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The family as producer of health — An extended grossman model.

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Abstract

Background: The Grossman model predicts that the individual will attain optimal investment in health when the (present value of) marginal cost of gross investments in health equals the (present value of) marginal benefits. This study reviews the model by Jacobson (2000) which attempted to examine whether, in a situation where the family makes health decisions together, they would equate the marginal benefit and marginal cost of gross investment of each family member to determine their optimal gross investment in health.
Results: In the single-person family, the individual invests in health until marginal benefits equal marginal costs. However in a two-person (husband and wife) or parents-child family with common preferences, the extended Grossman model reviewed in this study concluded that the family makes decisions together and to attain optimal investment in the health, the family members will invest in health until the rate of marginal consumption benefits equals the rate of marginal net effective cost of health capital. Consumption benefit is the utility that family members attain just by seeing other family members healthy or the the utility they attain for investing in the health of other family members.
Conclusion: The model concludes that poor families value a marginal change in child health higher than rich families. Also, a child with unhealthy (or selfish) parents can be expected to have lower health compared with a child with healthy (or altruistic) parents, because resources have to be spent on increasing the health of the unhealthy parents.

Keywords: Wealth, Health, investment, consumption benefit.

1 Historical Background

Economists have employed the capital theory to investigate individual's decisions to improve themselves and the potential future returns associated with it such as earning capacity. These economic investigations and application of the capital theory have provided frameworks for comprehending the rational choice of investing current resources in several aspects of observed human behaviour such as education and health with the aim of attaining future returns (Ben-Porath, 1967).

Formulations by Friedman and Kuznets (1945) and the crucial theory developments by Becker (1962, 1964) and Mincer (1958, 1962) have highlighted the relevance of the link between investment with present resources and the life-cycle of earnings. The central theme of their models is that increase in an individual's stock of knowledge or human capital such as education and on-the-job training are assumed to increase market and non-market or household sector productivity where he or she produces money earnings and commodities that enter his or her utility function respectively (Grossman, 1972b). In the quest of investigating the optimal quantity of investment in human capital at any age, Becker (1967) and Ben-Porath (1967), highlighted that the cost of investment includes direct outlays on market goods and the opportunity of time forgone. They further posited that optimal quantity of investment in human capital varies over the life cycle of the individual or individuals of same age (Grossman, 1972b).

Building on these economic developments but focusing on health, Grossman (1972b) built a demand for health model by making some significant justifications. He posited that health capital differs from other human capital in that as an individual's stock of knowledge affects his market and non-market productivity, his or her stock of health rather determines the total amount of time available to him or her in producing money earnings and commodities. The model also highlighted that, individuals do not demand health care services per se, but rather they demand 'good health or healthy days'. The model further assumes that individuals produce commodities with inputs of market goods and their own time. The model concluded that optimal investment in health is attained when the (present value of) marginal cost of gross investments in health equals the (present value of) marginal benefits. However, the gap in the literature was to find out, in a situation where the family makes health decisions together, whether they would equate the marginal benefit and cost of each family member to determine their optimal gross investment in health. This gap was filled by Jacobson's (2000) extended Grossman model which is reviewed in this study.

2 Introduction

The study reviews the "family as producer of health" model by Jacobson (2000). This model extends the Grossman model (Grossman, 1972a and 1972b) which assumed the individual as the decision-maker. In this model, the family is the decision-maker. The model is developed based on three stages of life or three different types of families as follows: (1) a model of a single-person family, thus, before marriage or after divorce (2) a model of a husband and wife family, thus, when the single person gets married without a child/children and, (3) a model of a parent with a child or children family or when the family of the married persons gives birth to a child or children. The model highlights that marital status, family size and the stages of life of an individual matters in health decision-making and investment. The model explains households behavior in terms of seeking health care for themselves and other members in the family. It reveals that child health policy interventions should not target the child (or children) only but its (or their) parents as well.

The fundamental relevance of the Grossman model (1972a and 1972b) is that individuals consume health care services because they demand 'good health' and the level of health affects the quantity and productivity of labour supply in an economy. Overtime, researchers were led to investigating policy effects on individuals' demand for health and health related behaviour in the present (i.e., direct effects) and over his or her lifetime (i.e., indirect effects). Observed inequalities in health depicts that policy affects different individuals differently. The novelty of the "extended Grossman" model is to highlight factors that impact inequalities in health within the family context.

Following Grossman (1972a and 1972b), the model argues that a family member receives investment and consumption benefits from investing in his or her own health and the health of other family members. Increased parent or child health means future time spent sick or for taking care of a sick child declines which increases family time available for market work, family income, consumption, and investment possibilities for all family members (i.e., investment benefits). A Family member derives utility from investing in his or her own health and the health of other family members (i.e., consumption benefits) such as spouse and children because he or she cares about them. The shadow price of health include, among other variables, the price of medical care and it is negatively correlated with the quantity of health demanded.

2.1 Research Objective

The study attempts to review the extended Grossman model by Jacobson (2000). It highlights the strengths, limitations and opportunities for extension of the model. It also explains the possible policy implications and testable hypotheses from the model.

3 Assumptions

Individual's income and wealth and the earnings of other family members are used in the production of health. Productivity may be determined by a family member's education and the education of other family members. The model makes the following assumptions:

1. The family (rather than the individuals making up the family) are assumed to

have a common preference/interests and make decisions concerning, but not limited to the investments in adult and child health.

2. The family produces commodities with inputs of market goods and their own time.
3. Complete certainty is assumed.
4. Medical care services are the only inputs in the production of health even though there are others like diet, exercise, and housing.
5. 'Other commodities' mentioned in the model are produced and consumed in period t, i.e., they cannot be stored.

4 Optimization Problems

Given each family member's initial health capital, the initial family wealth and production functions and prices, the family chooses the quantity of market goods to consume in each time period to maximize family lifetime utility. The time path of family wealth and that of each family member's health are then given by the optimal amounts of market goods selected. Optimal control approach with constraints is employed in this model (Chiang, 1992, pp. 276). The optimization problem for the single-person family, the husband-wife family and the parent-child family are discussed below.

4.1 Single-person family

The individual who is the decision-maker attains utility from his or her own health, H_t, and from the consumption of other commodities, Z_t. Thus, his or her strictly concave utility function in period t is:

$$u_t = u(H_t, Z_t) \qquad \text{t=time period} \tag{1}$$

The individual invests in his or her health as it depreciates during his or her lifetime. Hence, the stock of health of the individual will develop over time according to:

$$\frac{\partial H_t}{\partial t} = I_t - \delta_t H_t \tag{2}$$

where δ_t is the rate of depreciation and I_t is gross investment. Equation 2 is the equation of motion for the state variable "Health".

An individual produces other commodities, Z_t and gross investment in health, I_t, using market goods and services (i.e., M_t denotes medical goods and X_j denotes other goods), his/her own time used in the production of health and other commodities, (h_t) and efficiency parameters, $E_{t,H}$, as follows:

$$I_t = I_t(M_t, h_{t,H}; E_{t,H}) \tag{3}$$

$$Z_t = Z_t(X_t, h_{t,Z}; E_{t,Z}) \tag{4}$$

These production functions are assumed to be homogenous of degree one in both goods and time inputs.

Individual stock of wealth, W_t, develops according to:

$$\frac{\partial W_t}{\partial t} = rW_t + \omega_t(H_t, E_{t,\omega})h_{t,\omega,m} + B_t - p_t M_t - q_t X_t \tag{5}$$

where Equation 5 is the equation of motion for the state variable "Wealth". ω_t is the wage rates, B_t is transfer payments, and r is the market interest rate. $E_{t,\omega}$ includes the level of education and on-the-job training, and $h_{t,\omega,m}$ is his or her amount of time spent in market work. The p_t and q_t denote the prices of medical care M_j and other goods X, respectively. The $\omega_t(H_t, E_{t,\omega})$ can be termed as the 'labour market earnings rate of return on human capital' since, according to the formulation in Equation 5, an individual's productivity in market work is determined by his or her amount of health capital and level of education and on-the-job training.

The healthy time available in each period is:

$$\Omega = h_{t,\omega} + h_{t,H} + h_{t,Z} + h_{t,S} \tag{6}$$

where Ω is total time or time restriction. $h_{t,S}$ is time spent sick and it is determined by the individual's amount of health capital ($h_{t,S} = h_{t,S}(H_t)$). $h_{t,\omega}$ is time spent in market work. $h_{t,H}$ is time spent in producing health. $h_{t,Z}$ is time spent in producing other commodities. Assume that $\frac{\partial h_{t,S}}{\partial H_t} < 0$ and $\frac{\partial^2 h_{t,S}}{\partial^2 H_t} > 0$.

The individual chooses the time paths of the control variables M_t and X_t that maximizes his or her lifetime utility as follows:

$$\text{Max} \;\; U = \int_t^T e^{-\theta t} u(H_t, Z_t) \tag{7}$$

$$\text{such that} \;\; \frac{\partial H_t}{\partial t} = I_{t,H} - \delta_t H_t$$

$$\frac{\partial W_t}{\partial t} = rW + \omega_t(H_t, E_{t,\omega})h_{t,\omega} + B - p_t M_t - q_t X_t$$

$$\Omega = h_{t,\omega} + h_{t,H} + h_{t,Z} + h_{t,S}$$

$H(0)$=H_0, $W(0)$=W_0, H_0 and W_0 given

$H(T) = H_T \leq H_{min}$, $W(T)$ =$W_T \geq 0$, $W_T * \lambda_{T,W} = 0$

T free

and X_t, $M_t \geq 0$ for all $t \in [0, T]$,

The individual's inter-temporal utility function, U, is discounted by his or her rate of time preference. Individual's 'death stock' of health capital is represented by H_{min} and he or she dies when health passes below H_{min}. T denotes time of death and it is determined by H_{min}. Though the individual can borrow or lend money at each period, the bequest (W_T) cannot be negative.

The solution to the single person family optimization problem is (see appendix for calculations):

$$\left(\frac{e^{-\theta t}}{\lambda_{t,W}}\right)\frac{\partial u_t}{\partial H_t} + h_{t,\omega}\frac{\partial \omega_t}{\partial H_t} - \left(\frac{\varphi_t}{\lambda_{t,W}}\right)\frac{\partial h_{t,S}}{\partial H_t} = \pi_t\left[\delta_t + r - \left(\frac{\partial \pi_t}{\partial t}\right)/\pi_t\right] \tag{8}$$

Thus, the individual invests in health until the marginal benefit of new health equals the marginal cost of health.

The $\lambda_{t,W}$ and $\lambda_{t,H}$ are costate variables. $\lambda_{t,W}$ denotes economic stress. φ_t is the lagrange multiplier for the time restriction and it denotes time stress. $\frac{\partial u_t}{\partial H_t}$ is marginal utility of health capital. $\frac{\partial \omega_t}{\partial H_t}$ is the marginal effect of health on wage. $\frac{\partial h_{t,S}}{\partial H_t}$ is the marginal effect of health on the amount of sick time and π_t is the effective price of medical care goods and services (M_t). Note: $\pi_t = p/\left(\frac{\partial I_t}{\partial M_t}\right)$ (see appendix).

4.2 The husband-wife family Model

In this model, the family is the producer of health. Each family member is the producer of his own health and the health of his or her partner using the family earnings. Health is demanded by the family as a consumption good, directly entering the family lifetime utility function, u, (i.e., sick days is a source of disutility); and as an investment good, determining the total amount of time available for market and non-market activities. The level of health is assumed to be endogenous, depending (at least in part) on the resources allocated to its production. The utility function, u_i, of the family in period t is:

$$u_i = u_i(H_i, Z) \qquad \text{i=m,f} \tag{9}$$

The time subscripts are omitted for simplification. The health of the husband (male) and wife (female) are denoted as H_m and H_f, respectively. Z and M_i denote a vector of commodities consumed and market goods used in producing male and female health, respectively. It is worth noting that stock or state variables (W and H)

change over time but control variables (M and X) are chosen by decision maker(s) at any time.

Time used in the production of health is indicated by $h_{Hi,m}$ and $h_{Hi,f}$. The first subscript denotes what is produced; male or female health (Hi for $i = m, f$), the second subscript denotes who is the producer; the husband (m) or the wife (f). $E_{H,m}$ and $E_{H,f}$ indicate male and female productivity in health production (i.e., efficiency parameters such as maternal level of education). As in the single-person case, the family produces gross investment in health, I_i, to offset depreciation in health, δ_i, according to the production functions:

$$I_i = I_i(M_i, h_{i,H}; E_{i,H}) \qquad \text{i=m,f} \tag{10}$$

The net investment in health is also as follows:

$$\frac{\partial H_i}{\partial t} = I_i - \delta_i H_i \qquad \text{i=m,f} \tag{11}$$

Family wealth is also developed as follows:

$$\frac{\partial W}{\partial t} = rW + \omega_i(H_i, E_{\omega,i})h_{\omega,i} + B - p(M_m + M_f) - qX \qquad \text{i=m,f}$$

where $\omega_i(H_i, E_{\omega,i})$ for $i = m, f$ are the husband's and wife's wage rates or labour market earnings rates of return on human capital. $E_{\omega,i}$ for $i = m, f$ are the husband's and wife's level of education and on-the-job training, and $h_{\omega,i}$ for $i = m, f$ is his or her amount of time spent in market work. The time restrictions are:

$$\Omega_i = h_{w,i} + h_{Z,i} + h_{Hm,i} + h_{Hf,i} + h_{S,i} \qquad \text{for i=m,f}$$

Total time for each spouse Ω_i is allocated between time spent in market work $h_{w,i}$, in home production of health ($h_{Hm,i}$+ $h_{Hf,i}$) and other commodities $h_{Z,i}$ and time being sick $h_{S,i}$, where health determines the amount of sick time ($h_{S,i} = h_{S,i}(H_i)$).

The time path of family wealth and that of each family member's health are given by the optimal amounts of market goods chosen (Jacobson, 2000). The family faces the following optimization problem:

$$U = \int_t^T e^{-\theta t} u(H_m, H_f, Z) \tag{12}$$

such that:

$\frac{\partial H_i}{\partial t} = I_i - \delta H_i$ for $i = m, f$.

$$\frac{\partial W}{\partial t} = rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} + B - p(M_m + M_f) - qX$$

$$\Omega_i = h_{w,i} + h_{Z,i} + h_{Hm,i} + h_{Hf,i} + h_{S,i} \qquad \text{for i=m,f}$$

and boundary conditions:

$H_i(0)$ given for $i = m, f$ (initial health stock)

$H_i(T) \leq H_{min}$ for at least one of $i = m, f$ (individual dies when health equates or falls below the H_{min} level)

$W(T) \geq 0$, $W(T) * \lambda_W(T) = 0$ (the non-negativity and complementary slackness conditions)

T free

and X, $M_i \geq 0$ for all $t \in [0, T]$, j=m,f,c.

T is the lifetime of the husband-wife family.

The solution to Husband and wife family optimization problem is (see appendix for calculation):

$$\left(\frac{\partial u}{\partial H_m}\right) / \left(\frac{\partial u}{\partial H_f}\right) = \frac{\pi_m\left(\delta_m + r - (\frac{\partial \pi_m}{\partial t})/\pi_m\right) - [(\partial\omega_m/\partial H_m)h_{\omega,m} - (\varphi_m/\lambda_W)(\partial h_{S,m}/\partial H_m)]}{\pi_f\left(\delta_f + r - (\frac{\partial \pi_f}{\partial t})/\pi_f\right) - [(\partial\omega_f/\partial H_f)h_{\omega,f} - (\varphi_f/\lambda_W)(\partial h_{S,f}/\partial H_f)]} \tag{13}$$

where the effective price $\pi_i = p/\left(\frac{\partial I_i}{\partial M_i}\right)$ and $i = m, f$ (see appendix). In a Husband-wife family with common preferences, unlike the Grossman model, the husband and wife together invest in health until the rate of marginal consumption benefits (i.e., left hand side of Equation 13) equals the rate of marginal net effective cost of health capital (i.e., right hand side). Recall that consumption benefit is the utility that family members attain just by seeing other family members healthy or the the utility they attain for investing in the health of other family members.

The net effective cost of health capital equals the user cost of capital less the marginal investment benefit of health capital (in brackets). Thus, the cost and benefit associated with health capital investment. The marginal investment benefit of a partner's health is the sum of the monetary value of the change in time taking care of a sick partner, for a marginal change in the partner's health.

A similar result can be attained or deduced for lifetime utility of health such that (see F.O.C in the Appendix for the calculation):

$$\lambda_W = \frac{\lambda_{Hf}}{\pi_f} = \frac{\lambda_{Hm}}{\pi_m} \tag{14}$$

Equation 14 implies that family members will invest in health until the rate of marginal (lifetime) utility of health to the effective price of health is equal for all family members (and equal to the marginal utility of wealth).

4.3 Parent-child family Model

Assume a household/family that includes a father, mother and a child. The family members produce their own health and the health of their child. The family has a strictly concave utility function which is a function of their own health, H_{tj} (for j=m,f,c and t is time period), and the consumption of other commodities, Z_t, where utility in period t is:

$$u_j = u_j(H_j, Z) \qquad \text{j=m,f,c} \tag{15}$$

where u denotes family utility in period t. H_m, H_f, and H_c denote the health of the male (husband), female (wife) and child, respectively and Z represents a vector of commodities consumed. Time subscripts are omitted for simplification. The stock of health for the child will depreciate during his or her lifetime, but the parents can invest in health of the child (produce child health capital) to offset this depreciation in health capital. Parents produce own health and child health, H_j, using market goods and services (i.e., M_j and X_j for j=m,f, c) and parental time. It is worth noting that the parent-child family (i.e., parents) produces gross investments in health, I_j (for j=m,f,c), and other commodities, Z_j, according to the production functions below:

$$I_j = I_j(M_j, h_{Hj,m}, h_{Hj,f}; E_{H,i}) \qquad \text{j=m,f,c and i=m,f} \tag{16}$$

$$Z_j = Z_j(X_j, h_{Hj,m}, h_{Hj,f}; E_{H,i}) \qquad \text{j=m,f,c and i=m,f} \tag{17}$$

where market goods are denoted by M_j (i.e., medical care or goods or services for j=m,f,c) and X_j (i.e., other goods for j=m,f,c).

Parental and child health, H_j, develops over time (i.e., net investment in health) according to:

$$\frac{\partial H_j}{\partial t} = I_j - \delta_j H_j \qquad \text{j=m,f,c} \tag{18}$$

which is the equation of motion for the state variable *Health* (parental and child health), H_j (for j=m,f,c), and where δ_j is the rate of depreciation (for j=m,f,c). Family stock of wealth W_t will develop over time according to the equation of motion:

$$\frac{\partial W}{\partial t} = rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} + B - p(M_m + M_f + M_c) - qX \tag{19}$$

where $\omega_m(H_m, E_{\omega,m})$ and $\omega_f(H_f, E_{\omega,f})$ are the husband's and wife's wage rates or labour market earnings rates of return on human capital, respectively. $E_{\omega,m}$ ($E_{\omega,f}$) is the husband's (wife's) level of education and on-the-job training, and $h_{\omega,m}$ ($h_{\omega,f}$) his (her) amount of time spent in market work. The p and q denote the prices of medical care M_j and other goods X, respectively. The state variables are W_t and H_j (time subscript omitted). The control variables are M_j and X_j.

The time restriction for each parent (husband and wife) becomes:

$$\Omega_i = h_{\omega,i} + h_{Z,i} + h_{Hm,i} + h_{Hf,i} + h_{Hc,i} + h_{S,i} + h_{Sc,i} \qquad \text{i=m,f} \tag{20}$$

where total time for each spouse Ω_i is allocated between time spent in market work $h_{w,i}$, in home production of health ($h_{Hm,i}+h_{Hf,i}$) and other commodities $h_{Z,i}$ and time being sick $h_{S,i}$, where health determines the amount of sick time (*i.e.*, $h_{S,i} = h_{S,i}(H_i)$). $h_{Sc,i}$ is time taking care of a sick child for parent i, and where $\frac{\partial h_{Sc,i}}{\partial H_c} < 0$ and $\frac{\partial^2 h_{Sc,i}}{\partial H_c^2} > 0$.

The family chooses the amount of market goods (i.e., medical care goods/services, M, and consumption goods, X) to consume in each time period in order to maximize family lifetime utility, given initial parent-child family wealth and each family member's initial amount of health capital, and given the production functions and prices. The time path of family wealth and that of each family member's health are given by the optimal amounts of market goods chosen (Jacobson, 2000). The parent-child family optimization problem is stated as:

$$\text{Max} \;\; U = \int_t^T e^{-\theta t} u(H_m, H_f, H_c, Z) \tag{21}$$

such that (ie., state variables and time constraints):

$\frac{\partial H_j}{\partial t} = I_j - \delta H_j$ for $j = m, f, c$.

$$\frac{\partial W}{\partial t} = rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} + B - p(M_m + M_f + M_c) - qX$$

$$\Omega_i = h_{w,i} + h_{Z,i} + h_{Hm,i} + h_{Hf,i} + h_{Hc,i} + h_{S,i} + h_{Sc,i} \qquad \text{for i=m,f}$$

and boundary conditions:

$H_j(0)$ given for $j = m, f, c$ (initial health stock)

$H_j(T) \leq H_{min}$ for at least one of $j = m, f, c$ (individual dies when health equates or falls below the H_{min} level)

$W(T) \geq 0$, $W(T) * \lambda_W(T) = 0$ (the non-negativity and complementary slackness conditions)

T free

and X, $M_j \geq 0$ for all $t \in [0, T]$, j=m,f,c.

T is the lifetime of the parents-child family.

The solution to the Parent-child family optimization problem is (see appendix for calculation):

$$\frac{\partial u/\partial H_i}{\partial u/\partial H_c} = \frac{\pi_i(\delta_i + r - (\partial\pi_i/\partial t)/\pi_i) - [(\frac{\partial w_i}{\partial H_i})h_{w,i} - (\varphi_i/\lambda_W)(\partial h_{S,i}/\partial H_i)]}{\pi_c(\delta_c + r - (\partial\pi_c/\partial t)/\pi_c) - [-(\varphi_m/\lambda_W)(\partial h_{Sc,m}/\partial H_c) - (\varphi_f/\lambda_W)(\partial h_{Sc,f}/\partial H_c)]} \quad \text{i=m,f} \tag{22}$$

where $\partial u/\partial H_i$ and $\partial u/\partial H_c$ are the rate of marginal consumption benefits for parents and child, respectively. The effective price $\pi_j = p/\left(\frac{\partial I_j}{\partial M_j}\right)$. In a Parent-child family (with common preferences), unlike the Grossman model, the parents together invest in health until the rate of marginal consumption benefits (i.e., LHS) equals the rate of marginal net effective cost of health capital (i.e., RHS).

The Net effective marginal cost of child health (denominator in RHS) is equal to the user cost of child health capital (L.H.S) less the marginal investment benefit of child health (R.H.S in brackets). The marginal investment benefit of child health is the sum of the monetary value of the change in time taking care of a sick child for the father and mother respectively, for a marginal change in child health.

The rate of marginal net effective cost of health capital (numerator in RHS) equals the user cost of capital for the parents (L.H.S) less the marginal investment benefit of health capital (R.H.S in square brackets).

In the single-person family, the individual invests in health until marginal benefits equal marginal costs. However in a two-person (husband and wife) or parents-child family with common preferences, the husband and wife or the family invests together in health until the rate of marginal consumption benefits (L.H.S) equals the rate of marginal net effective cost of health capital (R.H.S).

From the First order conditions (See appendix), we realize or we can deduce that:

$$\lambda_W = \frac{\lambda_{HC}}{\pi_c} = \frac{\lambda_{Hf}}{\pi_f} = \frac{\lambda_{Hm}}{\pi_m} \tag{23}$$

This implies that the family invests in health until the rate of marginal utilities of (lifetime) health to effective price of health for all family members is equal (and equal to the marginal utility of wealth).

5 Graphical representation of the model

The optimal investment in the model and analysis are represented as follows. The optimal distribution of family health based on Equations 21 and 22 is presented in Figure 1 (See Appendix). Assume there is only one parent and one child in the family, given Z (i.e., other commodities). The parent health (H_i) is measured on the vertical axis and the child health (H_c) is measured on the horizontal axis. The right-hand side of equation 22 represents the slope of the production possibility curve (AB)[1]. The left-hand side of equation 22 denotes the slope of the indifference curve, UU, which represents the level of family utility. Points A and B are when all family

[1]i.e., the ratio of marginal net effective cost of adult health and marginal net effective cost of child health. The production possibility curve (AB) shows all possible combinations of child and parent health, given family time resources and initial wealth, and the user cost of capital (net of monetary benefit) and its shape is partly determined by the fact that as health is increased, more healthy time is allocated to market work, and hence family income increases.

time and resources are allocated to the production of parent health and child health, respectively.

The points on the segments AF and BD do not represent stable situations because health of the parent or child could be increased without decreasing the health of the other (not Pareto-efficient). Thus, from point B, when one amount of parent health is produced using family time and wealth, adult sick time will reduce resulting in increased family income and increased child health until health state D is reached. At point D, increased adult health is expensive and hence to make additional investments in adult health will mean decline in child health until health state F is reached. Child health had been reduced to get to point F, hence at that point, the parent would have to spend more time taking care of the sick child (and less time available for market work) hence family income would no longer be enough to make gross investments in health compensating for the depreciation so both child and parent health would fall (from F towards A). Note that the points on the segments AF and BD are only stable when lack of treatment prevents additional gross investment in health from offsetting depreciation. Hence, for a constant Z, the analysis will be focused on the negatively sloping part of the production possibility curve where the parent-child health trade-off exists. The optimal distribution of family health is based on several factors as discussed below.

5.1 Selfish Versus Altruistic parents

When parents are completely selfish, their utility function will not include child health per se hence indifference curves will be horizontal. Maximizing family utility, given Z_t, subject to the production possibility set (budget constraint) implies that parents would invest in child health until point F is attained. I opine that further than F (i.e., from F to D) would mean that the parent(s) would have to sacrifice or give up investment in his or her health and a selfish parent will not be willing to do that. This means that, based on investment benefit from health in terms of increased child health availing more time for market work and increasing family income, even selfish parents would invest in child health.

Completely altruistic parents' indifference curve, however, will be vertical and maximizing family utility implies that parents would invest in child health until point D (from A to D) is reached. I opine that further than D may not be advisable as health for both parent and child declines (i.e., from D to B). Thus, all other things being equal, the location of point P, optimal level of family health distribution, on the production possibility curve from F to D will depend largely on parent's selfishness or degree of altruism toward the child. A more altruistic parent will choose a point closer to D (invest more in child health relatively) than a less altruistic parent.

5.2 Initial endowments of Health capital

Assuming that, at the beginning of period t, point E denotes the endowed amounts of health capital (i.e., both parent and child are less healthier or are under-invested), the adult would invest in both his or her own health and child health until point P was attained. However, in a situation where there is lack of treatment for adult health then the adult would maximize utility by investing in child health until point O is attained.

Assuming that, at the beginning of period t, point O denotes the endowed amounts of health capital (i.e., the child's health is above and the parent's health is below what is regarded as optimal point, P), the parent would invest in his or her own health only and let the child health depreciate until point P, all other things being equal, was reached. It may look as though the parent under-invested in child health, but this would be a utility maximising behaviour given the restrictions he or she was faced with.

I add that if at the beginning of period t, point F denotes the endowed amounts of health capital (i.e., the child's health is below and the parent's health is above what is regarded as optimal point, P), then the parent would invest less in his or her own health and invest more in child health until the optimal point P, all other things being equal, was reached. Thus, I add that the location of point P on the production possibility curve between F and D will depend on the initial endowment of the parent's health; ceteris paribus, a more healthier parent would choose a point toward or closer to D than a less healthy parent.

5.3 Changes in exogenous variables

An increased depreciation rate, δ (or an increased coinsurance rate in the health insurance system, increases price of medical care goods and services p that increases π) increases the net cost of health capital hence would affect family health. If both child and parent depreciation rates increased, but that of the child δ_c increased more than that of the parent δ_p, then the P, optimal health, would move to P' in Figure 2 (see appendix). The income effect (move from P to P'') would decrease both child and parent health, but the substitution effect (move from P'' to P') would increase parent health while decreasing child health. The total effect (move from P to P') would be a reduction in child health, while the effect on parent health would be ambiguous.

It can be deduced that a reduction in the coinsurance rate for medical care utilisation by children (aimed to increase child health) would have a positive effect on child health but the effect on parent health is ambiguous. However, as the cost of child health is now reduced, resources previously used to produce child health can now partly be spent on adult health production (and partly on the production of other consumption commodities). Health related information will have a similar effect. Increased health related information, $E_{H,i}$ will make the parent more productive in producing new health and decrease both π_i and π_c (effective price).

Using Figure 3 (see appendix), if the value of parent time is set equal to his or wage rate (i.e., $\frac{\theta_i}{\lambda_W} = \omega_i$, i=m,f) and if some insurance exists (in the social insurance system) that covers x percent of losses accrued to taking care of a sick child, then the net cost of child health will be:

$$\pi_c(\delta_c + r - (\frac{\partial \pi_c}{\partial t})/\pi_c) - [-\omega_m(\frac{\partial h_{Sc,m}}{\partial H_c})(1-x) - \omega_f(\frac{\partial h_{Sc,f}}{\partial H_c})(1-x)] \qquad (24)$$

For $x > 0$, the net cost of child health in Equation 24 is higher than the net cost of child health in Equation 22 (the denominator on the right hand side) which implies a lower optimal level of child health. Thus, an increase in the level of compensation for income losses due to taking care of a sick child x decreases the monetary value of investments in child health, increasing the net (effective marginal) cost of child health (which is the user cost of child health capital less the marginal investment benefit of child health). This implies that an increased rate of compensation will reduce the incentive to invest in child health. Hence, the slope of the production possibility curve will increase from AB to AB' (see figure 3). Optimal health, P, will move to P'. The effect on child health will be negative or child health decreases as compensation level increases, while the effect on parent health (H_i) is ambiguous. The reason for the decline in child health is that, the parental time (or wage) is sensitive to child health hence, after the compensation increased, the parent cannot increase family income as much as before the compensation by investing in child health. An increase in the compensation for losses due to own parent illness will have a similar effect, however increase in the level of compensation will now partly be offset by the reduction in the wage rate caused by the parent's reduced health, H_i.

Family initial production possibilities are given by AB (see figure 3), and optimal health by point P. An increase in transfer payment (B) will shift the production possibility curve to the right and increase both parent and child health (move from P to P'') as it increases family resources available for family production of health and other commodities, leaving the ratio of net cost of health capital unchanged.

6 Testable Hypotheses

The following hypotheses from the model can be tested:

1. Rearranging Equation 23, $\lambda_{HC} = \lambda_W \pi_c$ is attained. This implies that when the wealth restriction is binding, poor families value a marginal change in child health higher than rich families and hence, families for who the wealth constraint is not binding (λ_W=0), they have a zero marginal utility of child health. Diminishing marginal utility of income depicts that the utility attached to additional wealth, λ_W, is higher for the poor and lower for the rich.

2. Even a selfish parent will invest in child health as it affects family income (i.e., investment benefit). However, a more altruistic parent will invest in child health more than a selfish or a less altruistic parent.

3. A child with unhealthy parents can be expected to have lower health compared with a child with healthy parents. Thus, resources are invested in the health of the unhealthy parents.

4. An increased rate of depreciation (in health) will decrease the individual's level of health. However, if the child's health depreciates more than that of the parent, then there would be a reduction in child health, while the effect on parent health would be ambiguous (i.e., total effect).

5. An increased coinsurance rate will decrease the individual's level of health. A decline in the coinsurance rate for health care use by children would increase child health but the effect on parent health is ambiguous.

6. Increased health related information will make the parent more productive in producing new health, decrease the effective price of producing health and increase child health.

7. When an individual's wage rate becomes more sensitive to differences in health,

the individual will invest more in health. Hence, an increase in the level of compensation (in the social insurance system) for income losses due to taking care of a sick child decreases the monetary value of investments in child health which increases the net cost of child health and decreases child health while the effect on parent health is ambiguous.

8. Increased transfer payments increases family resources available for family production of health and other commodities and hence it increases both parent and child health.

9. The more restricting the time constraint is, the higher the individual's valuation of time will be and the more the individual invest in health.

10. If we assume that because of lack of treatment the adult health cannot be increased then the model posits that the adult will maximise utility by 'over-investing' in child health. However, in case their endowed amounts of health capital were such that the child's health was above and the parent's health below what is regarded as optimal, then the parent will invest only in own health and let child health depreciate until optimum was reached.

6.1 Policy Implications

Policy implications of the model include:

1. Child health policies should not target children only but also other family members' health, preferences, education, and income. For instance, health policies could give transfer payments to parents and also provide them with affordable housing and health insurance especially the poor families.

2. The governments in Lower-Middle-Income countries should undertake universal public financing of childhood diseases and increase health coverage especially to poor families.

6.2 Relaxing the assumptions- Nash Bargaining model

Spouses may not always have common preferences and the one who has control of resources may have impact on how they are allocated. According to the Nash bargaining model, family decisions are the outcome of some bargaining process and family demands will depend on prices and total family income and the determinants of the threat points. The threat points at time t of the Nash-bargaining process are the maximum utility that each spouse would enjoy if cooperation breaks down at that same point in time. Thus, the utility or outcome at divorce. The threat point of a spouse, let's say the wife, will decrease relative to the threat point of the other spouse (i.e., husband) if she has the highest risk of becoming unemployed in case of divorce (Bolin et al., 2001). Using a Nash bargaining model and exploring the effect of wife's non-health income on family health, we have the following (see figure 4 in appendix).

Male health (H_m) and female health (H_f) is represented by the horizontal and vertical axis, respectively. An increase in the woman's non-earned income will shift the production possibility curve out similar to the increase in transfer payment in the common preference case (in Figure 3). However, in this case, an increase in non-earned income will also affect the iso–gain product curve (the bargaining analogue of indifference curves) through its effect on the threat-point[2]. Thus, if utility as single is the actual threat-point, then her bargaining power will increase, because the increase in her non-earned income will increase her utility as single. The iso–gain product curve will twist from NN to $N''N''$. The increase in female health will be larger, H''_f - H_f (in the Nash bargaining model) compared to H'_f - H_f (in the common preference case). However, if her threat-point is unaffected by this increase in non-earned income, then the new iso-gain product curve is given by the dashed curve $N'N'$.

[2]According to cooperative Nash bargaining model, the objective of the spouses is to maximise a utility–gain production function, defined as the product of the husband's gain and the wife's gain from marriage. These gains from marriage will decrease when utility as single (the threat point) increases.

The increase in the wife's non-earned income may also increase child health because (1) she cares more about child health than the father does, or (2) because she prefers more healthy goods than the husband does. The health of all family members will also increase.

6.3 Relaxing the assumptions- Complete certainty

People are uncertain about (1) the current size of the health capital, (2) the rate of depreciation of the health capital and (3) the effects of the various inputs in the health production function on the health capital. Hence, the (expected) total family health capital would be larger in the uncertain case than in the certain case. Thus, in an uncertain world, risk-averse individuals make larger investments in health and have greater expected health stocks than they would in a perfectly certain world.

With common preferences, the relative distribution of (expected) health capital among family members would remain the same as the certain case. With non-common preferences, however, the relative distribution may change, since family members may then have different attitudes towards risk and uncertainty. The optimal portfolio of health investments may be quite different for different family members, depending partly on diverging attitudes towards risk among family members.

6.4 Extended versions of the model and Future Research

1. Bolin et al. (2001) extends the current model and explains a situation where the spouses in the family are Nash-bargainers. Thus, a situation where spouses can use divorce to threaten each other to increase their bargaining power. This has been introduced in the current study but explained into detail by Bolin et al. (2001).

2. Bolin et al. (2002b) extends the models further beyond assuming complete certainty and spouses who are Nash-bargainers. They consider a situation where spouses interact strategically both in the production of own health and

in the production of health of other family members when divorce has actually happened. They consider situations where changes in family policies, such as child allowance and custody rules impact the distribution of health.

3. Bolin et al. (2002a) extends the model to consider an instance where an employer has some incentives to undertake investment in the health of a family member. The household and the employer are assumed to interact strategically in the production of health. The employer and the employee conditions such as market conditions, production technologies, taxes, and government regulation will impact the allocation of health investments and health capital within the family.

7 Strengths

1. Other models extended the Grossman model but based on the individual as producer of health. However, the model by Jacobson (2000) used the family as producer of health hence, unlike the other extended models, it can be applied to analyze children's demand for health and their health care utilization.

2. The influence of other family members on the individual's demand for health and demand for health care can be explained within the model.

3. Unlike other extended models, this model allows the explanation and analysis of resource allocation into the investment in parental (or adult) and child health.

4. In the Grossman model, an individual knows when he or she prefers to use his or her time and money to produce other commodities than health but it may be difficult to observe when 'enough' investments have been made in another person's health. The reviewed model makes this limitation in the Grossman model possible for analysis.

7.1 Limitations

1. The model did not consider real-world situations where employers of parents, the government or external agents invest in the health of the child.

2. Important family-related decisions such as family formation i.e., marriage or divorce, family size and inter-sibling allocation of resources were not considered.

3. The interaction between quantity and quality of children, and whether the transfers of resources from parents to children are based on efficiency or equity considerations were not considered.

8 Conclusion, Discussion and Recommendation

The model discusses situations where the family, other than an individual, makes decision concerning investment in health of its members together. This extension was crucial as it highlights the effect of the health status of family members on the health and health behavior of other family members, especially children. It proposes some policy implications and recommendations.

The model in this study developed a demand for health model that considers the characteristics and behavior of family members on the individual's health and health care utilization. It revealed that when each family member produces his or her own health and that of family members, then the family will not try to equalize marginal benefits and marginal costs of health capital for each family member as could be inferred from the Grossman model. They will preferably invest in health until the rate of marginal consumption benefits equals the rate of marginal net effective cost of health capital. Jacobson (2000) asserts that the production possibility set, the optimal level and distribution of family health is impacted by the level of compensation in the social insurance system, the effective price of care, health related information and transfer payments.

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10 Appendix

Solution

The Optimization problems for each family type is solved using the Optimal control theory with inequality constraints approach (Chiang, 1992, p. 277). The family problem will be to choose the time paths of the control variables M_m, M_f, M_c and X in order to maximize family lifetime utility (or the Hamiltonian, V):

$$V = u(H_m, H_f, H_c, Z)e^{-\theta t} + \lambda_{Hm}[I_m(M_m, h_{Hm,m}, h_{Hm,f}; E_{H,m}, E_{H,f}) - \delta_m H_m]$$

$+\lambda_{Hf}[I_f(M_f, h_{Hf,m}, h_{Hf,f}; E_{H,m}, E_{H,f}) - \delta_f H_f]$

$+\lambda_{Hc}[I_c(M_c, h_{Hc,m}, h_{Hc,f}; E_{H,m}, E_{H,f}) - \delta_c H_c]$

$+\lambda_W[rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} - p(M_m + M_f + M_c) - qX]$

subject to some constraints.

The Lagrangian expression for solving this problem is formed as (Chiang, 1992, p. 277):

$$L = V + \varphi[\Omega - h_{w,m} + h_{Z,m} + h_{Hm,m} + h_{Hf,m} + h_{Hc,m} + h_{S,m} + h_{Sc,m}]$$

$+ \varphi[\Omega - h_{w,f} + h_{Z,f} + h_{Hm,f} + h_{Hf,f} + h_{Hc,f} + h_{S,f} + h_{Sc,f}]$

Therefore:

L=u(H$_m, H_f, H_c, Z)e^{-\theta t}$

$+\lambda_{Hm}[I_m(M_m, h_{Hm,m}, h_{Hm,f}; E_{H,m}, E_{H,f}) - \delta_m H_m]$

$+\lambda_{Hf}[I_f(M_f, h_{Hf,m}, h_{Hf,f}; E_{H,m}, E_{H,f}) - \delta_f H_f]$

$+\lambda_{Hc}[I_c(M_c, h_{Hc,m}, h_{Hc,f}; E_{H,m}, E_{H,f}) - \delta_c H_c]$

$+\lambda_W[rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} - p(M_m + M_f + M_c) - qX]$

$+ \varphi[\Omega - h_{w,m} + h_{Z,m} + h_{Hm,m} + h_{Hf,m} + h_{Hc,m} + h_{S,m} + h_{Sc,m}]$

$+ \varphi[\Omega - h_{w,f} + h_{Z,f} + h_{Hm,f} + h_{Hf,f} + h_{Hc,f} + h_{S,f} + h_{Sc,f}]$(25)

where the Lagrangean multiplier φ is made dynamic, as a function of t. This is necessary because the time constraints apply throughout the lifetime of the family. Time period t is omitted for simplification. Assuming interior solution for each control variable (i.e., M, and X) in order to derive the first-order conditions for the constrained maximization, it is required that:

$$\frac{\partial L}{\partial M_j} = \frac{\partial L}{\partial X} = 0 \quad \text{for all t} \in [0, T] \quad \text{j=m,f,c}$$

and simultaneously it must also be set that;

$$\frac{\partial L}{\partial \varphi_m} = \frac{\partial L}{\partial \varphi_f} = 0 \quad \text{for all t} \in [0, T]$$

to ensure that the constraint will always be in force. The above must be supported by a second-order or concavity condition. The remaining maximum-principle conditions encompasses:

$$\frac{\partial H_m}{\partial_t} = \frac{\partial L}{\partial \lambda_{Hm}} \quad \text{equation of motion for the state variable H}_m$$

$$\frac{\partial H_f}{\partial_t} = \frac{\partial L}{\partial \lambda_{Hf}} \quad \text{equation of motion for the state variable H}_f$$

$$\frac{\partial H_c}{\partial_t} = \frac{\partial L}{\partial \lambda_{Hc}} \quad \text{equation of motion for the state variable H}_c$$

$$\frac{\partial W}{\partial_t} = \frac{\partial L}{\partial \lambda_W} \quad \text{equation of motion for the state variable W} \tag{26}$$

and

$$\frac{\partial \lambda_{Hm}}{\partial_t} = -\frac{\partial L}{\partial H_m} \qquad \text{equation of motion for } \lambda_{Hm}$$

$$\frac{\partial \lambda_{Hf}}{\partial_t} = -\frac{\partial L}{\partial H_f} \qquad \text{equation of motion for } \lambda_{Hf}$$

$$\frac{\partial \lambda_{Hc}}{\partial_t} = -\frac{\partial L}{\partial H_c} \qquad \text{equation of motion for } \lambda_{Hc}$$

$$\frac{\partial \lambda_{W}}{\partial_t} = -\frac{\partial L}{\partial W} \qquad \text{equation of motion for } \lambda_{W}$$

plus the transversality conditions.

F.O.C's

The first-order conditions (F.O.C's) are then give by:

$$\frac{\partial L}{\partial M_j} = \lambda_{Hj}\frac{\partial I_j}{\partial M_j} - \lambda_W p = 0 \qquad \text{j=m,f,c} \tag{27}$$

$$\frac{\partial L}{\partial X} = e^{-\theta t}\frac{\partial u}{\partial Z}\frac{\partial Z}{\partial X} - \lambda_W q = 0 \tag{28}$$

$$\frac{\partial L}{\partial \varphi_m} = \Omega - h_{w,m} + h_{Z,m} + h_{Hm,m} + h_{Hf,m} + h_{Hc,m} + h_{S,m} + h_{Sc,m} \tag{29}$$

$$\frac{\partial L}{\partial \varphi_f} = \Omega - h_{w,f} + h_{Z,f} + h_{Hm,f} + h_{Hf,f} + h_{Hc,f} + h_{S,f} + h_{Sc,f} \tag{30}$$

$$\frac{\partial L}{\partial \lambda_{Hj}} = I_j(M_j, h_{Hj,m}, h_{Hj,f}; E_{H,m}, EH, f) - \delta_j H_j \qquad \text{j=m,f,c} \tag{31}$$

$$\frac{\partial L}{\partial \lambda_W} = rW + \omega_m(H_m, E_{\omega,m})h_{\omega,m} + \omega_f(H_f, E_{\omega,f})h_{\omega,f} - p(M_m + M_f + M_c) - qX \tag{32}$$

$$\frac{\partial L}{\partial H_i} = \frac{\partial u}{\partial H_i}e^{-\theta t} - \lambda_{Hi}\delta_i + \lambda_W h_{\omega,i}\frac{\partial \omega_i}{\partial H_i} - \varphi_i\frac{\partial h_{S,i}}{\partial H_i} = -\frac{\partial \lambda_{Hi}}{\partial t} \qquad \text{i=m,f} \tag{33}$$

$$\frac{\partial L}{\partial H_c} = \frac{\partial u}{\partial H_c}e^{-\theta t} - \lambda_{Hc}\delta_c - \varphi_m\frac{\partial h_{Sc,m}}{\partial H_c} - \varphi_f\frac{\partial h_{Sc,f}}{\partial H_c} = -\frac{\partial \lambda_{Hc}}{\partial t} \tag{34}$$

$$\frac{\partial L}{\partial W} = -\frac{\partial \lambda_W}{\partial t} = \lambda_W r \tag{35}$$

This means that $\frac{\partial \lambda_W}{\partial t} = -\lambda_W r$

Solution to Single-person family

Rewriting Equation 27 gives:

$$\lambda_{Hj} = \lambda_W p / \left(\frac{\partial I_j}{\partial M_j}\right) = \lambda_W \pi_j \qquad \text{j=m,f,c} \tag{36}$$

where $\pi_j = p / \left(\frac{\partial I_j}{\partial M_j}\right)$

However, the time derivative of Equation 36 is:

$$\frac{\partial \lambda_{Hj}}{\partial t} = \frac{\partial \lambda_W}{\partial t}\pi_j + \frac{\partial \pi_j}{\partial t}\lambda_W \tag{37}$$

The solution to the Single-person family is attained by inserting Equation 37 into 33 and it gives:

$$\frac{\partial u}{\partial H_i}e^{-\theta t} - \lambda_{Hi}\delta_i + \lambda_W h_{\omega,i}\frac{\partial \omega_i}{\partial H_i} - \varphi_i \frac{\partial h_{S,i}}{\partial H_i} = -\left(\frac{\partial \lambda_W}{\partial t}\pi_i + \frac{\partial \pi_i}{\partial t}\lambda_W\right) \qquad \text{i=m,f} \tag{38}$$

Dropping the subscript i and using Equations 36 and 35 to substitute for λ_{Hm} and -$\frac{\partial \lambda_W}{\partial t}$ gives:

$$\frac{\partial u}{\partial H}e^{-\theta t} - \lambda_W \pi \delta + \lambda_W h_\omega \frac{\partial \omega}{\partial H} - \varphi \frac{\partial h_S}{\partial H} = \left(\lambda_W r \pi - \frac{\partial \pi}{\partial t}\lambda_W\right) \qquad \text{i=m,f} \tag{39}$$

Dividing through equation 39 by λ_W and rearranging it gives the solution:

$$\left(\frac{e^{-\theta t}}{\lambda_{t,W}}\right)\frac{\partial u_t}{\partial H_t} + h_{t,\omega}\frac{\partial \omega_t}{\partial H_t} - \left(\frac{\varphi_t}{\lambda_{t,W}}\right)\frac{\partial h_{t,S}}{\partial H_t} = \pi_t\left[\delta_t + r - \left(\frac{\partial \pi_t}{\partial t}\right)/\pi_t\right] \tag{40}$$

Thus, the individual invests in health until the marginal benefit of new health equals the marginal cost of health.

The $\lambda_{t,W}$ and $\lambda_{t,H}$ are costate variables. φ_t is the lagrange multiplier for the time restriction. $\frac{\partial u_t}{\partial H_t}$ is marginal utility of health capital. $\frac{\partial \omega_t}{\partial H_t}$ is the marginal effect of health on wage. $\frac{\partial h_{t,S}}{\partial H_t}$ is the marginal effect of health on the amount of sick time and π_t is the effective price of medical care goods and services (M_t).

Solution to Husband-wife family

Inserting equation 35 into equation 37 gives:

$$\frac{\partial \lambda_{Hj}}{\partial t} = -\lambda_W r \pi_j + \frac{\partial \pi_j}{\partial t}\lambda_W \tag{41}$$

Inserting equations 36 and 41 into equation 33 gives the solution:

$$\frac{\partial u}{\partial H_i} e^{-\theta t} - \lambda_W \pi_i \delta_i + \lambda_W h_{\omega,i}\frac{\partial \omega_i}{\partial H_i} - \varphi_i \frac{\partial h_{S,i}}{\partial H_i} = \lambda_W r \pi_i - \frac{\partial \pi_i}{\partial t}\lambda_W \qquad \text{i=m,f} \tag{42}$$

Setting i in the equation above equal to m and f, respectively, and dividing the expression for m with the one for f, we obtain the marginal condition ($e^{-\theta t}$ cancels out):

$$\left(\frac{\partial u}{\partial H_m}\right) / \left(\frac{\partial u}{\partial H_f}\right) = \frac{\pi_m \left(\delta_m + r - (\frac{\partial \pi_m}{\partial t})/\pi_m\right) - [(\partial \omega_m/\partial H_m)h_{\omega,m} - (\varphi_m/\lambda_W)(\partial h_{S,m}/\partial H_m)]}{\pi_f \left(\delta_f + r - (\frac{\partial \pi_f}{\partial t})/\pi_f\right) - [(\partial \omega_f/\partial H_f)h_{\omega,f} - (\varphi_f/\lambda_W)(\partial h_{S,f}/\partial H_f)]} \tag{43}$$

Thus, in a two-person family with common preferences, husband and wife together invest in health until the rate of marginal consumption benefits (left hand side of Equation 43) equals the rate of marginal net effective cost of health capital (right hand side). The net effective cost of health capital equals the user cost of capital less the marginal investment benefit of health capital (in brackets). From Equation 27 and 45, we realize or we can deduce that:

$$\lambda_W = \frac{\lambda_{Hf}}{\pi_f} = \frac{\lambda_{Hm}}{\pi_m} \tag{44}$$

Equation 44 implies that family members will invest in health until the rate of marginal lifetime utility of health to the effective price of health is equal for all family members (and equal to the marginal utility of wealth).

Solution to Parent-child family

Rewriting Equation 27 gives:

$$\lambda_{Hj} = \lambda_W \frac{p}{(\partial I_j/\partial M_j)} = \lambda_W \pi_j \qquad \text{j=m,f,c} \qquad \text{where} \qquad \pi_j = \frac{p}{(\partial I_j/\partial M_j)} \tag{45}$$

π_j is the effective price of health (or child health). The time derivative of Equation 45 is given as:

$$\frac{\partial \lambda_{Hj}}{\partial t} = \pi_j \frac{\partial \lambda_W}{\partial t} + \lambda_W \frac{\partial \pi_j}{\partial t} \qquad \text{j=m,f,c} \tag{46}$$

From Equation 45 we can write that;

$$\lambda_{Hc} = \lambda_W \pi_c \qquad \text{and putting it into equation 34, we have;}$$

$$\frac{\partial L}{\partial H_c} = (\frac{\partial u}{\partial H_c})e^{-\theta t} - \lambda_W \pi_c \delta_c - \varphi_m (\frac{\partial h_{Sc,m}}{\partial H_c}) - \varphi_f (\frac{\partial h_{Sc,f}}{\partial H_c}) \tag{47}$$

Solution to parents-child problem is by setting Eqn. 47 equal to Eqn. 46, taking into consideration Eqn. 35 and multiplying the R.H.S by -1:

$$(\frac{\partial u}{\partial H_c})e^{-\theta t} - \lambda_W \pi_c \delta_c - \varphi_m (\frac{\partial h_{Sc,m}}{\partial H_c}) - \varphi_f (\frac{\partial h_{Sc,f}}{\partial H_c}) = \lambda_W r \pi_c - \lambda_W (\frac{\partial \pi_c}{\partial t}) \tag{48}$$

Multiplying through Equation 48 by $\frac{1}{\lambda_W}$, we have:

$$(\frac{\partial u}{\partial H_c})\frac{e^{-\theta t}}{\lambda_W} = \pi_c(\delta_c + r - \frac{(\frac{\partial \pi_c}{\partial t})}{\pi_c}) + \frac{\varphi_m}{\lambda_W}(\partial h_{Sc,m}/\partial H_c) + \frac{\varphi_f}{\lambda_W}(\partial h_{Sc,f}/\partial H_c) \tag{49}$$

From Eqn. 33, Eqn. 34 and Eqn. 48, we can deduce that the solution for the husband-wife family would be:

$$\left(\frac{\partial u}{\partial H_i}\right) e^{-\theta t} - \lambda_W \pi_i \delta_i + \lambda_W h_{\omega,i} \frac{\partial \omega_i}{\partial H_i} - \varphi_i (\frac{\partial h_{Si,f}}{\partial H_i}) = \lambda_W r \pi_i - \lambda_W (\frac{\partial \pi_i}{\partial t}) \tag{50}$$

Divide through Eqn. 50 by λ_W:

$$\left(\frac{\partial u}{\partial H_i}\right)\frac{e^{-\theta t}}{\lambda_W} = \pi_i\left(\delta_i + r - \frac{(\frac{\partial \pi_i}{\partial t})}{\pi_i}\right) - h_{\omega,i}\frac{\partial \omega_i}{\partial H_i} + (\varphi_i/\lambda_W)\left(\frac{\partial h_{Si,f}}{\partial H_i}\right) \tag{51}$$

The marginal condition below is obtained by dividing Equation 51 for i=m,f with Equation 49 and cancelling out $\frac{e^{-\theta t}}{\lambda_W}$. We then have:

$$\frac{\partial u/\partial H_i}{\partial u/\partial H_c} = \frac{\pi_i(\delta_i + r - (\partial\pi_i/\partial t)/\pi_i) - [(\frac{\partial w_i}{\partial H_i})h_{w,i} - (\varphi_i/\lambda_W)(\partial h_{S,i}/\partial H_i)]}{\pi_c(\delta_c + r - (\partial\pi_c/\partial t)/\pi_c) - [-(\varphi_m/\lambda_W)(\partial h_{Sc,m}/\partial H_c) - (\varphi_f/\lambda_W)(\partial h_{Sc,f}/\partial H_c)]} \quad \text{i=m,f} \tag{52}$$

where $\partial u/\partial H_i$ and $\partial u/\partial H_c$ are the rate of marginal consumption benefits for parents and child, respectively. The Net effective marginal cost of child health (denominator) is equal to the user cost of child health capital (L.H.S) less the marginal investment benefit of child health (R.H.S in brackets). The marginal investment benefit of child health is the sum of the monetary value of the change in time taking care of a sick child for the father and mother respectively, for a marginal change in child health. The rate of marginal net effective cost of health capital (numerator) equals the user cost of capital for the parents (L.H.S) less the marginal investment benefit of health capital (R.H.S in brackets).

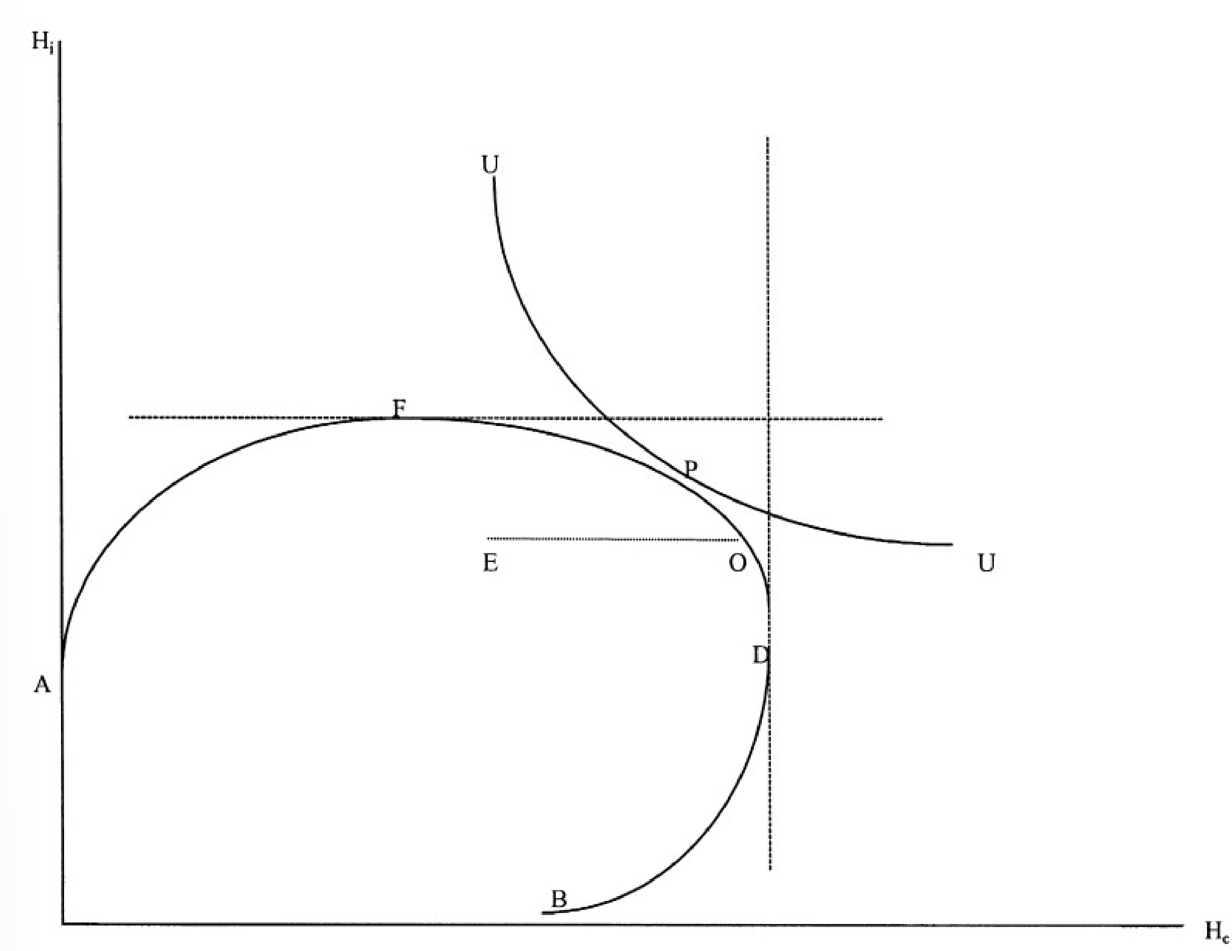
In the single-person family, the individual invests in health until marginal benefits equal marginal costs. However in a two-person (husband and wife) or parents-child family with common preferences, according to Jacobson (2000), husband and wife or the family invests together in health until the rate of marginal consumption benefits (L.H.S) equals the rate of marginal net effective cost of health capital (R.H.S).

From Equation 27 and 45, we realize or we can deduce that:

$$\lambda_W = \frac{\lambda_{HC}}{\pi_c} = \frac{\lambda_{Hf}}{\pi_f} = \frac{\lambda_{Hm}}{\pi_m} \tag{53}$$

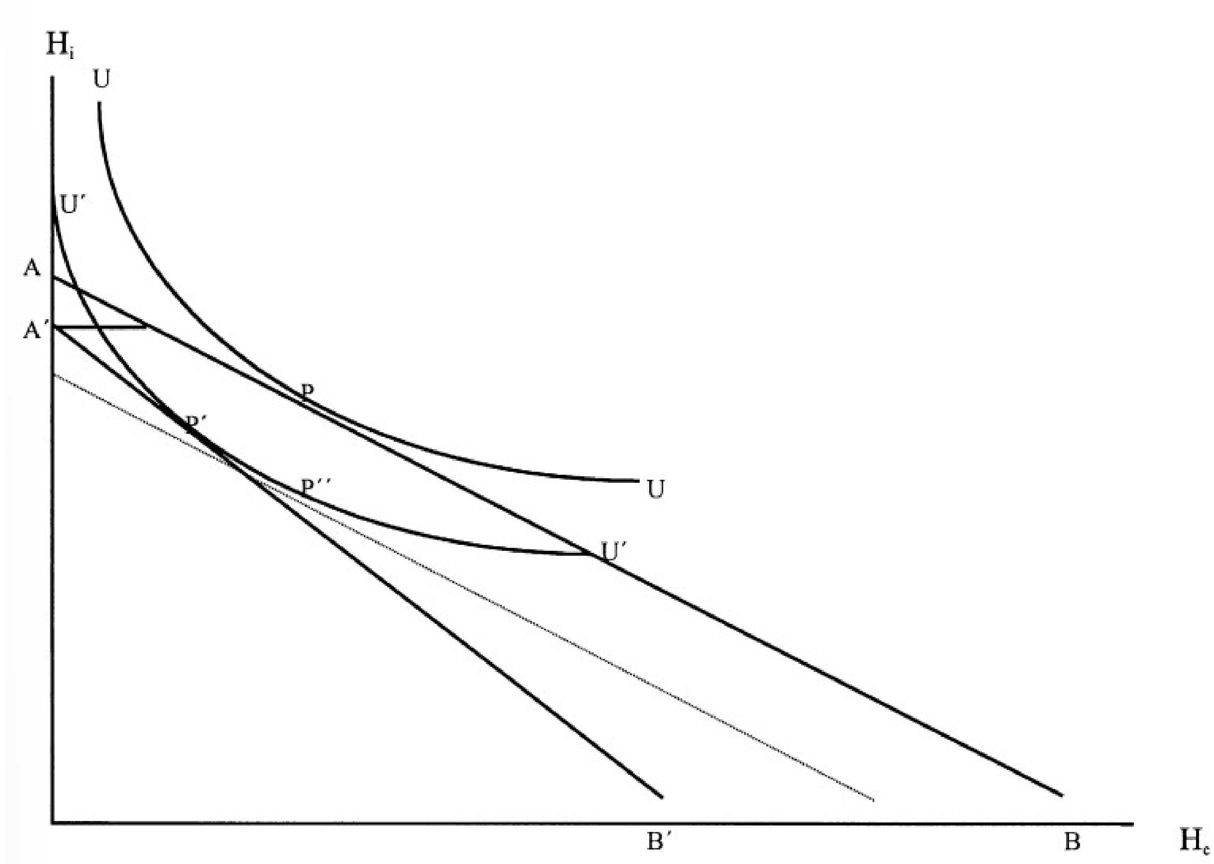
This implies that the family invests in health until the rate of marginal utilities of (lifetime) health to effective price of health for all family members is equal and equal to the marginal utility of wealth (Jacobson, 2000).

Figure 1: Representation of solution given by the marginal condition Equation 22



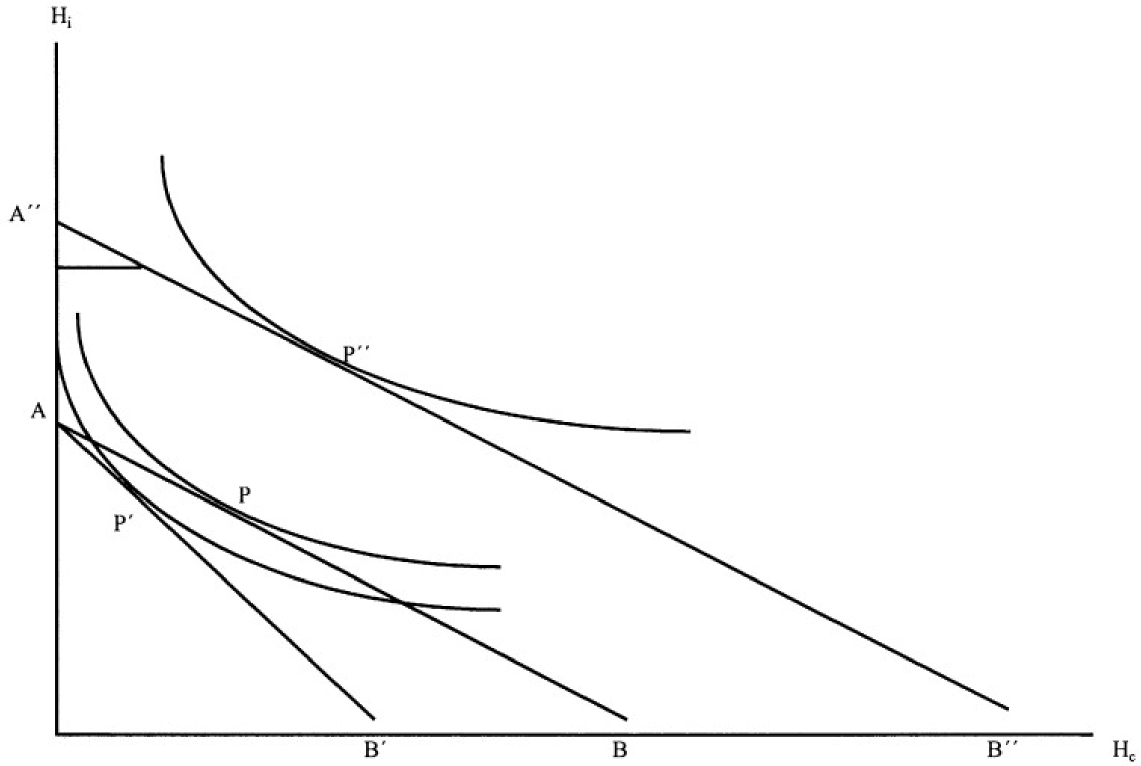
Source: Jacobson (2000)

Figure 2: Effects of changes in exogenous variables



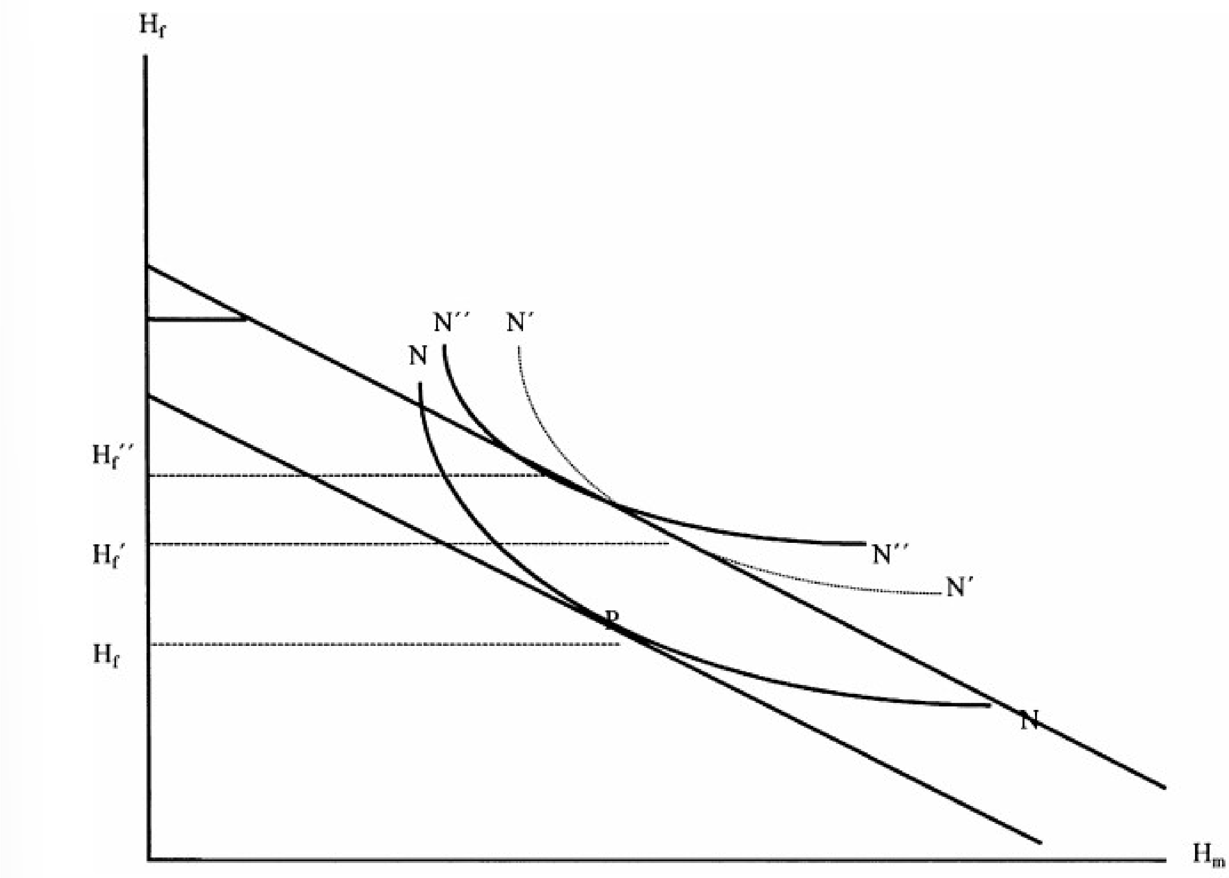
Source: Jacobson (2000)

Figure 3: Effects of changes in the level of compensation and transfer payments



Source: Jacobson (2000)

Figure 4: Nash bargaining model



Source: Jacobson (2000)