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医療費の地域格差と医療の社会資本の分析

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研究要旨

医療の経済の経済学分析においては医師，看護士，医療技術者，医療機関等によって構成される医療供給体制を「社会資本」あるいは「社会的共通資本」として捉えることが可能である。このとき，国民の健康水準，医療費は医療の社会資本との間に成立する関係として検討する必要がある。この研究は次の2つの研究を行う。第1は，国民の健康水準が医療の社会資本蓄積によってどのように決定されるかに関する研究である。第2は，医療費が医療の社会資本蓄積によってどのように決定されるかに関する研究である。平均余命等で測定した国民の健康水準は国際的に格差がある。他方，日本における健康水準の格差は小さい。ところが日本における１人当たり医療費には大きな地域格差がある。そこで健康水準の国際的格差のデータを用いて国民の健康水準の決定要因を分析する。次に，日本における医療費の地域格差のデータを用いて，医療費の決定要因の分析を行う。上記の2つの研究を行うにあたって，次の点を強調する。第1は，医療の社会資本が長期においてどのように蓄積されるかという社会資本蓄積の観点を強調することである。第2は，健康水準，医療費，医療の社会資本の成長率が長期的に収斂するか否かを強調した実証研究を行うことである。

この研究を行うことで，健康水準の決定要因，医療費の決定要因が明らかになる。このとき，医療の社会資本の長期的蓄積が，どのように健康水準，医療費に影響するかが判明する。

理論的研究の結果，医療に係る，物的資源，人的資源を医療サービスに関する社会的共通資本として分析する枠組みを作成した。実証研究により，平均余命の決定が，医療サービスには依存しないというパラドックスを確認した。さらに医療費については，地域差の説明要因を分析した。

A. 研究目的

医療の経済学分析においては医師，看護士，医療技術者，医療機関等によって構成される医療供給体制を「社会資本」あるいは「社会的共通資本」として捉えることが可能である。このとき，国民の健康水準，医療費は医療の社会資本との間に成立する関係として検討する必要がある。

この研究は次の2つの研究を行う。第1は，国民の健康水準が医療の社会資本蓄積によってどのように決定されるかに関する研究である。第2は，医療費が医療の社会資本蓄積によってどのように決定されるかに関する研究である。

平均余命等で測定した国民の健康水準は国際的に格差がある。他方，日本における健康水準の格差は小さい。ところが日本における１人当たり医療費には大きな地域格差がある。そこで健康水準の国際的格差のデータを用いて国民の健康水準の決定要因を分析する。次に，日本における医療費の地域格差のデータを用いて，医療費の決定要因の分析を行う。

上記の2つの研究を行うにあたって，次の点を強調する。第1は，医療の社会資本が長期においてどのように蓄積されるかという社会資本蓄積の観点を強調することである。第2は，健康水準，医療費，医療の社会資本の成長率が長期的に収斂するか否かを強調した実証研究を行うことである。

この研究を行うことで，健康水準の決定要因，医療費の決定要因が明らかになる。このとき，医療の社会資本の長期的蓄積が，どのように健康水準，医療費に影響するかが判明する。

B. 研究方法

第1の研究として，医療の社会資本の蓄積がどのように国民の健康水準に影響するかを検討した。ここではOECD Health Dataを利用して，OECD加盟国の20年間のデータを使用した分析を行った。そこでは平均余命を健康水準とし，これを決定する説明変数の係数を推定した。このような説明変数として，人口1人あたりの病床数を医療の社会資本の代理変数と想定した。

さらに，1人あたりの医療費，喫煙率，飲酒率等の消費者の行動様式等の説明変数として用いた。このとき，平均余命で測った健康水準が各国ともに自らの均衡水準に収斂していくという仮定を設け，どの程度の変化率で，この長期均衡水準に接近しているかを測定した。これを数式で表現すると次のようになる。

$$Y_{it}^{*} = Y_{it} - \frac{1}{N} \cdot \sum_{j=1} Y_{jt}$$

Y_{it}^{*}　i国の健康水準と平均的健康水準の格差.

第1項：Y_{it}　i国のt期の健康水準

第2項：OECD諸国の健康水準

両者の格差が長期的に縮小すると仮定する。その変化率($\dot{Y}_{it}$)は次の速度であると仮定する。

$$\dot{Y}_{it} = -\kappa (Y_{it} - Y_{i}^{*})$$

κ　長期的収斂速度

以上の仮定を設けて，長期的収斂速度を推計した。

第2の研究として，日本の１人当たり医療費の都道府県による地域格差を分析した。この地域格差は国民の需要する医療サービスの種類と量が地域によって大きく異なることを意味する。日本では国民皆保険が成立しているため，医療費の地域格差は，国民1人あたりの医療サービスの種類とその量が地域によって大きく異なることを意味する。このとき何が地域による医療サービスの相違をもたらすかという点が検討すべき課題となる。その第1の可能性は，地域により，住民の年齢構成，疾病構成が異なり，それが地域別の医療サービスの相違をもたらすとい

う説明である。第2の可能性は，地域により，医療機関，医師，看護士，医療機器等の供給体制の要因すなわち「医療の社会資本」の蓄積程度が地域によって異なり，それが医療サービスの需要の相違を招くという説明である。すなわち，住民1人当たりの医療の社会資本が大きくなると，小さい場合には発生しなかった医療サービス需要が顕在化するという説明である。この可能性は，医療経済学では「医師誘発需要」の名称で呼ばれていて，既存研究の多くはこれを医療費の地域格差の原因としている。

C.研究結果

医療費の地域格差についてはFolland and Stano (1989)が分析を行っている。日本の医療費の地域格差については，厚生労働省(毎年)は毎年データを収集して，類型的傾向を分析している。近年，大量のミクロデータを用いた経済学研究がなされるようになった。その代表は医療経済研究機構(1998)の報告書であり，そこでは1996年11月の診療報酬明細書データを用いた分析を行っている。これらは医療供給体制すなわち供給側の要因が医療費の地域格差をもたらしていることを示している。

しかし，このような既存研究には2つの問題がある。第1は，医師誘発需要，医療機関誘発需要を仮定しないでも，医療供給体制の地域間格差があればそれだけで，医療費の地域格差が説明できるという点である。むしろ日本では医療保険において決定される医療サービスの価格では医療の需要が供給を上回る場合が多く，このとき医療需要は供給制約の状態にあると想定することができる。第2の問題は，既存研究が一定時点のデータによって，医療費の地域格差を説明していることであり，長期にわたる医療費の変動について検討していないという点である。

本研究ではこれらの2つの問題を考慮して修正して，日本における医療費の地域格差を検討した。各都道府県別の医療費，薬剤費を，医療供給体制(医療機関数，入院病床数，医師数，看護士数)，地域住民の特性(人口，年齢構成，疾病構成)，その他の変数によって説明する。データを47都道府県，20年のパネル形式に整理することで長期分析を行った。さらにこの研究では医療供給体制を医療の社会資本として捉え，それが長期においてどのように蓄積されるかという社会資本蓄積の観点を強調した。また，医療の社会資本，医療費の成長率の長期的収斂を強調した実証研究を行った。

D. 考察

第1の研究では，医療費は平均余命に負の影響を持つという逆説が確認された。これは医療費の上昇が健康水準の上昇をもたらさないということである。この事実は他の研究でも確認されることであるが，なぜ医療費の増大が健康水準を増加させないかという原因については明確な答えはない。また，喫煙率は健康水準に負の影響を与えることが示された。開発途上国では健康水準が医療費でなく，教育水準あるいは衛生状態の向上によって増大するとされる。このようなことから，医療の社会資本の概念を拡大して，多様な社会的制度が国民の健康水準の決定要因となることが推測される。

さらに健康水準はＯＥＣＤ加盟国の間では長期的には収斂していることが確認され，本研究の推定値によれば30年ほどで，定常状態に収斂することが示された。したがって平均余命の国際間の格差は長期的には解消する傾向があることが判明した。

第2の研究では医療費の格差が医療の社会資本の蓄積の相違によって実際に説明されることが判明した。また，医療の社会資本の蓄積は長期的に収斂するため，医療費の地域格差が縮小することが示された。しかしながら，医療費の地域格差の収斂が，医療費抑制を目的とした政策の結果でもあるとすれば，本研究の結果には留保が必要である。

E. 結論

健康水準と医療費について，これが医療の社会資本とどのように関係するかに注目した実証研究を行った。これらの実証研究によって下記の問題を検討することができた。

第1は，医師，看護士，医療技術者，医療機関によって構成される医療供給体制を経済学的には，医療の社会資本として捉えることが妥当であることが示された。これを資本として想定することで，長期的に蓄積されるという特色を強調することが可能になる。他方，医療サービスはこの医療の社会資本から生み出されるサービスとして捉えることが可能になる。

第2は，国民の健康水準は医療サービスだけでなく，医療の社会資本，その他の社会資本，喫煙等の国民の習慣等によって決定されることが判明した。ここでは医療費は健康水準に負の影響を与えるという逆説が確認された。

第3に，健康水準は先進国では収斂する傾向があるということが判明した。

第4に，日本における医療費の地域格差に関する新たな解釈が可能になった。すなわち現時点で確認される，医療費の地域格差は，医療の社会資本の蓄積水準で説明されることがわかった。さらにその相違は長期においては解消する傾向が示された。

第5に，日本において医療供給体制すなわち医療の社会資本を長期的な視点でどのように蓄積すべきかという政策的課題に対する示唆が得られた。すなわち，医療費の地域格差は結果であり，医療の社会資本の蓄積の格差に注目した政策がより適切であることが示された。

Folland and Stano (1989) “Sources of Small Area Variations in the Use of Medical Care”, *Journal of Health Economics.* 8(1), 85-107.

医療経済研究機構(1998)『医療費の地域格差に関する研究』医療経済研究機構

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F. 研究発表

1. 論文発表

2. 学会発表

Anegwa, Tomofumi “Geographical Variance and Convergence of Medical Cost in Japan” in International Health Economics Association, 5-th World Congress, 2005, July 14 (予定)

G. 知的所有権の取得状況

1. 特許取得

なし

2. 実用新案登録

なし

3. その他

なし

健康の生産関数と社会的共通資本

(2003年)

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要旨 これは，原題，Health Production and Social Overhead Capital-Analysis of OECD Health Dataの未刊原稿を理論部分，実証部分について書き改めたものである。OECD諸国の平均余命で測定した健康水準は，1人当りの医療費と負の相関がある。これがどのような意味があるかを医師誘発需要，医療機関誘発需要の観点から分析した。さらに，平均余命の国際間の収斂が存在することを検証した。ここで展開された理論は，医療費用，健康水準の国際間あるいは地域間の相違の分析の枠組みを提供する。

Health Production and Social Overhead Capital

May, 2003

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Health Production and Social Overhead Capital

—Analysis of OECD Health Data —

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Summary

This paper proposes a framework for heath economics focusing on health capital and social over-head capital. By applying international data on OECD Health Data, this study estimates the "health production function." Empirical results show that medical expenditure have negative, while GDP has positive effects. Smoking has negative effects on health increase. Expenditure of pharmaceuticals has positive effects. These effects differ by the choices of different life expectancy by sexes and ages. The puzzle of negative effects of expenditure for health and the number of inpatients beds per population might be related to physician induced demand for medical services. We also find conditional convergence of health. Annual 3 per cent speed indicates that countries approach their own steady state health level in 30 years.

JEL Classification: I12, H42, H51

Key Words: health capital, social overhead capital, longevity, life expectancy, OECD, international, convergence

1. Introduction

There are three major questions in health economics. First is to provide definition and measurements for health of people. Second is to investigate what determines health. Third is to value health in monetary terms as criteria in health policy. To answer these questions, one needs to incorporate health capital and social overhead capital. First, health has a nature of capital. Like human capital, health should be accumulated and maintained by an investment. This notion is not well grasped in the WHO definition of health. Several health economists including Grossman (1972), Cropper (1977), Cutler and Richardson (1997) formulate health capital based on the literatures of capital theory. They characterize that utility of an individual depends on his/her health level and that health should be accumulated and maintained through the investment in health. In this sense, expenditure on medical goods and services are nothing but health investment. Second, medical sector supplying medical services should be interpreted as social overhead capital. Medical sector consists of the government, hospitals, universities, and research institutes, which are operated by non-profit motives and are financed publicly. Uzawa (1990) emphasizes the importance of public sector as the "social overhead capital," and he identifies medical sector as a typical example of social overhead capital. He explains that the government is responsible for constructing and managing hospitals, educate physicians, nurses, and para-medical technicians, and provide equipment and pharmaceuticals. The notion of the social overhead capital, however, is not well accepted in the literature of health economics. For example, popular text books on health economics such as Feldstein(1993), Getzen(1997), Zweifel and Breyer(1997) have only mentioned medical service in the literature of "pubic goods". Public goods are defined as goods and services with the nature of "non rivalness" or "non-exclusiveness" in consumption. Any person can use certain goods and services freely without excluding other people from the use. This nature is defined as non-rivalness or non-exclusiveness, which nature is the definition of public goods. On the contrary, social overhead capital is defined by the nature of rivalness or exclusiveness, in which use of goods and services by a person limit the use by others. The medical sector is better fitted to the notion of social overhead capital rather than pure public goods.

This study investigates the role of health and social overhead capital in dynamic optimization. The relationship of "health production function" is derived from the necessary condition of optimal health investment. This study apply the OECD Health Data in a similar fashion with Fench and Miller(1997). Section 2 surveys the empirical studies of health determinants. Section 3 develops models based on health capital and social overhead capital. Section 4 investigates how health is determined. Section 5 investigates the possibility of convergence of health among nations. Section 6 provides conclusions.

2. Survey of Empirical Studies

A question how health is determined has achieved attentions of researchers. For example, Lichtenberg (2002) attempts to estimate how U.S. longevity is determined by health expenditure, innovation in medical technologies, and other factors. He assumes linear health production relationship and uses U.S. annual data from 1960-1997. His method, however, has a major drawback in that improvement of life expectancy is hardly explained by time-series data when there are upward trend of health, health expenditure, medical innovations, and GDP per capita at the same time. A solution to this question is to conduct international comparison using pooled cross-section and time-series data. Because there are wide variances in health and other factors across countries, the use of international data is expected to identify determinants of health. Fench and Miller (1997) surveys studies of this type. They cite Stewart (1991), Cochrance, Leger, and Moore (1978), Rodgers (1979), and Zweifel and Ferrari(1992) as representative works. These studies focus on the relationship of "health production function" in which health is determined by various inputs. As a dependent variable, they use various indices of mortality or life expectancy by sexes and ages, then regress them on medical expenditure, income, degrees of equality in income distribution, environmental hygiene. Fench and Miller use the OECD Health Data as international data and find that medical expenditure has no positive effects on health, while income has positive effects.

However, these studies have other drawbacks. First, they specify a linear health production function without theory. Correspondingly, one has to be cautious about the choice of level or change in health as a dependent variable. Second, previous studies do not explicitly account for the roles of social overhead capital as a determinant of health. Third, because most studies use aggregate medical expenditure, they could not distinguish the effects of medical expenditure from those of pharmaceutical expenditure. Babazono and Hillman(1994) and Fench and Miller(1997) use the OECD Health Data based on the specification of disaggregation.

3. Model

This section introduces health capital and social overhead capital. An individual(α) consumes products. Consumer goods and investment goods are provided by firms (β). An individual enjoys certain level of health (K_α^H) which is accumulated and maintained by an individual. Medical services (X^M) are provided by medical sector whose capital is social overhead capital. Utility of a consumer (α) is expressed in equation (1).

$$U_\alpha(t) = U_\alpha(C_\alpha(t), K_\alpha^H(t)) \qquad (1)$$

C_α; Consumption by an individual (α)

K_α^H ; Health capital of an individual(α)

Utility of an individual α at t-th period depends on consumption of goods and health capital at t-th period.

Health capital is accumulated by investment in the form of purchase of medical service and medical products. Health is also depreciated. Medical services are provided by medical sector including government, hospitals, research institutes. These services include diagnosis, examination, treatment, operation, support, and prescription.

$$\dot{K}^{H}_{\alpha}(t) = \Phi^{H}_{\alpha}(X^{M}_{\alpha}(t), K^{H}_{\alpha}(t), X^{M}(t), V^{M}(t), Z(t)) - \delta^{H}_{\alpha}(t)K^{H}_{\alpha}(t), \quad (2)$$

$\dot{K}^{H}_{\alpha}$; change in health capital

Φ_{α}^{H} ; health production function relating the inputs to increase in health

X_{α}^{M} ; demand for medical service and goods by an individual (α)

X^{M} ; aggregate social demand for medical service and goods

V^{M} ; social overhead capital of the medical sector

δ_{α}^{H} ; depreciation rate of health capital of an individual (α)

Φ^{H}_{α} is a health production function relating health investment to the increase in health capital whose arguments are demand for medical service and goods (X_{α}^{M}), aggregate demand for medical service and goods (X^{M}), social overhead capital for medical sector (V^{M}). The increase in aggregate demand would cause congestion whose degree is measured by (X^{M}/V^{M}). Φ^{H}_{α} is specified as a health production function which corresponds to "installment function" or "adjustment cost function" in the literature of capital theory.

$$\frac{\partial \Phi^{H}_{\alpha}}{\partial (X^{M}_{\alpha}(t))} > 0, \frac{\partial^2 \Phi^{H}_{\alpha}}{\partial (X^{M}_{\alpha}(t))^2} < 0, \frac{\partial \Phi^{H}_{\alpha}}{\partial \left(X^{M}(t)/V^{M}(t)\right)} < 0$$

Firm (β) produces consumption goods (Y^{C}) and investment goods (Y^{I}). They use their own capital (K) and labor (N) as expressed in production function F.

$$F^{Q}_{\beta}(K_{\beta}(t), N_{\beta}(t)) \quad (3)$$

Q: Consumption goods (C) and investment goods (I)

$F_{\beta}{}^{Q}$: Production function of a firm β

K_{β} : Capital of a firm β

Capital accumulation of a firm β is represented by equation (4).

$$\dot{K}_{\beta}(t) = \Phi^{K}_{\beta}(I^{K}_{\beta}(t), K_{\beta}(t)) - \delta^{K}_{\beta}(t)K_{\beta}(t), \quad (4)$$

$\dot{K}_{\beta}$: Change in capital

Φ_{β}^{K}: Installment function relating investment to the capital accumulation

I_{β}^{K} ; Investment by a firm β

δ_{β}^{K}: Depreciation rate of capital

Medical sector (γ) provides medical services and goods, which sector consists of social overhead-capital (V) and proportional number of labor. Social overhead capital is accumulated through equation (5).

$$\dot{V}^{M}(t) = \Phi^{M}(I^{M}(t), V^{M}(t)) - \delta^{M}(t)V^{M}(t), \tag{5}$$

V^{M} ; social overhead capital

$\dot{V}^{M}$; change in social overhead capital

Φ^{M} ; transformation function relating investment to social overhead capital

I^{M} ; investment in social overhead capital

δ^{M} ; depreciation rate for social overhead capital

$$\frac{\partial \Phi^{M}}{\partial I^{M}(t)} > 0, \frac{\partial^{2}\Phi^{M}}{\partial (I^{M}(t))^{2}} < 0, \frac{\partial \Phi^{M}}{\partial (V^{M}(t))} > 0, \frac{\partial^{2}\Phi^{M}}{\partial (V^{M}(t))^{2}} < 0,$$

Social welfare is the sum of utility of all consumers. To maximize social welfare, one needs optimal capital accumulation of health capital, firm's capital, and social overhead capital. At the same time, the aggregate supply of ordinary goods used for consumption and investment should exceed the sum of aggregate consumption and investment.

$$\sum_{\beta} F_{\beta}(K_{\beta}(t), N_{\beta}(t)) \geq \sum_{\alpha} C_{\alpha}(t) + \sum_{\beta} I_{\beta}^{K}(t) + I_{\gamma}^{M}(t) \tag{6}$$

Labor input is measured by health level adjusted man-hour.

$$N_{\beta} = L_{\beta}(t)\overline{H_{\alpha}} \tag{7}$$

N_{β} : Labor input multiplied by health capital of an average individual

L_{β} : Labor input measured in man-hour

Aggregate Labor supply should exceed the aggregate demand for labor of firm and medical sector.

$$\sum_{\alpha} N(t) \geq \sum_{\beta} N_{\beta}(t) + N_{\gamma}(t) \tag{8}$$

The sum individual demand for medical services should be lower than the supply.

$$X^M(t) \geq \sum_\alpha X_\alpha^M(t) \tag{9}$$

One needs to maximize the sum of individual welfare subject to equation (2), (4), (5), (6), (8) and (9). By adding co-state variables $\lambda_\alpha^H(t), \lambda_\beta^K(t), \lambda_\gamma^K(t)$ respectively for equation (2), (4), (5), co-state variables $P(t)$, $w(t)$. $P^M(t)$ respectively for (6), (8), (9), we define Hamiltonian H as equation (10).

$$H = \int_0^\infty H(t)e^{-rt}dt \tag{10}$$

$H(t)$ is discounted with r from present to infinity.

$$
\begin{aligned}
H(t) &= \sum_\alpha U_\alpha(C_\alpha(t), K_\alpha^H(t)) \\
&+P(t)\left\{\sum_\beta F_\beta(K_\beta(t),N_\beta(t)) - \sum_\alpha C_\alpha(t) - \sum_\beta I_\beta^K(t) - I^M(t)\right\} \\
&+ w(t)\left\{\sum_\alpha N(t) - \sum_\beta N_\beta(t) - \sum_\gamma N_\gamma(t)\right\} \\
&+p^M(t)\left\{X^M(t) - \sum_\alpha X_\alpha^M(t)\right\} \\
&+\sum_\alpha \lambda_\alpha^H(t)\left\{-\dot{K}_\alpha^H(t) + \Phi_\alpha^H(K_\alpha^H(t), X_\alpha^M(t), X^M(t), V^M(t)) - \delta_\alpha^H(t)K_\alpha^H(t)\right\} \\
&+\sum_\beta \lambda_\beta^K(t)\left\{-\dot{K}_\beta(t) + \Phi_\beta^K(I_\beta^K(t), K_\beta(t)) - \delta_\beta^K(t)K_\beta(t)\right\} \\
&+\sum_\gamma \lambda^M(t)\left\{-\dot{V}^M(t) + \Phi^M(I^M(t), V^M(t)) - \delta^M(t)V^M(t)\right\}
\end{aligned} \tag{11}
$$

To maximize social welfare, the first order conditions are derived by differentiating H with respect to C_α, I_β^K, I^M, X_α^M, X^M, N_β, N_γ then put each equal to zero.

$$\frac{\partial U_\alpha(t)}{\partial C_\alpha(t)} = p(t), \tag{12}$$

$$P(t)=\lambda_{\beta}^{K}(t)\left(\frac{\partial\Phi_{\beta}^{K}}{\partial I_{\beta}^{K}(t)}\right), \tag{13}$$

$$P\ (t)=\lambda^{M}(t)\left(\frac{\partial\Phi^{M}}{\partial I^{M}(t)}\right), \tag{14}$$

$$P^{M}(t)=\lambda_{\alpha}^{H}(t)\left(\frac{\partial\Phi_{\alpha}^{H}}{\partial X_{\alpha}^{M}(t)}\right), \tag{15}$$

$$-P^{M}(t)=\sum_{\alpha}\lambda_{\alpha}^{H}(t)\left(\frac{\partial\Phi_{\alpha}^{H}}{\partial X^{M}(t)}\right) \tag{16}$$

$$w(t)=P(t)\frac{\partial F_{\beta}^{Q}(t)}{\partial N_{\beta}(t)}, \tag{17}$$

Euler conditions are achieved as follows.

$$\dot{\lambda}_{\alpha}^{H}(t)=-\frac{\partial U_{\alpha}(t)}{\partial K_{\alpha}^{H}(t)}-\lambda_{\alpha}^{H}(t)\left(\frac{\partial\Phi_{\alpha}^{H}}{\partial K_{\alpha}^{H}(t)}-\delta_{\alpha}^{H}(t)\right), \tag{18}$$

$$\dot{\lambda}_{\beta}^{K}(t)=-\frac{\partial F_{\beta}^{Q}(t)}{\partial K_{\beta}(t)}-\lambda_{\beta}^{K}(t)\left(\frac{\partial\Phi_{\beta}^{K}}{\partial K_{\beta}(t)}-\delta_{\beta}^{K}(t)\right), \tag{19}$$

$$\dot{\lambda}^{M}(t)=-\sum_{\alpha}\lambda_{\alpha}^{H}\left(\frac{\partial\Phi_{\alpha}^{H}}{\partial V^{M}(t)}\right)-\lambda^{M}(t)\left(\frac{\partial\Phi^{M}}{\partial V^{M}(t)}-\delta^{M}(t)\right), \tag{20}$$

To maximize social welfare, equation (12) should hold for all individuals.

$$\frac{\partial U_{\alpha_i}(t)}{\partial C_{\alpha_i}(t)}=\frac{\partial U_{\alpha_j}(t)}{\partial C_{\alpha_j}(t)}, \tag{21}$$

This equates marginal utility of consumption between individual I and j. Uzawa states this is a "marginal rate of distribution (MRD) " condition where an individual α_i and α_j should equate marginal utility.

$$MRD=\left(\frac{\partial U_{\alpha_i}(t)}{\partial C_{\alpha_i}(t)}\right)/\left(\frac{\partial U_{\alpha_j}(t)}{\partial C_{\alpha_j}(t)}\right)=1 \tag{22}$$

Equation (22) indicates the optimal investment condition for firm β. The product of the shadow value of capital $\lambda_{\beta}^{K}(t)$ and the marginal installment $(\partial\Phi_{\beta}^{K}(t)/\partial I_{\beta}^{K}(t))$ of investment should equal to the price *P(t)*. In the same manner, equation (14) indicates the optimum social investment. Equation (15) shows the optimal conditions for individual medical expenditure as an investment in health capital. An individual should invest in health to make the product of an individual health value $\lambda_{\alpha}^{H}(t)$ and the marginal transformation of health investment $(\partial\Phi_{\alpha}^{H}(t)/\partial X_{\alpha}^{H}(t))$ equal to the medical good price $P^{M}(t)$. Equation (16) shows that medical fees should be equal to the sum of marginal value of health of all individuals. The increase in the total demand for the services of social overhead capital is (X^{M}) would cause congestion. Equation (17) shows the optimal demand for labor. Equation (18), (19), (20) are Euler conditions. Equation (18) shows how health capital should be values. The value of health capital is the discounted value of utility of health in the future. This is identical with the definition of that in Cutler and Richardson (1997, p,227).

4. Estimation of Health Production

a. Specification

This section examines how health is determined based on equation (2).

$$\dot{K}_{\alpha}^{H}(t)=\Phi_{\alpha}^{H}(X_{\alpha}^{M}(t),K_{\alpha}^{H}(t),Z_{\alpha}(t),X^{M}(t),V(t))-\delta_{\alpha}^{H}(t)K_{\alpha}^{H}(t) \qquad (2)$$

X_{α}^{M} ; expenditure for medical service

H_{α} ; health capital

Z_{α} : other factors

X^{M} : aggregate demand for medical service

V ; social overhead capital

Φ_{α} ; individual α's health production function

The observed change in health is the effects of health production net of depreciation. We assume a following estimated equation.

$$\Delta K_{it}^{H}=\beta_1 X_{it}^{M}+\beta_2 K_{it}^{H}+\beta_3 Z_{it}+\beta_4(X_{it}^{M}/V_{it}^{M})+\mu_i+\varepsilon_{it} \qquad (23)$$

ΔK_{it}^{H} is the change in health measure at t. X_{it}^{M} is expenditure for health which is composed of two types of expenditure. One is "expenditure for medical services" and the other is "expenditure for pharmaceuticals". X_{it}^{M}/V_{it}^{M} is a measure for relative scale of demand for health relative to scale of social overhead capital.

This denotes the degree of congestion at medical sector. Z_{it} stands for other factors. μ_i is an individual effect for an individual (α). When individual effects are correlated with error terms, the OLS estimates would be biased. We transform the data by subtracting the mean value of each variable from the original variable. We obtain a following equation.

$$(\Delta K_{it}^{H} - \Delta \overline{K}_{i,\bullet}^{H}) = \beta_1 (X_{i,t}^{M} - \overline{X}_{i,\bullet}^{M}) + \beta_2 (K_{i,t}^{H} - \overline{K}_{i,\bullet}^{H})$$

$$+ \beta_3 (Z_{i,t} - \overline{Z}_{i,\bullet}) + \beta_4 (X_{it} / V_t - \overline{X_{i,\bullet}^{M} / V_{i,\bullet}^{M}}) + \varepsilon_{i,t} - \overline{\varepsilon}_{i,\bullet} \tag{24}$$

We assume error term $\varepsilon_{i,t} - \overline{\varepsilon_{i,\bullet}}$ has the mean value zero, homoskedastic covariance matrix. Under these conditions, OLS would yield unbiased estimate.

b. Data

This study uses *the OECD Health Data 2000*. It collects data of 29 member countries since 1960. Original data is provided with OECD by each country. Because the method and available data differ across countries, the data set is unbalanced panel data. This study represents the increase in health capital by "Life Expectancy (LE)" or "Potential Years of the Life Lost (PYLL)." These measures do not necessarily reflect true health level because they do not incorporate information on quality of life. Though other measurements such as "Quality Adjusted Life Years (QUALY)" are available for specific countries, LE or PYLL are sole reliable and readily available data for most countries. Table 1 summarizes the correlation of life expectancy and PYLL. PYLL stands for the "Potential Years Life Lost" by all causes, which is a summary measure of premature mortality. It provides an explicit way of weighting deaths occurring at younger ages, which are, a priori, preventable. The calculation for PYLL involves adding up deaths occurring at each age and multiplying this with the number of remaining years to live until a selected age limit. The limit of 70 years has been chosen for the calculations in OECD Health Data[1]. "Life Expectancy (LE)" is the average number of years which a person at that age is expected to live under the mortality pattern prevalent in the community or country based on a given set of age-specific death rates found in life tables. Because these figures differ significantly by sexes, we use female (F) and male (M) separately. Furthermore LE is defined at birth, at the age of 40, 60, and 80. For example, the variable LE_M_40 is life expectancy of male at the age of 40. LE_M_80 is defined as the difference between the life expectancy of female and of Male at the age of 80. Table 1 indicates the correlation among health level indices. Because of the wide variations, each of these indices is expected to convey different information.

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[1]OECD(2000), *OECD Health Data 2000.* Note

———Table 1———

The change in health is measured as the difference of the index between two periods. This study uses one-year, three-year, and five-year differences. Again they exhibit wide variations among indices, which fact should be interpreted that determinants of health affect health in various time lags. For example, epidemic such as influenza might affect health capital within one year, while smoking habit would affect health capital in longer periods such as 3 and 5 years. This study focuses on 5 years differences in health rather than one-year differences.

c. Results

Table 2 shows the determinants of health capital by life expectancy at birth. For example, D1_LE_F_B is the change in life expectancy of female at birth between the current year and previous year. The model 1 shows that D1 measure is not fully explained by this model. On the contrary explanatory power of models has increased when we use D3 and D5 measures. This implies that we had to use the difference in health measurement by taking three or five years lag to identify the effects. This is no wonder because the effects on health can be incorporated gradually in the long periods. We also find that the differences in sexes are significant. Some empirical works such as Fench and Miller (1997) pool the data of female and male together to solve the small number of samples. The procedure, however, is not appropriate because the coefficients may differ significantly between female and male. We have to treat female and male separately.

Our study indicates the following results. We use "medical expenditure" as health expenditure excluding expenditure for pharmaceutical. Medical expenditure has negative sign, which results seem to contradict our assumptions that medical expenditure would increase health. Previous empirical works such as Fench and Miller also indicate the same results. Unlike medical expenditure, pharmaceutical expenditure has persistent positive effects on female life expectancies. This result is found when D3 and D5 for female measures are used. On the contrary, pharmaceutical expenditure has neither positive nor significant effects on male. These results raise puzzles. To solve these puzzles, one needs micro data of individual patients relating medical expenditure and pharmaceutical expenditure to individual health. Current level of life expectancy has negative signs on the increase in life expectancy. The longer life expectancy means the shorter increase in life expectancy. This result indicates the usual decreasing return with respect to life expectancy holds. We would address this issue again in section 5 in terms of convergence. "GDP_PPP per Capita" denotes individual income in the GDP in purchasing power parity per capita. GDP has significant effects on any measurements for life expectancy. When compared with female, male life expectancy has increased more by the level of income.

Finally this study examines the effects of the social overhead capital through congestion of medical sector. The number of inpatients beds per population is used as index for the density of social overhead capital per capita. It has significant negative effects on male life expectancies. The negative effects in absolute terms are larger in order of D1, D5 and D3. We interpret that the effects have both instantaneous effects within one year and lingering effects as much as five years. This raises another puzzle because the more social overhead capital means less health improvement. We can introduce congestion of inpatients beds as follows.

$$Congestion = \frac{Beds \cdot Beddays}{Population \cdot 365} = \left(\frac{Beds}{Population}\right)\left(\frac{Beddays}{365}\right)$$

Because our measurement for congestion is decomposed into two terms, beds per population and the average beddays per capita in one year. We find a high correlation between the "congestion" and "beds per population". So "beds per population" does not mean less congestion but more congestion. If this is the case, we can infer that congestion in hospital service might reduce life expectancy.

————Table 2————

Table 3 summarizes the results with D5 life expectancy by sexes and ages. The explanatory power of the model is largest when the "life expectancy at birth" is used. It decreased gradually when the "life expectancy at 40," "life expectancy at 60," and "life expectancy at 80" are used. Durbin-Watson Index (DW) is far smaller than 2.0, which fact indicates that our model might leave some important explanatory variables out from equation. To correct the problem, this study attempts to estimate by the two stage least squares with AR1 process in error terms. The explanatory power and Durbin-Watson has increased but there is no difference in estimates. For female life expectancy, medical expenditure has negative effects on life expectancy. Their magnitude is largest for life expectancy of 40 and 60. On the other hand, pharmaceutical expenditure has significant positive effects. Its magnitude is much larger than the negative effects of medical expenditure. The increase in life expectancy has negative effects on the increase of the expectancy. The "beds per population" has insignificant effects for female expectancy. "GDP PPP per Capital" has positive effects whose magnitude is largest when we use "Life Expectancy at Birth," while smaller magnitude is found when the older life expectancy is used. The Male is different from the Female. Medical expenditure has negative effects when life expectancy at 40 and 60 are used. It has insignificant effects when life expectancy at birth and at 80 is used. Positive effects of pharmaceutical expenditure are found only for life expectancy at 60 and 80, whose magnitude is far less than those for the Female. The

Male life expectancy has negative effects on their increase as the Female, but with smaller magnitude. Unlike the Female "Beds per Population" has negative effect on the Male life expectancies at Birth, 40, and 60. If Beds per Population indicates congestion in the above sense, congestion would decrease the life expectancies at younger ages. The GDP PPP per Capital has the positive effects whose magnitude is much larger than the Female. These positive effects are largest at the age 40.

— Table 3. Health Determinants by Sexes and Ages—

We examine the effects of smoking habit by the "tobacco consumption per day". Data of smoking habit is available for Denmark, Finland, Iceland, Italy, Japan, Netherlands, and the United States. Sample period is between 1981-1999. Because of many missing data, we have only 60 observations of the unbalanced panel. Table 4 summarizes the results. For both Female and Male life expectancy at 40, tobacco consumption has the negative effects. The magnitude is large for Female (–0.0064) than for Male (-0.0047). For Female life expectancy at other ages, no effects are found. For Male life expectancy at birth has the negative effects. The life expectancy at 60 has negative but insignificant effects. Tobacco consumption has negative effects. Then we examine the effects of R&D expense among medical expenditure, public expenditure or payment by insurance among medical expenditure. These variables have no effects on health.

— Table 4. Effects of Smoking Habit—

5. Convergence of Health

a. Background

In the period 1960-1998, all OECD countries have experienced the rapid increase in health measured in life expectancy. Figure 1 and 2 relate the growth rate of life expectancy to the level of life expectancy. We use the period of 1960-1979 and 1980-1998 separately. The convergence of life expectancy may exist in weak manner among countries. There are two versions of the convergence. One is the "absolute convergence" where lower health countries tend to increase health more rapidly than higher health countries. The other is "conditional convergence" in which country tends to approach the long-run steady state of health level. In this case, countries with greater differences between the actual health and steady state health tend to increase health more rapidly than the countries with smaller differences. We find a negative slope of the relationship to support the "absolute convergence" theory. This relation is somewhat weak when several countries (Turkey, Mexico, Korea, Japan, Portugal) are excluded from sample. This section addresses this question. First question is the degree of convergence of health if it exists. Second