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FORMATIVE INDICATORS AND EFFECTS OF A CAUSAL MODEL FOR HOUSEHOLD HUMAN CAPITAL WITH APPLICATION

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□ *Dagum and Slottje (2000) estimated household human capital (HC) as a latent variable (LV) and proposed its monetary estimation by means of an actuarial approach. This paper introduces an improved method for the estimation of household HC as an LV by means of formative and reflective indicators in agreement with the accepted economic definition of HC. The monetary value of HC is used in a recursive causal model to obtain short- and long-term multipliers that measure the direct and total effects of the variables that determine household HC. The new method is applied to estimate US household HC for year 2004.*

Keywords Formative and reflective indicators; Latent variable; Short-term and long-term multipliers; U.S. household human capital distribution.

JEL Classification J24.

1. INTRODUCTION

The concept of human capital (HC) was formally introduced and quantified by Petty (1690) and Cantillon (1755) and conceptually analyzed by Adam Smith (1776). Later, in the second half of the twentieth century, several economists concentrated on the qualitative analysis of HC and introduced an earning function in terms of only years of schooling (Mincer, 1958, 1970) or of years of schooling, professional investment in HC, and on the job training (Becker, 1962, 1964), while other economists proposed different methods for the quantitative estimation of

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Unfortunately, Professor Camilo Dugam passed away. We would like to honor the memory of an exceptional scientist, an unforgettable friend, and great Master.

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HC. The retrospective method (Eisner, 1985; Kendrick, 1976) approached the problem from the viewpoint of the cost of production following the tradition of Cantillon (1755) and Engel (1883). But this method does not take into account social costs, such as public investment in education, home conditions and community environments, or the genetic contribution to HC, which includes health conditions. Moreover, it ignores the real effects on household income that investments in HC generate (Dagum and Slottje, 2000).

Inversely, the prospective method (Jorgenson and Fraumeni, 1989), following the pioneering actuarial contribution of William Farr (1853), considers the present actuarial value of an individual's expected income related to his skill, acquired abilities, and education. This approach however, reduces HC investment to its monetary value in terms of an assumed flow of only one variable, earned income, hence ignoring the amount of investment in education and job training, estimating the productivity of time spent at leisure and at work as having equal importance (Dagum and Slottje, 2000; Le et al., 2003).

The educational attainment method (Barro, 1991; Mankiw et al., 1992; OECD, 1998; Mulligan and Sala-i-Martin, 2000; Wößmann, 2003) relates the aggregate stock of HC to the highest level of education completed by each adult. However it does not take into account that the impact of one year of schooling on the quantity and quality of the stock of HC can be strongly influenced by several aspects, such as the quality of the educational system, the diverse returns of different levels of schooling, or personal characteristics such as intelligence and family background (Le et al., 2003; OECD, 1998; Wößmann, 2003).

Of the various limitations these methods present, the principal defect common to all of them is that they provide only an aggregate measure of the HC stock. Therefore what is needed is a new method of HC estimation that provides a microeconomic estimation of personal and household HC distribution as recommended in the 1998 OECD report on HC (p. 89): 'It should be accepted that a full understanding of the relationships between investment and benefit cannot be obtained by aggregate data alone.' In this direction Dagum and Slottje (2000) defined household HC as a latent variable (LV) and proposed its monetary estimation by combining an LV estimation method with an actuarial mathematical approach. These authors applied their method to estimate the monetary household distribution of 1983 HC in the U.S. In their breakthrough study, Dagum and Slottje (2000) provided a thorough analysis of the actuarial method while proposing only a general method for obtaining HC as an LV, providing little elaboration or detail.

The main purpose of this paper is to introduce an improved method for the estimation of household HC as an LV, starting from previous retrospective, prospective, and educational attainment approaches, in

agreement with the accepted economic definition of HC. The monetary value of HC is estimated and used in a recursive causal model to obtain short- and long-term multipliers that measure the direct and total effects of the predetermined variables or formative indicators that determine household HC.

Section 2 gives the definition of HC as a latent variable. Section 3 presents a new estimation method of HC as an LV, simultaneously determined by formative and reflective socio-economic indicators. Section 4 justifies chosen formative and reflective indicators for the estimation of HC and substantiates their selection. Section 5 discusses the results obtained for U.S. households using data from 2004. A monetary value of HC is obtained by following the actuarial approach introduced by Dagum and Slottje (2000). The distribution of U.S. household HC for year 2004 is then exhibited and analyzed. Section 6 applies the household HC monetary estimates to a recursive causal model in order to assess the effects of the formative indicators on HC by means of the short- and long-term multiplier matrices, respectively. Finally, Section 7 offers a conclusion as well as several policy implications.

2. DEFINITION OF HUMAN CAPITAL AS A LATENT VARIABLE

In the OECD report (1998: 4), HC is defined as 'the knowledge, skill, competencies and attributes embodied in individuals that are relevant to economic activity.' Hence HC is a complex, multifaceted concept with various intangible dimensions that are not directly observable and that cannot be measured with precision by a single attribute, a set of attributes, or their combined sum (Le et al., 2003). Following this viewpoint, Dagum and Slottje (2000) have defined household HC as that multidimensional nonobservable construct generated by personal ability, home and social environments, and investments in the education of the household head and spouse whose effects are indirectly measurable by means of the present value of a flow of earned income throughout an individual life span. Whereas the latter is an indicator of the prospective method, the former can be found in the educational attainment and retrospective approaches. It is these particular HC characteristics that prompted Dagum and Slottje (2000) to treat it as a sui generis LV.

Taking into account the partial least squares (PLS) path diagram approach to LVs (Tenenhaus et al., 2005), we provide an improved definition of the links between the socioeconomic concept of HC and its statistical definition as an LV. An LV can be defined in two different ways, both of which match the main characteristics of HC, which can be seen either as "an unobservable composite variable" of a set of indicators (Wold, 1982) or as a multidimensional construct that causes, and therefore is indirectly measured by means of observed indicators (Bentler, 1992).

By combining these two definitions, HC can be defined as a double-faced LV: an unobservable composite variable of the formative indicators related to investments in HC and simultaneously a multidimensional latent cause of a reflective indicator that measures the formative indicators' effects.

Formally, **HC** is supposed as a unidimensional $(n \times 1)$ latent variable measured, in Equation (1), as a linear combination of a set of (zero mean) p formative indicators embedded in the full rank matrix $\mathbf{F}$ $(n \times p)$, hence

$$\mathbf{HC} = \mathbf{Fg} + \mathbf{u}, \tag{1}$$

where $\mathbf{g}$ denotes the $(p \times 1)$ vector of weights (parameters) of the formative indicators and $\mathbf{u}$ $(n \times 1)$ is the random component vector, and simultaneously as a "latent cause" of the zero mean reflective indicators embedded in the $(n \times q)$ matrix $\mathbf{Y} = (\mathbf{y}_1, \ldots, \mathbf{y}_j, \ldots, \mathbf{y}_q)'$ that describe their effects (reflective indicators):

$$\mathbf{Y} = \mathbf{HCk}' + \mathbf{W}, \tag{2}$$

where $\mathbf{k}$ is the $(q \times 1)$ parameter vector and $\mathbf{W} = (\mathbf{w}_1, \ldots, \mathbf{w}_j, \ldots, \mathbf{w}_q)$ the $(n \times q)$ matrix of random components. In the next section a statistical model will be developed that simultaneously obtains the LV **HC** from the indicators **F** and **Y** by means of Equations (1) and (2).

3. ESTIMATION OF HUMAN CAPITAL AS A LATENT VARIABLE

There are numerous estimation methods for latent variables in statistical literature. For example, whenever only one LV is a latent cause of indicators **Y**, as in model (1)–(2), the multiple indicators and multiple causes of a single LV model (MIMIC), developed by Jöreskog and Goldberger (1975), is often applied. If we use this model, the LV denoted by $\mathbf{HC}^\circ$ is linearly determined by a set of observable exogenous causes **F**, subject to a disturbance $\mathbf{u}^\circ$:

$$\mathbf{HC}^\circ = \mathbf{Fg}^\circ + \mathbf{u}^\circ \tag{3}$$

and as latent cause of **Y**, so that

$$\mathbf{Y} = \mathbf{HC}^\circ\mathbf{k}^{\circ\prime} + \mathbf{W}^\circ \tag{4}$$

with the covariance structure

$$\mathbf{\Sigma_Y} = \sigma_u^2\mathbf{k}^\circ\mathbf{k}^{\circ\prime} + \mathbf{\Sigma_{W^\circ}}, \tag{5}$$

where $\Sigma_\mathbf{Y}, \Sigma_{\mathbf{W}^\circ}$ (diagonal) denote the matrices of variances of **Y** and $\mathbf{W}^\circ$, respectively, and σ_u^2, denotes the variance of $\mathbf{u}^\circ$.

In this case, however, **HC** cannot be simultaneously estimated by means of the formative indicators and the reflective indicators because the $\mathbf{k}^{\circ}$ parameters and the scores of $\mathbf{HC}^{\circ}$ are obtained from Equations (4) and (5), while the formative indicators **F** are only involved in the determination of the weights **g** that link them to **HC**. Therefore the MIMIC is not consistent with the socioeconomic definition of HC.

Dagum and Slottje (2000) followed an alternative approach utilizing Wold's PLS mode B method, where HC is expressed as an "unobservable composite variable" of a set of observed indicators **F** (Wold, 1982); it can be proved that the estimation of the standardized LV $\mathbf{HC}(\mathbf{HC}'')$,

$$\mathbf{HC}'' = \mathbf{Fg}'', \tag{6}$$

is equivalent to the first principal component of **F** standardized to unit variance. Hence even if the Dagum and Slottje (2000) method is the first contribution toward obtaining a zero-dimensional standardized estimation of household HC, it is not fully consistent with its economic definition. In fact, utilizing the PLS method, HC is determined only by the formative indicators **F**, as in the retrospective economic definition, without taking into account the return of investments in HC.

3.1. A New Estimation Method of HC as an LV

To overcome the limitations of the factor model and PLS, we propose the estimation of HC as standardized unobservable multidimensional linear combination of the formative indicators **F**, which better fits the reflective indicators **Y**. Hence replacing **HC** in Equation (2) by Equation (1), we have

$$\mathbf{Y} = \mathbf{HCk}' + \mathbf{E} = \mathbf{Fgk}' + \mathbf{E}, \tag{7}$$

where $\mathbf{E} = (\mathbf{uk}' + \mathbf{W})$. The solution of Equation (7) can be obtained by the redundancy analysis model (van den Wollenberg, 1977), which maximizes the sum of squared correlations (*cor*) between each reflective variable ($\mathbf{y_j}$) and **Fg** (redundancy index),

$$\sum_{j=1\ldots q} cor^2(\mathbf{Fg}, \mathbf{y_j}), \tag{8}$$

in respect to **g** under the restriction of variance unit for the **Fg** combination,

$$\mathbf{g}'\mathbf{F}'\mathbf{Fg} = 1. \tag{9}$$

As is known, using Lagrangian multipliers, the maximization (8) under (9) is achieved with the largest λ eigenvalue and corresponding $\hat{\mathbf{g}}$ eigenvector

of the matrix $(\mathbf{F}'\mathbf{F})^{-1}\mathbf{F}'\mathbf{Y}\mathbf{Y}'\mathbf{F}$. From Equations (1) and (11) we obtain the estimate of **HC**,

$$\widehat{\mathbf{HC}} = \mathbf{F}\hat{\mathbf{g}}, \tag{10}$$

and from Equations (7) and (9), the estimate of the parameter **k**,

$$\hat{\mathbf{k}} = \hat{\mathbf{g}}'\mathbf{F}'\mathbf{Y}. \tag{11}$$

The estimate of HC coincides with the first redundancy component of the formative indicators **F** with respect to the reflective indicators **Y**, i.e., the first linear combination of **F** maximally (multiple square) correlated with **Y**.

In case of a unique reflective indicator, Equation (8) maximizes the *R*-square of **y** onto **F**.

This method can be extended to the case of formative mixed indicators. In this case, Equation (2) is expressed as

$$\mathbf{HC} = \mathbf{F_c}\mathbf{g_c}\mathbf{k_c'} + \mathbf{F_q}\mathbf{g_q}\mathbf{k_q'} + \mathbf{u}, \tag{12}$$

where the matrix $\mathbf{F} = (\mathbf{F_c}, \mathbf{F_q})$ of formative indicators is partitioned into matrices $\mathbf{F_c}$ and $\mathbf{F_q}$, of qualitative and quantitative variables, respectively. The parameter vectors **g** and **k** are also partitioned into two components, $\mathbf{g} = (\mathbf{g_c}, \mathbf{g_q})$ and $\mathbf{k}' = (\mathbf{k_c'}, \mathbf{k_q'})$, respectively.

Therefore we look for algorithms of optimal scaling that generalize classical multivariate techniques such as principal components, multiple regression, and canonical correlation. Our preferred choice is the application of linear models in the context of ALSOS (alternating least squares with optimal scaling) methods, which sequentially estimates the parameter vector $\mathbf{g_c}$ and quantifies the categorical indicators $\mathbf{f_{jc}}$ (contained in $\mathbf{F_c}$) by means of a unique iterative algorithm that respects the simultaneity required, as shown in Equations (8)–(11), continuing until the values of $\hat{\mathbf{k}}$, $\hat{\mathbf{g}}$, $\widehat{\mathbf{HC}}$, and $\widehat{\mathbf{F}}_\mathbf{c}$ converge (Young et al., 1976). In this way, the case of mixed indicators is extended to the case of quantitative indicators achieving the final scores of HC by simultaneously estimating it as an unobservable multidimensional construct by utilizing mixed formative and reflective indicators.

Finally, in order to pass from the zero-dimensional standardized estimate $\widehat{\mathbf{HC}}$ in Equation (10) to a monetary HC, we followed the actuarial method proposed by Dagum and Slottje (2000).

4. THE SET OF HC FORMATIVE AND REFLECTIVE INDICATORS

The concept of HC as a macroeconomic aggregate indicator has been measured by means of many different variables related to education, health, social institutions, public and private investments, and others (World Bank, 1992; United Nations, 2002; Wößmann, 2003). However, these indicators cannot be arbitrarily chosen for the estimation of household (microeconomic) HC if we want to remain consistent with the economic definition given to this concept. To achieve a representative set we examined the indicators used in the educational attainment, retrospective, and prospective methods and chose those appropriate to inserting new indicators where appropriate.

4.1. Educational Attainment Indicators

4.1.1. *Educational Indicators*

The macroeconomic educational attainment method recommends measuring HC with indicators such as the number of person–school years embodied in the labor force, the educational infrastructures, the ratio of government spending on education to G.D.P, the educational expenditure per student, and the student–teacher ratio (Barro and Lee, 1996; Hanushek, 1996; OECD, 1998; Wößmann, 2003). These indicators, however, are not adequate for the measurement of household HC because they are not sufficiently disaggregated. We replace them with years of schooling, household debt, and educational debts.

4.1.2. *Demographic Indicators*

The educational attainment approach also suggests that region of residence, age, race, and gender can alter the effects of equal amounts of investment in HC (Jorgenson, 1995; OECD, 1998; Wößmann, 2003). For this reason, in the prospective approach the aggregate average level of HC is obtained as a weighted sum for particular groups and categories (Jorgenson, 1995; Wößmann, 2003). We have included these variables in our LV HC method.

4.1.3. *Training: On the Job Participation*

The effects of time investment on the job in training on the stock of household HC are influenced by gender, levels of education, and age (OECD, 1998; Wößmann, 2003), as well as by levels of training (OECD, 1998), experience gained through 'learning by doing' (Wößmann, 2003: 38), job status, occupation, sector of activity (Jorgenson, 1995), years of full-time and part-time work, and age of entrance into the labor

market. These variables have also been selected from among the formative indicators for the estimation of household HC as an LV.

4.1.4. *Parental Characteristics*

Educational disadvantage can perpetuate itself over generations, and family background can change the effects of an equal level of education on earning power (Wößmann, 2003). Therefore information on parents' wealth, educational attainment, qualifications, and occupation are not included in the group of formative indicators because they are not disposable.

4.1.5. *Adult Skills*

It has been stated that it is not only the quantity but also the quality of years of schooling that determines the value of education, 'i.e. the cognitive skills learned during each one of these years' (Wößmann, 2003: 19). In this direction, the quality ranking of schools and universities attended is strongly connected with quality of an educational institution and can also be utilized as a proxy of HC. Moreover, different skills or abilities, tested at the end of school or university attendance, are directly connected with investment in HC and therefore could belong to the formative indicators used for estimating HC. For this reason international agencies propose general literature (IALS, OECD) or mathematical and scientific tests for estimating the macroeconomic aggregate HC (see, among others, OECD, 1998; Wößmann, 2003).

However, information regarding the school attended, its quality, and the test results collected on samples of students is not generally linked to other information regarding individuals, single households, and their investment in HC. Therefore even if it were worthwhile to employ ability measurements, they are not currently available and hence not considered here for the estimation of household HC.

4.1.6. *Family Characteristics*

When measuring household HC, the stock of the investment of HC depends on the characteristics of the household. Information such as marital status (single, couple, partner) and other information regarding householder and spouse in the household are important for determining formative indicators. We also take into account the number of children, which influences many aspects related to HC.

4.2. Retrospective Method Indicators

The retrospective method has suggested measuring HC similarly to physical capital by means of the amount of the cost of the resources

invested. However, it should be kept in mind that the value of HC (like the value of physical capital) depends not only on the cost of production but also on its demand as well as by nonmarket activities (Jorgenson and Fraumeni, 1989; Le et al., 2003). Macroeconomic considerations aside, it is extremely difficult to measure the cost of individual and family investment in HC. In fact, Dagum and Slottje (2000) have stated that the total costs of education, housing, food, clothing, health care, and transportation are indistinguishable from the costs of investment in HC, so these types of indicators are not taken into account in our household HC estimation.

4.3. Prospective Method Indicators

The aggregate prospective method recommends quantifying the HC stock of an individual or a household by measuring earning power. According to the OECD report (1998: 28), 'The ratio of the earnings of higher-educated to lower-educated workers provides a measure of the formers' human capital.'

To measure the effects of HC investment, the rate of return of earned income must be calculated, so the lifelong household income based on personal income, actualized by means of an adequate actuarial method, can be considered as a proxy of the effects of investment in HC and utilized as a reflective indicator. Various earnings categories (i.e., higher post-tax earnings, extra tax earnings, capital income derived by investment in HC) can be used as reflective indicators (OECD, 1998). Survival probability and rate of productivity must also be taken into account in order to actualize the earning income (United Nations, 2002).

The literature regarding HC suggests that there are abundant sources available for measuring the return of the investment in HC (i.e., aggregate rate of employment, number of highly skilled workers, labor market training programs, technical know-how, and innovation). While average benefits to individuals and employment prospects are often clear, it is not always easy to quantify the benefits to society and above all to individuals and households (OECD, 1998). Finally, there is a lack of general surveys on individuals regarding these characteristics (OECD, 1998).

5. APPLICATION: THE U.S. HOUSEHOLD HC IN 2004

We first discuss the results obtained for the estimation of the zero dimensional (standardised) HC for the U.S. households corresponding to year 2004. We use the 2004 Survey of Consumer Finances (SCF) (Bucks et al., 2006), which contains detailed information about income, wealth and sociodemographic information on U.S. households. The data are taken from over 4,500 households, representative of more than

110 million U.S. families. For each household we consider indicators involving household head (H) and spouse (S). No adult skills or parental characteristic indicators useful for the estimation of household HC can be obtained from the SCF, and we use household earned income as the only reflective indicator.

Table 1 gives the formative indicators (and relative weights estimates) that were found significant (based on t values and significance, Sign) for determining the standardized HC. Indicators in upper case are quantitative, whereas variables in lower case are categorical and thus quantified following the procedure discussed in Section 3.

The results confirm the expectations of economic theory, which assumes that in the process of HC formation the largest weights are found for those variables related to education and job training, such as years of schooling and job status of the head of the household, household debt, years of full-time work, and type of occupation. Among demographic indicators, note that gender has more weight than age or race; among family characteristics, marital status is more important than the number of children.

TABLE 1 Weight estimates of quantitative and categorical HC formative indicators

Formative indicators	Description	Weights estimates, $\hat{g}$	Standard error	t value	Sign
		0	112.3	756.9	<.0001
Educational attainment	H YEARS OF SCHOOLING	0.23559	4.2	1042.9	<.0001
Educational attainment	S YEARS OF SCHOOLING	0.05271	4.3	538.3	<.0001
Educational attainment	HOUSEHOLD DEBT	0.21731	0.1	2590.8	<.0001
Educational attainment	EDU_LOAN	0.03702	0.2	457.6	<.0001
Demographic	H gender	0.07414	33.5	635.8	<.0001
Demographic	H AGE	0.08301	1.2	515.7	<.0001
Demographic	S AGE	0.05794	1.4	211.2	<.0001
Demographic	H race	0.03061	11.1	379.1	<.0001
Family characteristics	H marital status	0.08687	20.7	274.1	<.0001
Family characteristics	NUMBER OF CHILDREN	0.01315	10.1	147.7	<.0001
Training on the job	H job status	0.3669	7.4	4502.5	<.0001
Training on the job	S job status	0.16499	16.1	1006.1	<.0001
Training on the job	H type of occupation	0.18016	8.2	1679.6	<.0001
Training on the job	S type of occupation	0.0348	12.1	341.6	<.0001
Training on the job	H YEARS FULL-TIME JOB	0.1403	1.3	999.6	<.0001
Training on the job	S YEARS FULL-TIME JOB	0.05655	1.8	418	<.0001
Training on the job	H PART-TIME JOB	0.00257	2.7	27.1	<.0001
Training on the job	S PART-TIME JOB	0.01217	2.9	133.6	<.0001
Training on the job	H sector	0.07245	4.1	905.4	<.0001
Training on the job	S sector	0.02741	5.4	250.4	<.0001
Training on the job	H AGE STARTING JOB	−0.01255	1.2	−119.6	<.0001
Training on the job	S AGE STARTING JOB	−0.00613	1.5	−52.5	<.0001

All variables in upper cases letters are quantitative; those in lower case letters are categorical transformed into quantitative ones. H denotes household head and S household spouse.

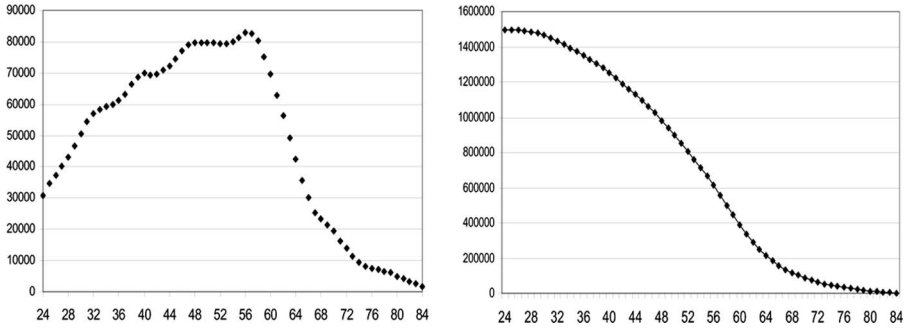

FIGURE 1 Household head (a) average earnings by age and (b) expected earnings in the life cycle.

In order to obtain the monetary value of household HC we apply the actuarial method proposed by Dagum and Slottje (2000); in particular, starting by average earnings y_x by age of household head (as representative cross-sectional data for the estimation of HC), depicted in Figure 1a (where large random fluctuations are reduced by smoothing the average earnings and the total weights by age with a 7-term moving average), we construct the series $h(x)$ representing the expected flow of earned income for a household head of age x (HC life cycle value), shown in Figure 1b, assuming a discount rate of 5% (approximately equal to Treasury bonds' interest) to actualize future earnings, capitalized by a rate of productivity (taking maximum value 3% at age 24, with a constant decrease in time until the age of 64, when it becomes null), and finally weighted by the survival probability to older ages, considering the American life tables for males (NVSR, 2000).

Finally we have obtained Av(h), the monetary mean of U.S. household HC, averaging $h(x)$ over age x of household heads and weighted by

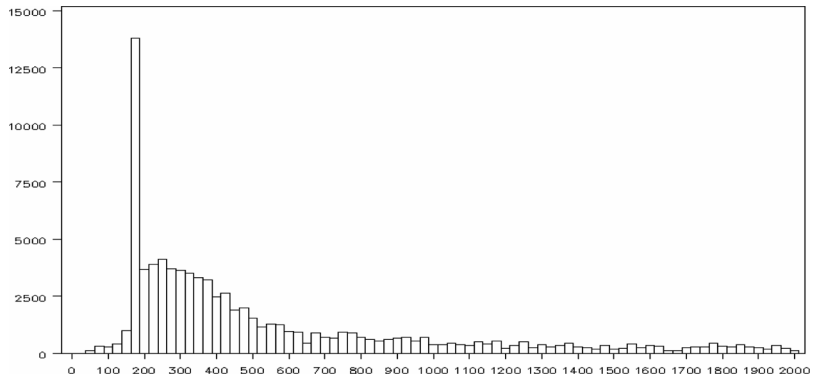

FIGURE 2 HC distribution of U.S. households ($1000).

the number of household population that ith household in the sample represents. Hence the obtained HC monetary mean for U.S. households is \$852,533, the median equal to \$982,401, and the Gini ratio is 0.656.

Figure 2 exhibits the monetary U.S. household HC for the year 2004.

6. ASSESSING THE EFFECTS OF THE EXPLANATORY VARIABLES ON HC

Starting from the new monetary estimation for household HC and an r-order vector $\mathbf{x}$ of explanatory (exogenous) variables, with an m-order vector $\mathbf{z}$ of endogenous variables, the Dagum recursive model $\mathbf{Bz} + \Gamma\mathbf{x} = \mathbf{u}$ is specified, where $\mathbf{B}$ is an $m \times m$ triangular matrix, $\mathbf{\Gamma}$ is an $m \times r$ matrix of structural parameters, and $\mathbf{u}$ is an m-order vector of independent random variables with zero mean and constant variance.

The variables used in the recursive model were obtained from the 2004 Survey of Consumer Finances (SCF) (Bucks et al., 2006) and are shown in Table 2.

For all the variables, the 2004 SCF provides the necessary statistical information for estimating the specified recursive model. In fact, using the magnetic tape of the 2004 SCF Manual and Codebook and the estimated vector of HC given in Section 3.1, we obtain the estimates of the recursive model to obtain the short- and long-term multiplier matrices that assess the direct and total effects of these variables on HC. Short- and long-term multiplier matrices (Johnston, 1984) can be deduced from the structural and the reduced forms of the model, respectively. In particular, the short-term multiplier matrices $\mathbf{ST_{zz}} = \mathbf{I} - \widehat{\mathbf{B}}$ and $\mathbf{ST_{zx}} = -\widehat{\mathbf{\Gamma}}$ are direct causal effects of vectors $\mathbf{z}$ and $\mathbf{x}$ on the vector $\mathbf{z}$, respectively, whereas the long-term multiplier matrix $\mathbf{LT_{zx}} = \widehat{\Pi} = -\widehat{\mathbf{B}}^{-1}\widehat{\mathbf{\Gamma}}$ gives the total causal effects of $\mathbf{z}$ and $\mathbf{x}$ on $\mathbf{z}$.

TABLE 2 Variables in the recursive Dagum model

a) Exogenous variables	b) Endogenous variables
$\mathbf{x}_1$ = age of household head (H)	$\mathbf{z}_1$ = years of schooling of H; $\mathbf{z}_2$ = years of schooling of S
$\mathbf{x}_2$ = gender of H	$\mathbf{z}_3$ = number of children; $\mathbf{z}_4$ = years of full-time work of H
$\mathbf{x}_3$ = race of H	$\mathbf{z}_5$ = years of not full-time work of H
$\mathbf{x}_5$ = marital status of H	$\mathbf{z}_6$ = years of full-time work of S
$\mathbf{x}_6$ = age of the spouse (S)	$\mathbf{z}_7$ = years of not full-time work of S; $\mathbf{z}_8$ = job status of H
$\mathbf{x}_7$ = gender of S	$\mathbf{z}_9$ = occupation of H; $\mathbf{z}_{10}$ = industry of H; $\mathbf{z}_{11}$ = job status of S
	$\mathbf{z}_{12}$ = occupation of S; $\mathbf{z}_{13}$ = industry of S
	$\mathbf{z}_{14}$ = household HC (estimated LV).

6.1. Estimation of the Short- and Long-Term Multiplier Matrices

The values of coefficients of the recursive model (matrices $\widehat{\mathbf{B}}$, $\widehat{\mathbf{\Gamma}}$ and those of the reduced form matrix $\widehat{\mathbf{\Pi}}$) are shown in Appendix 1.

It should be kept in mind that the weights estimated for the formative indicators discussed in the previous section concern the formation of standardized HC. On the other hand, the coefficients of these short- and long-term multiplier matrices refer to monetary household HC, where the effect of labor demand is incorporated. Depending on labor market conditions, high levels of household HC are not necessarily in proportion to high earned income. From the estimated short term multiplier $\mathbf{ST_{zz}}$, (Table 3 in Appendix 1), we can deduce:

(I) A first set of formative indicators with a high impact on monetary HC, $\mathbf{z}_{14}$, which concerns labor market conditions, such as job status ($\mathbf{z}_8$ and $\mathbf{z}_{11}$), part-time employment ($\mathbf{z}_5$ and $\mathbf{z}_7$), type of occupation ($\mathbf{z}_9$), and sector ($\mathbf{z}_{10}$), as follows:

(Ia) $\partial\mathbf{z}_{14}/\partial\mathbf{z}_8 = 14,877.5$ and $\partial\mathbf{z}_{14}/\partial\mathbf{z}_{11} = 8,011.7$, meaning that monetary household HC is strongly related to job status,

(Ib) $\partial\mathbf{z}_{14}/\partial\mathbf{z}_5 = -14,759.9$ and $\partial\mathbf{z}_{14}/\partial\mathbf{z}_7 = -9,332.1$, i.e., a one-year increase in part-time employment contributes to a decrease of \$14,759.9 and \$9,332 of household head (H) and spouse (S) HC, respectively.

(Ic) $\partial\mathbf{z}_{14}/\partial\mathbf{z}_9 = 3,266.3$ and $\partial\mathbf{z}_{14}/\partial\mathbf{z}_{10} = 4,250.1$, which indicate that the type of occupation and sector strongly determine the valorization of HC.

(II) A second set of direct causal effects regards the links between education indicators $\mathbf{z}_1$ and $\mathbf{z}_2$ on household HC, $\mathbf{z}_{14}$ as follows:

(IIa) $\partial\mathbf{z}_{14}/\partial\mathbf{z}_1 = 7,092.1$ and $\partial\mathbf{z}_{14}/\partial\mathbf{z}_2 = 3,262$, i.e., the marginal increase of HC resulting from a one-year increase in schooling of the household head (H) and spouse (S) are \$7,092 and \$3,262, respectively, indicating that the level of education plays a highly significant role in monetary HC.

(III) From the estimated short-term multiplier matrix $\mathbf{ST_{zx}}$ (Table 4 in Appendix 1) we can analyze the direct causal effects of the purely exogenous variables $\mathbf{x}$ relative to those of the vector $\mathbf{z}$. In particular, regarding the links of HC with age ($\mathbf{x}_1$) and race ($\mathbf{x}_3$), we observe

(IIIa) $\partial\mathbf{z}_{14}/\partial\mathbf{x}_1 = -2,433.8$, i.e., a one-year increase in the age of household head determines a marginal decrease of HC of \$2,433.8. This result is in line with the statistical evidence in the U.S. and many other countries, providing cross-sectional data that show an increasing trend of the average years of schooling of the population, hence a

TABLE 3 MATRIX: $\widehat{\mathbf{B}}$ (Short-term multiplier $\mathbf{ST}_{zz} = \mathbf{I} - \widehat{\mathbf{B}}$)

Model	$\mathbf{z}_1$	$\mathbf{z}_2$	$\mathbf{z}_3$	$\mathbf{z}_4$	$\mathbf{z}_5$	$\mathbf{z}_6$	$\mathbf{z}_7$	$\mathbf{z}_8$	$\mathbf{z}_9$	$\mathbf{z}_{10}$	$\mathbf{z}_{11}$	$\mathbf{z}_{12}$	$\mathbf{z}_{13}$	$\mathbf{z}_{14}$
$\mathbf{z}_1$	1	0	0	0	0	0	0	0	0	0	0	0	0	0
$\mathbf{z}_2$	−0.524	1	0	0	0	0	0	0	0	0	0	0	0	0
$\mathbf{z}_3$	0	0	1	0	0	0	0	0	0	0	0	0	0	0
$\mathbf{z}_4$	0	0.335	0.798	1	0	0	0	0	0	0	0	0	0	0
$\mathbf{z}_5$	0	0	0	0.070	1	0	0	0	0	0	0	0	0	0
$\mathbf{z}_6$	0	−0.407	−0.522	−0.074	0	1	0	0	0	0	0	0	0	0
$\mathbf{z}_7$	0	−0.196	0	0	0	0.112	1	0	0	0	0	0	0	0
$\mathbf{z}_8$	−0.036	0	0.023	−0.042	0	0	0	1	0	0	0	0	0	0
$\mathbf{z}_9$	0	0	0		0	0	0	−0.591	1	0	0	0	0	0
$\mathbf{z}_{10}$	−0.107	0	0	0.047	0.074	0	0	0	−0.482	1	0	0	0	0
$\mathbf{z}_{11}$	0	0	0	0	0	0.011	0	0	−0.075	0	1	0	0	0
$\mathbf{z}_{12}$	0	0.069	0	0	0	0	0	0	0	0	0.066	1	0	0
$\mathbf{z}_{13}$	0	0	0	0	0	−0.073	0	0	0	0	0	−0.611	1	0
$\mathbf{z}_{14}$	−7092.1	−3262.0	−3492.0	−1672.7	14759.9	−672.7	9332.1	−14877.5	−3266.3	−4250.1	−8011.7	−2686.4	−1887.0	1

TABLE 4 MATRIX: $\widehat{\mathbf{\Gamma}}$ (Short-term multiplier $\mathbf{ST_{zx}} = -\widehat{\mathbf{\Gamma}}$)

Model	$\mathbf{x}_1$	$\mathbf{x}_2$	$\mathbf{x}_3$	$\mathbf{x}_5$
$\mathbf{z}_1$	0.018	0	−1.255	0
$\mathbf{z}_2$	0.008	−10.93	−0.239	0
$\mathbf{z}_3$	−0.024	0	0.099	0
$\mathbf{z}_4$	−0.086	−4.192	−0.874	0
$\mathbf{z}_5$	0.038	−0.354	0	0
$\mathbf{z}_6$	0	0	0	−0.539
$\mathbf{z}_7$	0	0	−0.180	0
$\mathbf{z}_8$	0.040	0	0	0
$\mathbf{z}_9$	0.017	−0.221	0	0
$\mathbf{z}_{10}$	0	−0.353	−0.147	0
$\mathbf{z}_{11}$	0	0	0	0.060
$\mathbf{z}_{12}$	0.007	0	0	0
$\mathbf{z}_{13}$	0	0	0	0
$\mathbf{z}_{14}$	2433.8	0	−4428.3	−953.6

marginal increase of age decreases the monetary value of HC; in fact, Table 4 (Appendix 1) demonstrates that a marginal increase of age ($\mathbf{x}_1$) determines a marginal decrease of years of schooling ($\mathbf{z}_1$);

(IIIb) $\partial \mathbf{z}_{14}/\partial \mathbf{x}_3 = 4,428.3$, i.e., there is a larger interracial inequality of the monetary amount household HC.

(IV) The observations made for the short-term multipliers conform to those drawn from the long-term multiplier coefficient matrix $\mathbf{LT_{zx}}$ (Table 5 in Appendix 1), which give the total effect of combined

TABLE 5 MATRIX: $\widehat{\mathbf{\Pi}}$ (Long-term multiplier $\mathbf{LT_{zx}} = \widehat{\mathbf{\Pi}} = -\widehat{\mathbf{B}}^{-1}\widehat{\mathbf{\Gamma}}$)

Model	$\mathbf{x}_1$	$\mathbf{x}_2$	$\mathbf{x}_3$	$\mathbf{x}_5$
$\mathbf{z}_1$	−0.018	0.000	1.255	0.000
$\mathbf{z}_2$	0.014	10.910	0.896	0.000
$\mathbf{z}_3$	0.024	0.000	−0.099	0.000
$\mathbf{z}_4$	0.071	7.848	1.096	0.000
$\mathbf{z}_5$	0.033	−0.197	−0.077	0.000
$\mathbf{z}_6$	0.024	−5.015	0.497	0.539
$\mathbf{z}_7$	0.000	1.575	−0.299	−0.060
$\mathbf{z}_8$	−0.038	0.329	0.089	0.000
$\mathbf{z}_9$	0.039	0.416	0.053	0.000
$\mathbf{z}_{10}$	−0.014	0.200	0.058	0.000
$\mathbf{z}_{11}$	−0.003	0.084	−0.009	−0.055
$\mathbf{z}_{12}$	0.006	−0.754	0.062	0.004
$\mathbf{z}_{13}$	0.002	−0.824	0.074	−0.037
$\mathbf{z}_{14}$	−3293.9	1833.0	18160.6	55769.6

exogenous and lagged endogenous variables on monetary household HC. Particularly, we observe that

(IVa) $\partial \mathbf{z}_{14}/\partial \mathbf{x}_3 = 18,160.6$, i.e., the total effect of race on HC is much higher than that drawn from the short-term multiplier, and

(IVb) $\partial \mathbf{z}_{14}/\partial \mathbf{x}_5 = 55,769.6$, i.e., the total effect of marital status on household HC has an extremely high value.

7. CONCLUSIONS AND POLICY IMPLICATIONS

In this study we have introduced a new method for the estimation of household HC, defined as an unknown composite variable made up of formative indicators whose return is measured by the reflective indicator given by earned income (net wealth). First, we present a statistical method, which, differently from PLS and the factor model, estimates household HC simultaneously from formative and reflective indicators and hence is consistent with the economic definition of HC. We then select an appropriate set of formative indicators related to educational, demographic, and family characteristics. The new method has been applied to estimate the household HC of the U.S. population in 2004, using household earned income as the only reflective indicator.

The results have confirmed the expectations of economic theory, in the sense that the largest impact on the formation of household HC, measured as an LV, is due to indicators related to education and job training, such as years of schooling and job status of the household head, years of full-time work, and type of occupation. Among demographic indicators, gender had more weight than age or race, and within family characteristics, marital status was found to be more important than the number of children.

We used the Dagum–Slottje (2000) actuarial method to calculate monetary household HC and applied the result to a causal recursive HC model in order to estimate short- and long-term multiplier matrices for the assessment of the direct and indirect patterns of causation among endogenous indicators. The results, given by the short- and long-term multiplier matrices, demonstrated that formative indicators, found highly significant for the estimation of standardized HC, were also important for monetary HC, with the exception of the race variable, which became relevant in the monetary HC but not in the standardized HC.

The new model and estimation method for household HC offers relevant information for the evaluation of policy choices on educational programs, research and development, labor markets, regional development, and more. For example, concerning

(a) The quality of the educational and job training system, household HC estimation gives a long-term indicator of the increase of technical,

professional, and scientific qualifications connected with the investment in HC determined by educational attainment and training on the job.

(b) The amount of investment in research and development (R&D) and the increase in productivity, the investment in R&D determines an accumulation of high levels of HC incorporated into economic processes and consequently, an increase in productivity, which is the outcome of R&D. The estimation of household HC can become a new indicator of the return in the investment in R&D and of its consequences on productivity. Moreover, the higher levels of HC could be matched with appropriate advanced investment by the corporations and the corresponding public investment in the socioeconomic infrastructure of the region to be able to assure the demand for high endowment of HC.

(c) The evaluation of financial investment projects by firms or by state and public authorities, their effectiveness could be measured by the amount and increase of household HC, which is, in many sectors, more influential than the amount of physical capital.

(d) The reduction of the inequality in income and wealth distribution, the increase of the amount of household HC and the decrease of the inequality in its distribution determines the decrease of the inequality of personal earned income distribution and consequently the increase of regional economic growth, development, and labor share. Moreover, an investment in HC contributes to a decrease in the inequality of the distribution of wealth and of capital income, wealth being the personal source of capital income.

(e) The utilization of the invested household HC in the economic system, we suggest the evaluation of the amount of employed and unemployed household HC in different economic sectors and regions.

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