions for the existence of different equilibria will be thus expressed in terms of the efficiency of human capital technology, $B$. Firstly, after some algebra manipulation, A1 can be rewritten as

$$B_t < \left\{ \frac{\beta sl - \gamma\mu\tau[sl - \chi(1-\phi)]}{\gamma\mu\phi\tau w} \right\}^{\frac{1}{\tau\mu}} \left( \frac{1}{\phi} \right)^{\frac{1}{\tau}} \frac{1}{sl} \equiv B^*. \tag{16}$$

Hence, *ceteris paribus*, a low level of $B$ ensures the existence of a stable equilibrium of subsistence. In other words, if the inequality (16) holds, a poverty trap emerges. This is extremely important if it is considered that productivity is likely to be at a very low level at the genesis of an economy. It should be noted that improved $B$ results in higher preference for child quality due to its effect on the cost of child rearing. In fact, it is related to higher levels of human capital and thus, a higher cost of time dedicated to children. Graphically, increasing the level of the productivity term shits up the policy function, and its intersection with the 45° line gets closer and closer to the threshold level of income $\tilde{z}$. If $B$ is sufficiently high, the equilibrium of subsistence disappears.

Similar considerations apply when considering the interval $(z, \tilde{z}]$. Higher levels of human capital and income caused by improved $B$ are related to a greater amount of resources dedicated to child nutrition. Given the properties of the utility function, this circumstance is translated into lower marginal utility of child nutrition relative to education; see (14). As a consequence, a raise in $B$ has a positive effect on the preference for child education. In terms of the policy function, its slope positively depends on $B$,

$$\frac{\partial z'_{t+1}}{\partial B} = \frac{\mu^2 \phi^{1+\mu} \tau^2}{B[\phi z_t - \chi(1-\phi)]} \left\{ \frac{B\gamma\mu\tau[\varphi z_t - \chi(1-\phi)]}{\beta - \gamma\mu\tau} \right\}^{\mu\tau} > 0. \tag{17}$$

Therefore, rewriting A2 in terms of $B$, for $z_t \to \bar{z}$,

$$B > \left\{ \frac{\chi[\beta\phi + \gamma\mu(1-\phi(1+\tau))]}{\gamma\mu\phi w} \right\}^{\frac{1}{\mu\tau}} \left( \frac{1}{\phi} \right)^{\frac{1}{\tau}} \frac{1}{\chi\phi\tau} \equiv B^{**} \tag{18}$$

ensures that the policy function provide only a stable steady state in the interval $(\underline{z}, \bar{z}]$ under (16) (that is, if an equilibrium exists in $(0, \underline{z}]$). On the contrary, if (16) does not hold and (18) holds, $z_{t+1} > z_t, \forall z_t < \bar{z}$. In other words, if the productivity term is sufficiently high, the level of income per capita will tend to a level higher than the threshold level $\bar{z}$, for any level of parents' income $z_t < \bar{z}$ and therefore, all dynasties will start to invest in child education independently from the initial health status and economic conditions of the ancestors.

Improved $B$ has the same effect on the rest of the interval of existence of (12), that is, it both shifts up the policy function and affects its slope, which becomes steeper with $B$. On the contrary, an initial low level of the productivity with which nutrition inputs are converted into energy and cognitive output results both in the existence of the equilibrium of subsistence and, possibly, it determines that such equilibrium is the only steady state provided by the policy function. Hence, when it is assumed that an economy is initially characterized by a very poor level of human capital and the incapacity (or unfavourable conditions) to efficiently use resources in order to achieve high levels of health status, the initial condition may be represented by the equilibrium of subsistence $z^1$. Apart from the theoretical conditions that define these situations, historical evidence suggests that the now developed economies have experimented a very large period of quasi-absent growth, during which resources available for nutrition were scarce.

### 4. Health improvements and economic growth

If health status affects the ability to learn and the evolution of human capital, the level of human capital is likely to influence health status (e.g. Grossman, 1972; Kendel, 1991; Arendt, 2005). In particular, educated parents have been shown to bring up healthier children, and not only for their consequent better economic possibilities. Healthy behaviours, for example, are the result of improved human capital and have the potential to increase the efficiency with which the same amount of resources influences nutrition and the level of health status. In order to assess the temporal evolution of human capital when an economy is stuck at the equilibrium of subsistence, it is considered the introduction in the model economy of new behaviours related to health. The sequence $[B_t]_{t\geq 0}$ might depend on changing health-related behaviours or other factors not directly liked to economic performance, such as the composition of diets, migration to healthier areas or institutional changes that result in better health status.

Innovations are assumed to occur randomly at the beginning of each period $t$ with probability $p(h_t) \in (0,1)$. In other words, the probability of arrival of an innovation is a function of the level of human capital of population, where $p' > 0$ and $p'' < 0$. The sequence $[B_t]_{t\geq 0}$ however, is not a stochastic process because innovations in health behaviours in the past affect the level of human capital and thus, they influence the probability of arrival in the subsequent periods. The arrival of an innovation boosts the productivity $B$ by a constant factor

$$B_{t+1} = \rho B_t, \ \rho > 1 \tag{19}$$

and the innovation is assumed to be freely accessed by each member of the economy and could not be made excludable. Therefore, the technology of production of health status is a positive function of the level of human capital of agents. When uneducated and deprived individuals populate the economy, the probability of arrival of an innovation is arbitrarily low, though still positive. In other words, it is assumed that persons endowed with a low level of human capital may occasionally introduce a novelty or adapt their behaviours in order to live a healthier life. For high levels of human capital, productivity growth will be faster, provided that the rate of arrival of innovations is higher.

It is now assumed that assumption (16) holds, and the model economy is initially characterized by the equilibrium of subsistence $z^1$. Under this scenario, the arrival of an innovation in health-related behaviours has different consequences that can be addressed. Firstly, $B_{t+1} = \rho B_t \Rightarrow z_{t+1} = w\left[(\rho B_t sl)^{\tau}\varphi\right]^{\mu}\xi > z_t$. In other words, held constant the total amount of resources dedicated to child human capital, the level of income per capita is increasing with $B_t$. The important point to make here is that improved health via increased productivity shifts up the steady-state equilibrium of subsistence but it doesn't determine the take off of the economy. Explicitly, while the level of human capital and income may slightly increase in the time-consuming process of innovation during the Malthusian regime, parents' choices remain unaffected. In fact, parents do not allocate more resources to child consumption and the only source of improved nutrition and learning capacity is the arrival of an innovation in health-related behaviours, i.e. a change in productivity. Excess resources, in fact, are devoted to enlarge family size.

Hence, during Malthusian Stagnation, an increase in the productivity $B_t$ at time $t$ determines an increase of the total number of births per adult. In order to understand this effect, equation (9) should be considered. As mentioned above and represented in Figure 5.1, improved income results in higher fertility when $z_t < \tilde{z}$. The relationship across increased productivity $B$, higher income, and higher fertility, is consistent with Malthusian population growth, in that the greater availability of resources is dedicated to fertility and not to increase child quality.[10] It is interesting to observe here a difference with Galor and Weil (2000), who link technological progress in the productive sector to population growth. The predictions of this model suggest that the existence of correlation between progress and population growth is due to the opposite causal relationship. Population expands when more resources are available or, in other words, slight improvements in human capital determines higher income and, given the preferences of agents, a larger family size.

Improved human capital has a positive effect on $B$, through the rate of arrival of an innovation. Graphically, since it has been assumed that $z_t = z^1 = \left[(B_t sl)^{\tau}\phi\right]^{\mu}$, the growth path of the economy during this phase would be represented by points of the 45° line in the $z_{t+1} - z_t$ plane and infrequent steps from $z_t = \left[(B_t sl)^{\tau}\phi\right]$ to $z_{t+1} = \left[(\rho B_t sl)^{\tau}\phi\right]$.

[10] See, for instance, Botticini and Siow (2005) for evidence regarding the positive relationship between family wealth and the number of surviving children, and Kelly (2004) for the positive effect of income on population growth.

When $B_t$ achieve a level for which (16) does not hold, however, further improvements will be devoted to child nutrition, and a different dynamic of development begins, i.e. the economy enters in the post-Malthusian regime, which is characterized by improving nutritional status. It should be noted that

$$B^* < B^{**} \Rightarrow z_t \to z^2. \tag{20}$$

That is, the escape from Malthusian Stagnation does not imply the definitive passage to the modern growth regime, but it may determine the convergence to a (pseudo)-equilibrium characterized by higher levels of human capital and a level of child consumption above the subsistence. Three main features characterise this phase of development; firstly, improved child nutrition increases the level of human capital and, through this channel, the probability of arrival of new innovations. Hence, further improvements are more likely. Secondly, improved health is linked to higher learning capacity, and the preference for child education progressively increases. Thirdly, any increase in the level of income does not generate a raise in the growth rate of population as during Malthusian Stagnation. The phase during which individuals improve their health status through nutrition is preparatory for the subsequent regime of growth. When $B_t$ achieves a level for which (18) holds, the improvement in human capital and income is driven by education and the economy crosses the threshold that separates the transition from the regime of modern growth regime.

In order to summarize these results Figure 5.2 provides a graphical example of the evolution of the system $(z_t, B_t, n_t, cn_t, e_t)$ through the different regimes. During Malthusian Stagnation, the level of income is equal to the (pseudo)-equilibrium

$z_t = \left[(B_t sl)^{\tau}\phi\right]^{\mu}$, fertility increases with the level of human capital, child nutrition is stuck at the subsistence level, and the length of schooling is equal to zero. The rate of arrival of innovations in health-related behaviour, or advancements that positively affects health status, is positively correlated to the human capital level of the population. Hence, the probability that an improvement occurs is positive but arbitrarily small. Since improved productivity in the health production function determines higher fertility, the greater availability of resources does not generate a dynamic of growth. However, the progressive and time-consuming increase in $B_t$ results in higher human capital levels and a lower preference for child quantity. When $B_t > B^*$, parents dedicate further improvements in health status, human capital and income to child nutrition, reducing fertility. In other words, during the post-Malthusian regime, the level of child nutrition begins to increase, fertility rates decrease, and education is still null. Improved nutrition results in higher levels of human capital, increased probability of arrival of innovations and a greater preference for child education. This phase of transition continues up to a point in which the productivity $B_t$ and the health status of children are sufficiently high to induce parents to invest in child education.

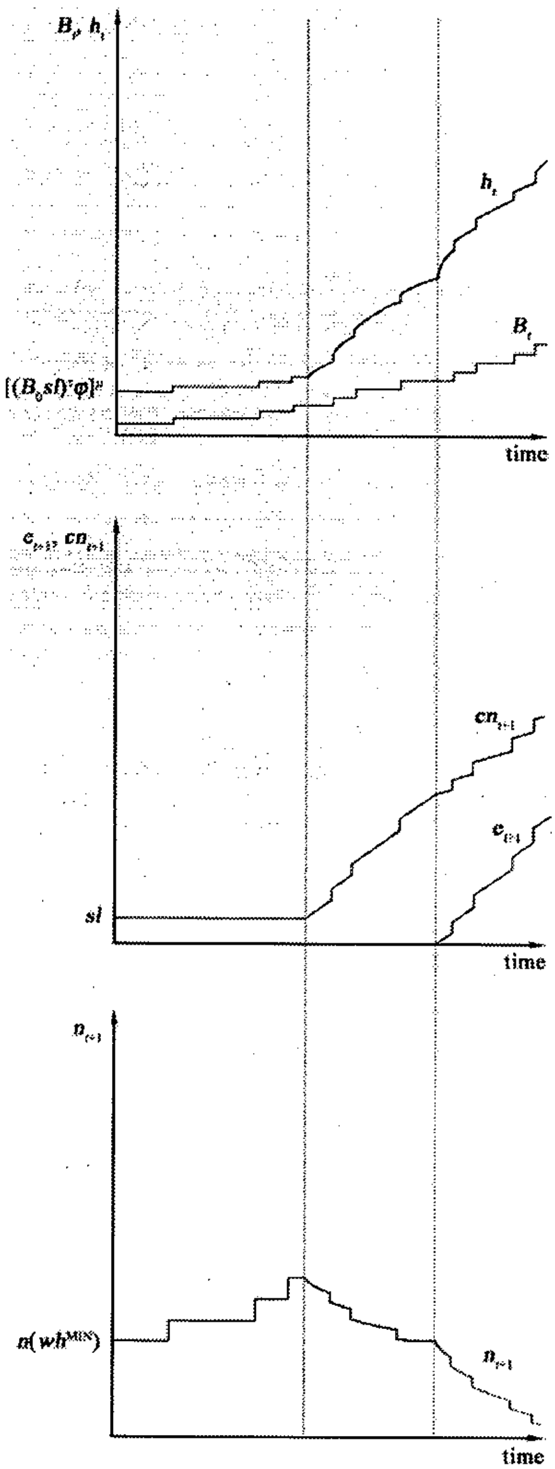


**Figure 5.2**. Temporal evolution of human capital, child nutrition, education and fertility during the three growth regimes.

During the modern growth regime, fertility further decreases with income, while the level of child nutrition and the length of schooling increase (and child labour decreases). The model predicts the existence of a fourth regime of development, which is characterized by the lowest (and constant) fertility rate, the dedication of the whole childhood to education, and still increasing levels of child consumption and nutrition.

## Conclusions

This chapter develops a two periods, overlapping generation model in order to underline the importance of health status in the Transition out of Malthusian Stagnation. It is an attempt to address the impossibility of a transition to the modern growth regime without sustained improvements in health. With respect to the existing literature on transition, which highlights the role of education, it is argued that the development of intellectual human capital and, thus, the take-off of economies, have occurred after individuals have achieved a sufficient level of health status. The maximizing behaviour of adults implies choices about their consumption, fertility and education as well as nourishing of their children. Depending on the initial level of human capital and income of parents, the model predicts different choices with respect to these variables. Firstly, it is shown that fertility follows a non-monotonic pattern, in that it is initially increasing with income and, when the level of earnings allows for investments in child quality, it turns out to be decreasing. Moreover, it tends to a constant, minimum level for sufficiently high levels of human capital. Child nutrition is initially stuck at the subsistence level, which constrains, *inter alia*, child ability to learn, and it is then increasing with income. The length of schooling is also increasing in income, though individuals start undertaking positive investments in education when income and the level of child nutrition have achieved a certain level. From the first order conditions of the maximization problem it is obtained a policy function, which may provide multiple equilibria. In particular, conditions for the emergence of equilibria can be expressed in terms of the productivity with which consumption inputs are converted into energy and learning productivity output.

The relevant question arises when it is assumed that, initially, the level of income of the representative agent and the productivity in the health status formation function are so low that the economy converges to an equilibrium of subsistence, characterized by no education and investment in child nutrition at the subsistence level. It is assumed in the model that, depending on the level of human capital in the economy, agents may randomly introduce innovations in health-related behaviours or other novelties that potentially improve the health status of population, held constant the quantity of available resources. The arrival of innovations related to health behaviours during the first stage of Malthusian Stagnation generates distinct consequences that will have long-lasting effects on the growth path of the model economy. Firstly, innovations result in improved human capital and, thus, increased income. However, the increased availability of resources has a direct effect on the total number of children per adult, in accordance with Malthusian population growth. In other words, a greater productivity in the formation of health human capital does not imply the take-off of the economy but it shifts up the (pseudo)-equilibrium of stagnation. When the productivity is sufficiently high, however, agents begin to undertake positive investments in child nutrition and human capital increases accordingly. It should be noted that improved human capital has an effect on the arrival of innovations and the increase of productivity and thus, the causation between health and human capital runs in both direction. This phase of transition during which the health status of the population improves, while intellectual human capital is stuck at its minimum level, can be viewed as a pre-condition for the subsequent passage to the modern growth regime. In fact, when income levels, the amount of resources dedicated to nourishing and productivity are sufficiently high, parents choose for their children positive lengths of schooling, and the increase in human capital levels becomes steeper.

It might be argued that technological progress in the productive sector would have the same effects in terms of evolution of human capital and income and hence, it may drive the transition to the modern growth regime. In Galor and Weil (2000), for example, technological progress improves the productivity of the non-producible factor, and increases the demand for human capital via the return to education. A key assumption in that paper is that technological progress depends both on education and population size. However, the link between improvements in the production system and the number of inhabitants fails to explain why overcrowded, low-income countries does not experiment growth. When technological progress is assumed to depend exclusively on education, on the contrary, it is difficult to understand how uneducated people can contribute to development through this channel. The model presented in this chapter suggests that, during the first stage of development, human capital increases thanks to improved health and this is the main driving force that leads to the subsequent investment in education and, possibly, technological progress. The rationale behind the occurrence of health improvements during Malthusian Stagnation, in contrast to technological progress, is that the enhancement of health status appears to be more income-independent. In fact, factors other than income levels have been shown to explain the permanent change in levels of health status, such as the discovery of vaccines or social and behavioural changes (e.g. Arora, 2005). Another point is that technological progress does not determine a direct increase in levels of human capital. In other words, though technological progress may cause a raise in the wage per efficiency unit of labour and, thus, higher income levels, the greater availability of resources would be dedicated exclusively to increase family size during Malthusian Stagnation. Improved health, however, is an improvement of human capital itself, and it may help to take advantage of the existing environment, even when resources are scarce and technological progress is absent.

# VI. Conclusions

Learning ability and the incentives to undertake positive schooling-based human capital investments depend on child health status. By constructing an ability proxy using survey data from Brazil, an indicator that takes into account the capacity of children to successfully complete school years, it has been demonstrated that healthier individuals are more likely to accumulate higher levels of human capital respect to schoolmates of the same age. Therefore, children endowed with an unfavourable health status develop a lower capacity to generate income during adulthood, even when they dedicate the same amount of time to education as healthy children. This circumstance, in turn, is likely to result in poor socio-economic status during adulthood, including unfavourable health conditions.

In addition, reduced learning ability has an effect on the level of human capital investments, provided that agents consider the return to schooling when making their decisions. In fact, when individuals are assumed to maximize lifetime earnings, a lower ability to transform educational inputs into human capital output reduces the expected income from higher schooling investments and thus, dedicating more time to labour might result in higher levels of well-being or utility. Empirical data suggest that improved health status negatively affects the age of school initiation or, in other words, it has been shown that unhealthy children begin to study in later ages. Provided that the opportunity cost of schooling increases with age, school initiation may reveal the total number of years that individuals will dedicate to education. Explicitly, when it is assumed that health status only influences the age of school initiation, and children are identical respect to other characteristics, an early beginning of the educational process might determine larger human capital accumulation. When adults only are considered in the analysis, provided that they have finished their educational period, it is possible to show that health status has a positive impact on the total amount of time dedicated to schooling. In other words, healthy individuals are likely to spend more time at school, independently from their educational achievements. In fact, the main variable being considered reflects school length only and it is thus a proxy of schooling-based human capital investments. Therefore, unhealthy individuals, who are endowed with lower learning ability, dedicate fewer resources to education, a circumstance that further reduces their real opportunities.

Unhealthy children, who accumulate a low level of human capital and obtain low income when adults are likely to transmit their unfavourable condition to the next generation. The existence of this intergenerational relationship is robust to the use of different health indicators, both objective and subjective measures, as well to the use of data from a developing country as considered here. Since health status itself is a constitutive component of human capital, analysing health mobility may shed light on human capital mobility. Moreover, when healthy parents rear unhealthy children, the new generation faces the same constraint relative to the accumulation of intellectual human capital and therefore, deprivation is likely to characterize the whole dynasty. In other words, the transmission of health status is linked to the persistence of deprivation.

The complementarity of health and education, and the intergenerational transmission of health status may thus help to better understand the persistence of deprivation. The theory proposed in this thesis suggests that children of very poor families dedicate a short period of childhood to education and the rest of the available time is devoted to labour in order to fulfil basic needs related to nourishing, which their parents cannot satisfy adequately. Only when parents' economic possibility allows for ensuring better nutrition and children enjoy a minimum level of health status, schooling begins to increase. The consideration of these mechanisms may give raise to threshold effects of adult income and in fact, when human capital and income are below a critical level, the model predicts that a dynasty may converge to a poverty trap of low education, poor nutritional and health status and high fertility. In other words, when the initial level of income is sufficiently low, scant investments in nourishing and education determine the persistence of deprivation for the whole dynasty.

Yet this result is strongly dependent on the value of parameters of the model and poverty traps might emerge only in particular circumstances. Independently from the existence of multiple equilibria, however, investments in schooling increase when the socio-economic condition of the family of origin ensures an adequate level of nourishing and liberates children from the necessity of dedicating time to labour. In addition, health always has a multiplier effect on education through learning capacity and, consequently, enhancing the health status of the poor might favour the escape from deprivation.

In order to improve health status and the educational level of deprived children, national and international institutions are increasingly promoting school feeding programmes. Providing meals at school has the objectives of improving nutritional status and attracting poor children to school. However, it is shown that while school feeding does result in larger length of schooling, it may fail to achieve the first aim. One argument for this conclusion is that intra-household allocation may determine a redistribution of the benefit from school feeding to other members of the family and therefore, child nutritional status would remain stuck at its initial level. For example, parents might withdraw calories as an efficient response to this policy. The model presented here, however, suggests the existence of another potential failure of this policy. School feeding induces children to choose larger length of schooling, which in turn reduces the amount of time dedicated to labour and, thus, resources for nourishing. Schooling increases up to a point in which resources for child nutrition provided at school are equal to the total amount that they would have obtained by working. In this way, they are able to maintain their nutritional level while working less and increasing school lengths in order to improve their level of human capital.

Positive effects of school feeding programmes on nutritional status might emerge at the intergenerational level. Improved human capital, in fact, allows future parents to offer more favourable conditions to their children, included a larger amount of resources for nutrition. Though this is not the desired or expected result of school feeding programmes, it is a positive consequence that should be considered. The effects of school feeding on the first generation predicted by the model are bounded to improved school attendance, reduction of child labour, and enhanced human capital levels independently from nutritional status. Caution should be exercised in interpreting these results. In fact, the model has been simplified in order to highlight a potential failure of school feeding but a number of factors might reduce the impact of conclusions, such as the consideration of a positive effect of schooling on the efficiency with which nutritional inputs are used or the different quality of meals provided at home respect to school meals.

The consideration of health poverty traps has aimed the last part of this thesis, which is an attempt to investigate if the Transition to the Modern Growth regime that now-developed countries have experimented in their history could have taken place without sustained health improvements. On considering Malthusian times, when income growth was quasi-absent and economies were stuck in a long-term equilibrium of deprivation, claiming for a causal relationship running from income to improved health appears problematic. In contrast to this view, it is argued here that changes in behaviours or the arrival of health-related innovations, which are aimed by the struggle for survival and depend on the level of human capital of the population, may have caused a progressive adaptation of individuals to the environment by improving their capacity to enhance health status with a given amount of resources. Though improved income is devoted to augment population size during Malthusian Times, it also results in a raise of the opportunity cost of binging up a child, which depends on the level of adult human capital. Hence, the time-consuming adaptation and improvement of health conditions (independent from the amount of resources per capita) continues up to a point in which parents start changing child quantity for quality in terms of nutrition in order to increase their utility. The main characteristic of the post-Malthusian regime, thus, is the increase of child health status, which is in turn a precondition for the development of intellectual human capital. In fact, when parents have the opportunity to endow their offspring with a minimum level of health status, children are allowed to attend school and it is this circumstance, namely the progressive improvement of intellectual human capital, which determines the passage to the Modern Growth regime.

## Appendix A

### 2SLS estimates and endogeneity

In this appendix 2SLS estimations of equation (4), chapter II, are considered, and special attention is devoted to the choice of instruments, their testing, and the conclusion regarding the absence of endogeneity of the health proxy. Endogeneity may emerge in this situation due to two main causes. The first is concerned with double causation between health and education, while the second possible source of endogeneity is related to omitted variables, which could affect both health and educational outcomes. For instance, health and educational investments might be equally influenced by some factor related to parents' behaviours and decisions. In both situations, the correlation with the error term would result in biased estimates. Provided that the literature suggests that endogeneity might emerge when considering health and education in the same model, an instrumental variables (IV) approach has been chosen in order to deal with this problem. The method of IV is a general approach to assess this question. In particular, in the basic relationship

$$EAC^{i} = \beta_0 + \beta_1 H^{i} + \varepsilon^{i}, \qquad \text{(A.1)}$$

where $H^{i}$ might be endogenous, the estimate of $\beta_1$ could be biased. It is possible to obtain an instrumental variable estimate of $\beta_1$ by

$$\beta_1^{IV} = \frac{Cov(y,z)}{Cov(x,z)} = \frac{Cov(\beta_0 + \beta_1 H + \varepsilon z)}{Cov(x,z)} = \frac{Cov(x,z)\beta_1 + Cov(\varepsilon,z)}{Cov(x,z)}. \tag{A.2}$$

If the instrument $z$ is a good instrument, that is $Cov(\varepsilon, z) = 0$, therefore

$$\beta_1^{IV} = \frac{Cov(x,z)\beta_1 + Cov(\varepsilon,z)}{Cov(x,z)} = \frac{Cov(x,z)\beta_1}{Cov(x,z)} = \beta_1. \tag{A.3}$$

Hence, the IV estimator is an unbiased estimator of $\beta_1$. The method used here is two-stages least squares (2SLS). In the first step, the value of $H^i$ is predicted by the instruments $z^i$ as well as by other variables included in the main model, $w^i$,

$$\hat{H}^i = \alpha_0 + \alpha_1 z_1^i + \alpha_2 w^1. \tag{A.4}$$

Secondly, the predicted value of $H^i$ is used in an OLS regression predicting $EAC^i$,

$$EAC^i = \beta_0 + \beta_1 \hat{H}^i + \beta_2 w^i + \varepsilon^i. \tag{A.5}$$

On considering the predicted value of $H^i$ instead of real values, the residuals from the first equation have been left behind. Provided that $z$ is an exogenous shock on $H^i$, those residuals are the part of $H^i$ which are potentially endogenous with $EAC^i$.

The choice of instrumental variables, however, is not a trouble-free task, since most of the variables usually included in datasets are potentially correlated with both child health and education. Instrumental variables, in fact, have to satisfy three basic conditions in order to obtain unbiased estimates: a) they should not be included in the main model as explicative variables; b) the correlation with the error term should be theoretically null; and c) they should be correlated with the variable for which they are used as instruments. While it is not difficult to satisfy condition (c), condition (b) is almost always a problem. On considering the analysis of health and education, the possibility that both health outcomes and education attainments reflect household decisions regarding investments in children's human capital (e.g. Beherman, 1996) results in the possible emergence of endogeneity as well as in the difficulty to find good instruments. Variables used in the analysis have been chosen from a large number of candidates and several tests have proved their inefficiency.

In particular, instruments tend to present a good explanatory power for the endogenous variable, and passed satisfactorily identification / IV relevance tests (Anderson canonical correlation likelihood ratio; Anderson-Rubin, 1949), weak identification tests (Cragg-Donald statistic; Cragg-Donald, 1993), but fail the overidentification test of all instruments (Sargan, 1958). In other words, the most relevant problem is the potential correlation of instruments with the error term.

The most natural candidates for being instruments of BMIFA are the proxies of parents' health status, and the best variables, which have been selected for the analysis, are BMIM and BMIF. Chosen instruments for HFA, however, are HEIGHTM and HEIGHTF. Equation (4), thus, has been estimated by 2SLS using these instruments, and Table A.1 presents results of the first stage regression, as well as a number of statistics related to IV relevance. Results replicate the conclusions obtained when considering the intergenerational transmission of health status and the interest of Table A.1 is primarily concerned with instruments testing. First stage regressions are significant and, more important, instruments have a relevant explanatory power.

**Table A.1**. 2SLS estimates: results of the first stage regression.

| Dependent variable | BMIFA | HFA |
|---|---|---|
| **Excluded instruments** | (1) | (2) |
| **BMIM** | **.0056*** | **.1736*** |
| | (7.90) | (7.55) |
| **BMIF** | **.0083*** | **.3249*** |
| | (9.12) | (10.65) |
| **Included instruments** | | |
| **EDUM** | **.0018** | **.0704** |
| | (1.52) | (1.81) |
| **EDUF** | **.0019** | **.0733*** |
| | (1.68) | (2.02) |
| **LOGRD** | **.0008** | **.6471*** |
| | (0.19) | (4.52) |
| **WHITE** | **.0015** | **.2545** |
| | (0.20) | (1.04) |
| **MALE** | **-0012*** | **2.5261*** |
| | (-.19) | (11.30) |
| **NORTH** | **-.0424*** | **-1.7051*** |
| | (-5.59) | (-6.84) |
| **URBAN** | **-.0053** | **.0262** |
| | (-0.58) | (0.08) |
| **Anderson canon. corr. Likelihood ratio** | 166.49* | 198.55* |
| **Cragg-Donald N*minEval F stat.** | 86.02 | 102.30* |
| **Sargan Statistic** | 1.619 | 2.148 |
| **Wu-Hausman F test** | 1.6234 | .0370 |
| **Model statistic (F)** | 59.67* | 65.35* |
| **Cent-R2** | .1043 | .1610 |
| **Obs** | 2922 | 3922 |

Anderson canonical correlation likelihood ratio test allows for rejecting the null hypothesis of underidentification of the matrix of reduced form coefficients, and the Cragg-Donald statistic provides an argument against the hypothesis of weak identification. Finally, the Sargan statistics suggests that BMI is not correlated to the error term and hence, it is possible to conclude that instruments are acceptable.

The most interesting conclusion that can be draw from 2SLS estimations is the exogeneity of the health proxy, suggested by the Wu-Hausman test. Three considerations may help to better understand this conclusion. The first point is a premise, which strengthens the rest of remarks, and it is concerned with the education proxy used in the analysis. It is worth noting, in fact, that EAC is not an indicator of educational outcomes, such as completed school years, but by definition it measures child achievement respect to possibilities. This consideration is important because if the source of endogeneity are omitted variables related to parents' decisions, it could be argued that adults can choose to school their children but they cannot choose that their children will successfully complete school years. Another question is that child ability is not likely to affect health outcomes directly and while child health is primarily determined during the first years of life, the effect of their own education on health status is likely to emerge in later ages, that is, when a child's decisions (and, possibly, income) are more independent from the influence of parents. Provided that our sample includes young children, thus, their control on health status is weak in all probability. In addition, the age of children provides another justification for the absence of endogeneity. Students considered in the sample attend compulsory, free school (at the time of the survey, schooling was mandatory for children aged up to 14 years) and schooling decisions, therefore, are not related to parents' behaviour. In other words, parents' choices about human capital investments during the first years of life of children are more concerned with nutrition and health status, while schooling is mandatory. The only relevant choice about education is the age of school initiation, which can differ among children because the first years of education, prior to the "primeiro grau" (first degree, primary school in the Brazilian education system) are not mandatory. And in fact, endogeneity has been detected when considering the age of school initiation, as discussed in Chapter III.

## Appendix B

### Intergenerational effects of education on health status

The level of education of parents is likely to influence both their own health status and the health status of their offspring. Throughout chapter II, it has been shown that the inherited physical condition plays a central role in explaining the learning ability of children, and their school performance. In addition, chapter III shows that the initial health stock might affect the level of human capital investments. A normative implication of those considerations is straightforward: mandatory schooling causes improved education, better health status when adults and, hence, better conditions for the development of the following generations. In other words, compulsory schooling may have intergenerational effects, which are concerned with the improved health and cognitive capacity of children. In order to analyse this topic, the basic framework of chapter III is extended by assuming that each individual born at $t$ brings up only one child at the beginning of $t+1$. For the sake of simplicity, children inherits from their parents their level of health status during adulthood according to

$$P_{t+2} = P_{t+1}, \tag{B.1}$$

where $P_{t+2}$ is the initial endowment of health status of an individual born at $t+1$. Functions (1) and (4) of chapter III imply that (B.1) can be interpreted as a health status policy function,

$$P_{t+2} = P(e_t, P_t), \tag{B.2}$$

which expresses the initial endowment of health status of one generation as a function of both the initial health stock and the amount of time dedicated to education of the previous generation. In addition, assumption A implies

$$P'_{t+2}(P_t) > 0 \quad P''_{t+2}(P_t) < 0 \tag{B.3}$$

$$\lim_{P \to 0} P_{t+2} = P^{MIN}. \tag{B.4}$$

The properties of (B.2) appear to be consistent with the empirical literature. For instance, Currie & Moretti (2005) find a positive relationship between mothers' and children's birth weight. The concavity of the functions being considered, and (B.4) ensure that the health status of population and the length of schooling converge to a stable equilibrium, $\{P^E, e^E\}$.

It is now assumed that the model economy is at its long-term equilibrium of education and health, and a Government agency is able to enforce a minimum length of schooling, $e^C$. For the generation affected by the compulsory schooling law (CSL), mandatory schooling has three main effects. Firstly,

$$e^E < e^C \Rightarrow E_t^C(e^C, P_t) > E_t(e^E, P_t). \tag{B.5}$$

Additional schooling results in higher educational attainments, *ceteris paribus*, and in improved human capital. Enhancing schooling has a direct impact on the accumulation of human capital, though the consequences of compulsory schooling appear to be stronger when the effects of education on health status are considered. In fact,

$$E_t^C > E_t^E \Rightarrow P_{t+1}(E_t^C) > P_{t+1}(E_t^E) \tag{B.6}$$

Hence, when compulsory schooling is introduced in the model economy, individuals that would choose $e^E < e^C$ accumulate a larger amount of human capital, both because they achieve higher educational attainments, and because of improved health. However, the maximization problem implies

$$E_t^C > E_t^E \Rightarrow z(e^C) < z(e^E). \tag{B.7}$$

This effect of compulsory schooling constitutes the reason for not investing in education an amount of time greater than $e^E$ at the equilibrium. The benefit arising from dedicating additional time to education in terms of improved human capital, does not balance the reduction of time dedicated to labour, and compulsory education thus reduces individuals' expected lifetime earnings. It should be noted that real lifetime earnings might be actually higher, when individual decisions are influenced by variables that alter the perception of the returns to education. Oreopoulos (2006) observes that the decision to leave school before graduation usually leads to sub-optimal lifetime outcomes for the individual dropout. Adolescent decision-making may be affected by cultural or peer influences, and youths may underestimate the rewards from staying at school. In other words, individuals could be better off by choosing larger length of schooling. Parents' influence is expected to exert an important role in child investments, and it could result in larger length of schooling. Nevertheless, compulsory schooling should be regarded as a measure opposed to individuals' preferences and in favour of an expected social benefit.

On considering the policy function (C.2), it could be observed that

$$E_t^C(e^C, P_t) > E_t^E(e^E, P_t) \Rightarrow P_{t+2}^C(E_t^C) > P_{t+2}^E(E_t^E); \qquad \text{(B.8)}$$

the next generation is better off when lifetime earnings of the preceding generation are sub-optimal form the individual's point of view. One important result is that, since health status influences the ability to learn and understand, and educational attainment by (1, chapter III), compulsory schooling enhances the quality of students of the next generation. Even when the following generation dedicate the same amount of time to schooling, i.e. $e^C$, new students will be able to achieve higher educational attainments, thanks to improved child learning capacity. The relevant point is that the decrease in earnings suffered by parents takes place during the first period of life, while income and health status increase during adulthood (however, it should be noted that improved income do not balance the loss in terms of lifetime earnings). Since parents' SES, which is relevant for children well-being, is the status of adults during child bearing and rearing, children are better off when CSLs are enforced.

These considerations offer an economic justification for public support of education, which is not concerned with the existence of positive economy-wide spillovers: CSLs can be regarded in this framework as an instrument to force an intergenerational transfer, which reduces lifetime earnings of one generation in favour of the development of the following. On considering this result, however, the feasibility of

CSLs should be taken into account, since the loss of income in the first period of life may undermine individual well-being.

## Appendix C

### C.1 Club convergence: computational experiment

The distribution of income per capita in Brazil has been shown to follow a dynamic of club convergence, which begun to appear at the end of the past century (e.g. Laurini et al., 2005). In particular, it has been underlined the formation of two convergence clubs, the first formed by the poorer regions of the North and Northeast, and another high income club formed by the Centre-West, Southeast and South regions. Silveira-Neto and Azzoni (2006), analysing the growth of income per capita in Brazilian states over the period 1985-2001, confirm the persistence of those two geographical clusters. The dataset used in chapters II and III provides interesting data that could be analysed in order to assess the emergence of club convergence in Brazil because it includes observations recollected in the Southern and Northern regions of that country between 1996 and 1997. In addition, about 68% of families included in the dataset with a level of income included in the first quintile of the distribution function of income per capita live in the Northern regions of Brazil and hence, the dynamic of income per capita is to a great extent the dynamic of regional differences.

The specific set of baseline values of parameters implies that the economy converges to a unique steady state, independently from the initial level of income. As observed in chapter IV, however, this circumstance does not impede the existence of club convergence. The model, in fact, generates twin-peaknedness despite the initial unimodality of the distribution function of income, as depicted in Figure C.1, which represents kernel plots of the distribution functions of estimated personal income at $t$ (initial period), $t+1$, $t+2$, $t+3$, $t+4$ (time horizon 92 years).

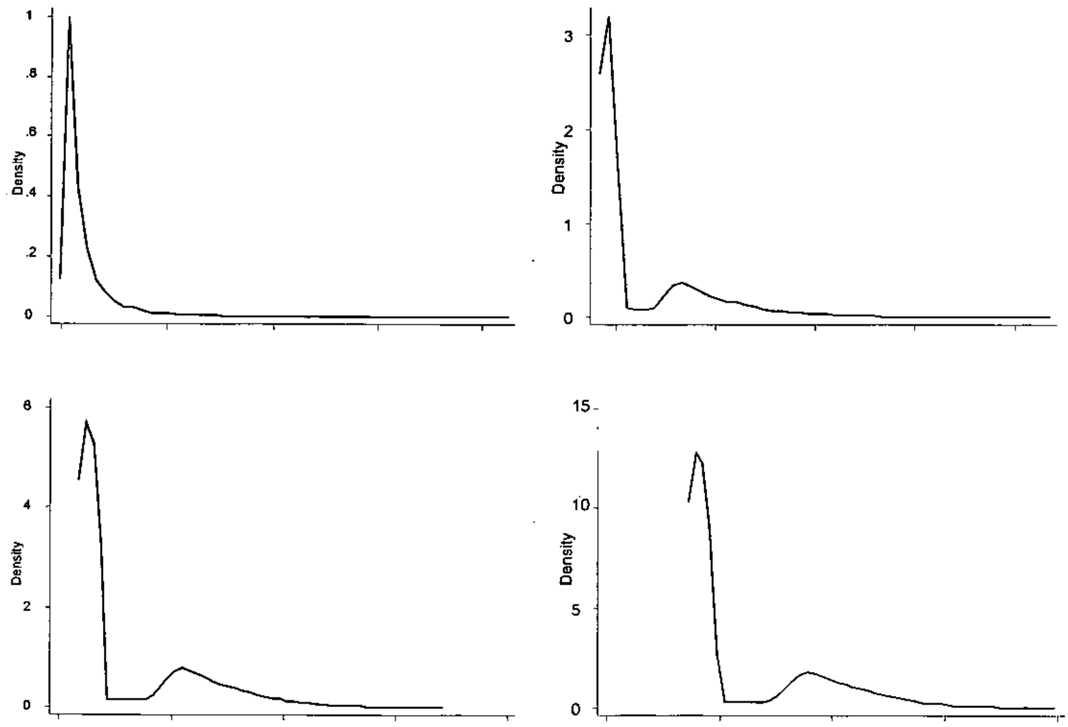


**Figure C.1**. Emergence of club convergence: Kernel density estimates of $z$ at $t$ (top), $t+1$ (centre), $t+2$ (bottom).

It is worth noting that the model predicts that children of every family dedicate the whole of their childhood to education starting from the fourth period, that is, after three generations or 69 years, and the distribution of income converges then to a unimodal distribution.

## C.2. Effects of parameters variation

Table 4.1 in the main text presents the baseline values of parameters used in the computational experiment. This Appendix considers the effects of parameters variations on the main variables, namely fertility, mean levels of length of schooling, resources dedicated to child nutrition, human capital and income per capita. Table C.1 presents the results of this exercise for ± 10% deviation from the baseline level of each parameter.

**Table C.1**. Effects of parameters variation.

| | value | $\overline{n}_t$ | $\overline{e}_{t+1}$ | $\overline{N}_t$ | $\overline{h}_{t+1}$ | $\overline{z}_{t+1}$ |
|---|---|---|---|---|---|---|
| baseline | | 1.229414 | 0.5983539 | 0.0435037 | 0.2384761 | 1.345977 |
| $\chi$ | 0.0726 | 1.241446 | 0.5902289 | 0.0456902 | 0.2426568 | 1.36217 |
| | 0.0594 | 1.214334 | 0.6087853 | 0.0414771 | 0.2346117 | 11.330907 |
| $\beta$ | 0.43634559 | 1.198557 | - | - | - | 1.37683 |
| | 0.35701003 | 1.261902 | - | - | - | 1.312409 |
| $\psi$ | 0.413941 | 1.210467 | 0.5795625 | 0.047321 | 0.2156097 | 1.257941 |
| | 0.338679 | 1.246396 | 0.6192676 | 0.0397592 | 0.2652722 | 1.445812 |
| $\phi$ | 0.077 | 1.105282 | 0.6077503 | 0.0458209 | 0.243534 | 1.365307 |
| | 0.063 | 1.380647 | 0.5894656 | 0.0413489 | 0.2336919 | 1.3412 |
| $\gamma$ | 0.1585199 | 1.339824 | - | - | - | 1.350043 |
| | 0.1296981 | 1.116919 | - | - | - | 1.350097 |
| $\eta$ | 0.4693711 | 1.219665 | 0.625203 | 0.0425488 | 0.2358491 | 1.387879 |
| | 0.3840309 | 1.238908 | 0.5787338 | 0.0446257 | 0.241712 | 1.311224 |
| $\tau$ | 0.73332 | - | - | - | - | 1.425322 |
| | 0.6 | - | - | - | - | 1.258338 |
| $A$ | 7.7 | - | - | - | - | 1.480575 |
| | 6.3 | - | - | - | - | 1.211379 |

Firstly, the parameter $\chi$ is crucial for determining optimal choices of agents, and its variation affects all variables being considered. The inverse relationship between this parameter and the length of schooling is a direct consequence of the increase of the opportunity cost of education. Thus, higher remuneration of child labour prevents poor children to attend school for larger periods. In contrast, the total amount of resources dedicated to child nutrition increases with $\chi$. The rationale behind this result is that children of deprived families, who attend school for the minimum period predicted by the model, receive more resources, which results in improved nutrition. The overall effect on human capital is positive, in that higher income from child labour favours underprivileged children and, therefore, it causes increased average human capital. This circumstance is reflected in the level of income per capita in the model economy.

Variations of $\beta$ only affect the level of fertility and income per capita through savings. As expected, income per capita increases with savings and, thus, with $\beta$. The parameter $\psi$ represents the return to nutrition and includes the direct effect of nourishing on human capital as well as the indirect effect through educational adequacy. The amount of resources dedicated to child nutrition is increasing with this parameter and, in contrast, the length of schooling is decreasing. Provided that the return to education is always higher than the return to nourishing, a positive variation of $\psi$ determines a reduction of the average level of human capital, which in turn is reflected by the level of income per capita. Opposite consequences are caused by a variation of the return to schooling, $\eta$. The effects of an increased time-cost of bringing up a child, $\phi$, are straightforward: fertility decreases with this parameter and human capital investments increase.

## Appendix D

### Proof of Proposition 1, Chapter IV

Under A3, if A2 holds for $z^i$, then $z^i$ is a point of (12) in $(\underline{z}, \bar{z}]$ and thus, by definition, it is a steady state of the policy function. In order to demonstrate stability, consider that if $z^1 \in (0, \underline{z}]$ is a stable steady state of (12), then $z_t > z_{t+1}, \forall z_t \in (z^1, \underline{z}]$ and hence, $z_t > z_{t+1}$ for $z_t \to \underline{z}$ from above. Given the concavity of (12) in $(\underline{z}, \bar{z}]$, either $z^2 < z^3$, in which situation $z_t > z_{t+1} \forall z_t < z^2$ and $z_t < z_{t+1} \forall z_t > z^3$, or $z^2 = z^3$ and $z_t > z_{t+1} \forall z_t < z^2 = z^3$. On the contrary, if the policy function does not provide any equilibrium in the interval $(0, \underline{z}]$, $z_t < z_{t+1} \forall z_t \in (0, \underline{z}]$ for A3 and A2.

# References

Acemoglu, D., S. Johnson, and J. Robinson (2003). Disease and Development in Historical Perspective. *Journal of the European Economic Association* 1: 397-405.

Agarwal D.K., S.K. Upadhyay, A.M. Tripathi, and K.N. Agarwal (1987). *Nutritional Status, Physical Work Capacity and Mental Function in School Children.* Nutrition Foundation of India New Delhi, India.

Ahlburg, D. (1998). Intergenerational Transmission of Health. *American Economic Review* 88(2): 265 270. Papers and Proceedings of the Hundred and Tenth Annual Meeting of the American Economic Association.

Alderman, H., J.R. Beherman, V. Lavy, and R. Menon (2001). Child Health and School Enrollment: A Longitudinal Analysis. *Journal of Human Resources* 36: 185-205.

Alderman, H., J. Hoddinott, and B. Kinsey (2006). Long term consequences of early childhood malnutrition. *Oxford Economic Papers* 58(3): 450-474

Arendt, J. N. (2005). Does education cause better health? A panel data analysis using school reform for identification. *Economics of Education Review* 24: 149-160.

Arora, S. (2001). Health and Human Productivity and Long-Term Economic Growth. *Journal of Economic History* 61(3), 699-749.

_____ (2005). On Epidemilogic and Economic Transition: A Historical View. In: Guillem López-Casasnovas, Berta Rivera and Luis Currais (Eds.). *Health and Economic Growth: Findings and Policy Implications*. Cambridge: MIT Press; p. 197-238.

Anderson, T.W., H. Rubin (1949). Estimation of the parameters of single-equation estimators. A single equation in a complete system of stochastic equations. *Annual of Mathematical Statistics* 20: 46-63.

Ayalew, T. (2005). Parental Preference, Heterogeneity, and Human Capital Inequality. *Economic Development and Cultural Change* 53: 381–407.

Aylward, G.P., S.I. Pfeiffer, A. Wright, and S.J. Verhulst (1989). Outcome studies of low birth weight infants published in the last decade: a meta analysis. *Journal of Paediatrics* 115: 515-20.

Azariadis, C., J. Stachurski (2005). *Poverty Traps*; P. Aghion, and S. N. Durlauf (eds.). New York, North Holland.

Bantle, C., J. P. Haisken-DeNew (2002). Smoke Signals: The Intergenerational Transmission of Smoking Behavior. *DIW Discussion Paper* 277. Available at SSRN: http://ssrn.com/abstract=381381

Basov, S. (2002). Heterogeneous human capital: life cycle investments in health and education. *Department of Economics working paper* 838. Melbourne, Victoria: University of Melbourne.

Becker, G.S., N. Tomes (1986). Human capital and the rise and fall of families. *Journal of Labor Economics* 3 (1): S33-58.

Behrman, J.R. (1988). Nutrition, health, birth order and seasonality: Intrahousehold allocation among children in rural India. *Journal of Development Economics* 28 (1): 43-62

_____ (1993). The Economic Rationale for Investing in Nutrition in Developing Countries. *World Development* 21: 1749-1771.

_____ (1996). The impact of health and nutrition on education. *World Bank Research Observer* 11 (1): 23-37.

Beherman, J., and A. Deolalikar (1998). Health and Nutrition. In: H. Chenery and T.N. Srinivasan (eds) *Handbook of Development Economics*, Vol. 1. New York, North Holland.

Berti Ceroni, C. (2001). Poverty Traps and Human Capital Accumulation. *Economica* 68: 203-219.

Bianchi, M. (1997). Testing for convergence: evidence from non-parametric multimodality tests. *Journal of Applied Econometrics* 12 (4): 393-409.

Blackburn, K., G.P. Cipriani (2002). A model of longevity, fertility and growth. *Journal of Economic Dynamic and Control* 26(2): 187 – 204.

Bloom, D.E., D. Canning, and J. Sevilla (2003). Geography and Poverty Traps. *Journal of Economic Growth* 8 (4): 355-378.

Bloom, D.E., D. Canning, and J. Sevilla (2004). The Effect of Health on Economic Growth: A Production Function Approach. *World Development* 32: 1-13.

Botelho, A., and L. Costa Pinto (2004). Students' expectations of the economic returns to college education: results of a controlled experiment. *Economics of Education Review* 23 (6): 645-653.

Botticini, M., and A. Siow. (2005). The Value of Sons in Pre-modern Economies: A View from the Marriage Market. *2005 Meeting Papers* 822, Society for Economic Dynamics.

Brown, P.H. (2006). Parental Education and Investment in Children's Human Capital in Rural China. *Economic Development and Cultural Change* 54: 759–789.

Bugarin, M.N.S. (2006). Human Capital and Income Concentration in Brazil. Mimeo, University of Illinois at Urbana-Champaign.

Cantarero, D., and M. Pascual (2005). Socio-economic status and health: evidence from the ECHP. *Applied Economics Letters* 13 (7): 1-17.

Case, A., D. Lubotsky, and C. Paxson, (2002). Economic Status and Health in Childhood: The Origins of the Gradient. *The American Economic Review* 92 (5): 1308-1334.

Case, A., A. Fertig, and C. Paxson (2005). The lasting Impact of Childhood Health and Circinstance. *Journal of Health Economics* 24: 365-389.

Chakraborty, S. (2004). Endogenous Lifetime and Economic Growth. *Journal of Economic Theory* 116: 119-137.

Chakraborty, S., and M. Das (2005). Mortality, human capital and persistent inequality. *Journal of Economic Growth* 10 (2): 159 – 192.

Chevalier, A., C. Harmon, V. O'Sullivan, and I. Walker (2005). The impact of income and education on the schooling on their children. *IZA Working Paper* 1496.

Church, A.T., and M.S. Katigbak (1991). Home environment, nutritional status, and maternal intelligence as determinants of intellectual development in rural Philippine preschool children. *Intelligence* 15: 49-78.

Cragg, J.G., and S.G. Donald (1993). Testing Identifiability and Specification in Instrumental Variable Models. *Econometric Theory* 9 (2): 222-240.

Currais, L., and B. Rivera (2005). Individual returns to health in Brazil: A Quantile Regression Analysis. In: Guillem López-Casasnovas, Berta Rivera and Luis Currais (eds) *Health and Economic Growth: Findings and Policy Implications*. Cambridge, MIT Press.

Currie, J., and E. Moretti (2005). Biology as Destiny? Short and Long-Run Determinants of Intergenerational Transmission of Birth Weight. *California Center for Population Research On-Line Working Paper Series*. Los Angeles, University of California.

Datar, A. (2006). Does delaying kindergarten entrance give children a head start? *Economics of Education Review* 25 (1): 43-62.

de la Croix, D., and M. Doepke (2003). Inequality and Growth: Why Differential Fertility Metters. *The American Economic Review* 93: 1090-1113.

Doppelhoffer, G., R. Miller, and X. Sala-i-Martin (2004). Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach. *American Economic Review* 94: 813-35.

Durlauf, S. N., and P. Johnson (1995). Multiple regimes and cross-country growth behaviour. *Journal of Applied Econometrics* 10 (4): 365-84.

Fogel, R.W. (1991). New sources and new techniques for the study of secular trends in nutritional status, health, mortality and the process of ageing. *Working paper series on historical factors in long run growth* no. 26 (May), National Bureau of Economic Research, Cambridge, Mass.

_____ (1994a). Economic growth, population theory, and physiology: the bearing of long-term processes on the making of economic policy. *The American Economic Review* 84 (3): 369-395.

_____ (1994b). The relevance of Malthus for the study of mortality today: long run influences on health, mortality, labour force participation, and population growth. In *Population, Economic Development, and the Environment*, edited by L. K. Kerstin and L. Hans. Oxford and New York: Oxford University Press, pp. 231-284.

_____ (2002). *Nutrition, physiological capital, and economic growth.* Washington, D.C.: Pan American Health Organization and Inter-American Development Bank. Available at http://www.paho.org/English/HDP/HDD/fogel.pdf

_____ (2004). *The Escape from Hunger and Premature Death, 1700-2100: Europe, America and the Third World.* Cambridge University Press: Cambridge, UK.

Fogel, R. W., and L. T. Wimmer (2002). Early indicators of later work levels, disease, and death. *Working paper series on historical factors on long run growth* no. 38 (June), National Bureau of Economic Research, Cambridge, Mass.

Galor, O. (1996). Convergence? Inferences from Theoretical Models. *Economic Journal* 106: 1056-69.

Galor, O., and D.N. Weil. (1999). From Malthusian Stagnation to Modern Growth, *The American Economic Review* 89: 150-154.

_____ (2000). Population, Technology and Growth: From the Malthusian regime to the Demographic Transition. *The American Economic Review* 110: 806-828.

Glewwe, P., H. Jacoby, and E.M. King (2001). Early Childhood Nutrition and Academic Achievement: A Longitudinal Analysis. *Journal of Public Economics* 81: 345-68.

Grantham-McGregor S. M., E. Pollit, T. D. Wachs, S. J. Meisels, and K.G. Scott (1999). Summary of the nature and determinants of child development and their implications with young children. *Food Nutrition Bulletin* 20 (1): 4-6.

Grantham-McGregor, S.M., L.C. Fernald, K. Sethuraman (1999). Effects of Health and Nutrition on Cognitive and Behavioral Development in Children in the First Three Years of Life. Part 1: Low Birth Weight, Breastfeeding, and Protein-energy Malnutrition. *Food and Nutrition Bulletin* 20(1): 53-75.

Grantham-McGregor, S. M., S. P. Walker, S.M. Chang, and C.A. Powell (1997). Effects of Early Childhood Supplementation with and without Stimulation on Later Development in Stunted Jamaican Children. *American Journal of Clinical Nutrition* 66: 247-53.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy* 80: 223-255.

Haas, J. D., E. J. Martinez, S. Murdoch, E. Conlisk, J.A. Rivera, and R. Martorell. (1995). Nutrtional supplementation during the preschool years and physical work capacity in adolescent and young adult Guatemalans. *Journal of Nutrition* 125 (4): 1078S-1089S.

Haveman, R., and B. Wolfe (1995). The determinants of children attainments: a review of methods and findings. *Journal of Economic Literature* 33 (4): 1829-78.

Hazan, M. and B. Berdugo (2002). Child Labour, Fertility, and Economic Growth. *The Economic Journal* 112: 810-828.

Hille E. T., A. den Ouden, L. Bauer, C. van den Oudenrijn, R. Brand, and S.P. Verloove-Vanhorick (1994). School performance at nine years of age in very premature and very low birth weight infants: perinatal risk factors and predictors at five years of age. Collaborative Project on Preterm and Small for Gestational Age (POPS) Infants in The Netherlands. *Journal of Pediatrics* 125(3): 426-34.

Hille, E. T., A. den Ouden, S. Saigal, D. Wolke, M. Lambert, A. Whitaker, J. Pinto-Martin, L. Hoult, R. Meyer, and J. Feldman (2001). Behavioural problems in children who weigh 1000 g or less at birth in four countries. *The Lancet* 357: 1641-1643.

House J. S., V. Strecher, H.L. Metzner, and C.A. Robbins (1986). Occupational Stress and Health Among Men and Women in the Tecumseh Community Health Study. *Journal of Health and Social Behavior* 27: 62-77.

Hopfer C. J., M. C. Stallings, and J.K. Hewitt (2001). Common genetic and environmental vulnerability for alcohol and tobacco use in a volunteer sample of older female twins. *Journal of Studies on Alcohol* 62(6): 717-23.

Instituto Brasileiro de Geografia e Estadística, IBGE (2003). *Pesquisa sobre Padroes de Vida 1996-1997.* Rio de Janeiro: IBGE.

Jacoby, H.G. (2002). Is There an Intrahousehold 'Flypaper Effect'? Evidence From a School Feeding Programme. *Economic Journal* 112: 196-221.

Johnson, E. O., G. A. Chase, and N. Breslau (2002). Persistence of cigarette smoking: familiar liability and the role of nicotine dependence. *Addiction* 97 (8): 1063-1070.

Johnston, F.E., S.M. Low, Y. De Baessa, and R.B. MacVean (1987). Interaction of nutritional and socioeconomic status as determinants of cognitive development in disadvantaged urban Guatemalan children. *Physical anthropology* 73 (4): 501-506.

Kelly, M. (2004). Living Standards and Population Growth: Malthus was Right. *Mimeo,* University College: Dublin.

Kendel, D. (1991). Health behaviour, health knowledge and schooling. *Journal of Political Economy* 99 (2): 287-305.

Knowles, J. (1999). Can parental decisions explain U.S. income inequality? Mimeo, University of Pennsylvania.

Laurini, M., E. Andrade, and P. Valls Pereira (2005). Income convergence clubs for Brazilian municipalities: a non-parametric analysis. *Applied Economics* 37(18): 2099-2118.

Leigh, J.P. (1983). Direct and indirect effects of education on health. *Social Science and Medicine* 17: 227-234.

Lleras-Muney, A. (2005). The Relationship Between Education and Adult Mortality in the United States. *Review of Economic Studies* 72, 189-221.

Lucas, Robert E., Jr. (2002). *Lectures on Economic Growth.* Cambridge, Mass.: Harvard University Press.

Malakellis, M. (1994). *ORANI-INT: An Intertemporal GE Model of the Australian Economy.* PhD Thesis, Centre of Policy Studies and Impact Project, Monash University.

Menaghan, E.G., and T.L. Parcel, (1991). Determining children's home environments: The impact of maternal characteristics and current occupational and family conditions. *Jornal of Maridaje and the Familia* 53: 417-431.

Martorell, R. (1995). *The effects of improved nutrition in early childhood: The Institute of Nutrition of Central America and Panama (INCAP) follow-up study 1995*, vol. 125: 1127S-1138S

Martorell, R., J. -P. Habicht, and J.A. Rivera (1995). History and design of the INCAP longitudinal study (1967-77) and its follow-up (1988-89). *Journal of Nutrition* 125: 1027S-1041S.

Mayer-Foulkes, D. (2001). The Long Term Impact of Health on Economic Growth in Latin America. *World Development* 29: 123-126.

_____ (2003). Convergence Clubs in Cross-Country Life Expectancy Dynamics. In: Rolph van der Hoeven and Anthony F. Shorrocks (eds) *Perspectives on Growth and Poverty*. Tokyo, United Nations University Press.

Micronutrient Initiative and United Nations Children's Fund (2004). *Vitamin and Mineral Deficiency Reports*. Available at http://www.micronutrient.org/reports/report.asp?cntry=Full

Miguel, E. (2005). Health, Education and Economic Development. In: Guillem López-Casasnovas, Berta Rivera and Luis Currais (Eds.). *Health and Economic Growth: Findings and Policy Implications*. Cambridge: MIT Press.

Miguel, E., and M. Kremer (2004). Worms: identifying impacts on education and health in the presence of treatment externalities. *Econometrica* 72 (1): 159-217.

Moock P., J.Leslie (1986). Childhood schooling and malnutrition in the Terai region in Nepal. *Journal of Development Economics* 20: 33-52.

Omran, A.R. (1971). The Epidemiologic Transition: A Theory of the Epidemiology of Population Change. *Milbank Memorial Fund Quarterly* 49, 509-38.

Oreopoulos, P. (2006). The compelling effects of compulsory schooling: evidence from Canada. *Canadian Journal of Economics 39,* 22-52.

Pollitt, E. (1990). Malnutrition and infections in the classroom: Summary and conclusions. *Food and Nutrition Bulletin* 12: 178-190.

Pollit, E., K.S. Gorman, P. Engle, R. Martorell, and J.A. Rivera (1993). Early supplementary feeding and cognition: effects over two decades. *Society for Research in Child Development* 58 (7): 1-99.

Quah, D.T. (1996). Twin peaks: growth and convergence in models of distribution dynamics. *The Economic Journal* 436 (106): 1045-1055.

_____ (1997). Empirics for growth and distribution: Stratification, polarization and convergence clubs. *Journal of Economic Growth* 2(1): 27-59.

Rosenzweig, M.R., and Schultz, T.P. (1982). Child mortality and fertility in Colombia: individual and community effects. *Health Policy Education* 2 (3-4): 305-48.

Sahn, D.E., and H. Alderman (1988). The Effects of Variables of Human Capital on Wages, and the Determinants of Labor Supply in a Developing Country. *Journal of Development Economics* 29: 157-83.

Saigal, S., B.L. Stoskopf, D. Feeny, W. Furlong, E. Burrows, P.L. Rosenbaum, and L. Hoult (1999). Differences in Preferences for Neonatal Outcomes Among Health Care Professionals, Parents, and Adolescents. *Journal of the American Medical Association* 281: 1991 - 1997.

Saigal, S., J. Pinelli, L. Hoult, M.M. Kim, and M. Boyle (2003). Psychopathology and Social Competencies of Adolescents Who Were Extremely Low Birth Weight. *Pediatrics* 111: 969 - 975.

Sargan, J. (1958). The estimation of economic relationships using instrumental variables. *Econometrica* 26(3): 393–415.

Schultz, P. (1999). Health and Schooling Investment in Africa. *Journal of Economic Perspectives* 13: 67-88.

Silveira-Neto, R., and C.R. Azzoni (2006). Location and regional income disparity dynamics: the Brazilian case. *Papers in Regional Science* 85(4): 599-613.

Simeon, D.T. (1998). School feeding in Jamaica: a review of its evaluation. *The American Journal of Clinical Nutrition* 67 (suppl): 790S-4S

Simpson, J. (2003). "Mom matters: maternal influence on the choice of academic roles", *Sex Roles: A Journal of Research* 48: 447-460.

Soares, R.R. (2007). On the determinants of mortality reduction in the developing world. *Population and Development Review* 33 (2): 247-287.

UNICEF and WHO (2004). *Low birthweight: country, regional and global estimates*. UNICEF: New York.

van Zon, A., H. Kiiver (2006). On the Persistence of Inequality and the Distribution of Personal Abilities and Income. *UNU-MERIT Working Paper series* 2006-13. Maastricht: United Nations University - Maastricht Economic and social Research and training centre on Innovation and Technology.

Waaler, H.T. (1984). Height, Weight and Mortality: the Norwegian Experience. *Acta Medica Scandinava.* Supplementum 679: 1 – 56.

Wachs, T.D., M. Sigman, Z. Bishry, W. Moussa, N. Jerome, C. Neumann, N. Bweibo, and M. McDonald (1992). Caregiver child interaction patterns in two cultures in relation to nutritional intake. *International Journal of Behavioural Development* 15: 1-18.

Weil, D. (2005). Accounting for the Effect of Health on Economic Growth. *NBER Working Papers* 11455. National Bureau of Economic Research, Inc.

Wendner, R. (1999). A Calibration Procedure of Dynamic CGE Models for Non-Steady State Situations Using GEMPACK. *Computational Economics* 13 (3): 265-287.

WHO (2007). *World Health Statistics 2007*. Geneva: WHO Press.

WHO, WFP, SCN, and UNICEF (2007). *Community-based management of severe acute malnutrition.* World Health Organization/World Food Programme/United Nations System Standing Committee on Nutrition/The United Nations Children's Fund: 2007.

Wickrama, K.A.S., R.D. Conger, L.E. Wallace, and G.H. Elder Jr. (1999). The Intergenerational Transmission of Health-Risk Behaviors: Adolescent Lifestyles and Gender Moderating Effects. *Journal of Health and Social Behavior*, 40 (3): 258-272.

Wickrama, K.A.S., R.D. Conger, and F.O. Lorenz (1994). Work, marriage, lifestyle, and change in men's physical health. *Journal of Behavioural Medicine* 18: 97-111.

Wilson, K., B. Wolfe, and R. Haveman (2005). The Role of Expectations in Adolescent Schooling Choices: Do Youths Respond to Economic Incentives? *Economic Inquiry* 43 (3), 467-492.

Yashin, A.I., and I.A. Iachine (1997). How frailty models can be used for evaluating longevity limits: taking advantage of an interdisciplinary approach. *Demography* 34 (1): 31-48.