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The Regional Economic Value of Nonmarket Household Production Time: Combining an I-O Framework with Time Use Data

James E. Pratt
Cornell University – USA

Abstract. Since their inception in 1934, the National Income and Product Accounts of the U.S. (NIPAs) have excluded estimates of household production from total economic activity. Many proposals have been made for including the value of household production in the NIPAs, all of which rest on some form of imputed value to be added to Gross Domestic Product. This paper uses U.S. data from 2006 to determine economy-wide implicit values for the time spent by household members in unpaid household activities, specifically unpaid child care time. I demonstrate a method that combines household time allocation within an Input-Output (I-O) framework to allow for an implicit rather than an imputed valuation of household time. The values for work and work-related time as well as family care time by industry and by occupation are universally large and do not follow a pattern which might be suggested by wages alone.

1. Introduction

Increased interest is being focused on the role of child care in economic development (Warner, 2006a, 2007; Folbre, 2006, 2008). Regional economists have conducted detailed analyses of the child care sector using traditional Input-Output (I-O) approaches (Warner, 2006b; Warner and Liu, 2005, 2006) as well as hypothetical extraction methods to capture the predominantly forward linkages for service industries such as childcare (Pratt and Kay, 2006; Kay, Pratt, and Warner, 2007). Because parental care accounts for the majority of care that children receive (Folbre 2008), adequately capturing the short-run economic value of child care also requires a frame of analysis that includes the role of nonmarket household care. Failure to adequately account for household-provided care leaves a gaping hole in our valuation of care activities (Crittenden, 2001; Warner, 2009).

It has long been recognized that measurements of several areas of nonmarket activities, such as household production, formal education, health investments, nonprofit and government activities, and environmental assets and services, are missing from our National Income and Product Accounts (NIPA's) (Abraham and Mackie, 2005). Consequently, these are also missing in most economic policy studies. The concern and debate over excluding unpaid household production (King, 1923; Pigou, 1920; Carson, 1975) predates the formal establishment of the NIPA's (Kuznets, 1934). Arguments against counting the economic contributions of unpaid household production usually rest on the difficulties of measuring and valuing these 'nonmarket' inputs and outputs (van de Ven et al., 1999) and on the large variance in estimates that result when different valuation methods are used (Reich, 1991, 2001)[1]. Various imputed wage estimates of the unmeasured value of household production

[1] "At one point national accountants may have been inclined to yield to the demand of including housework in the accounts, but when empirical studies showed quantitative ranges between 30 per cent and 60 per cent of GDP it became obvious that adding those amounts to the two sides of the account in identical values would render the transaction approach meaningless" (Reich, 2001, p. 27).

time using satellite accounts have added from 12% to 80% to U.S. Gross Domestic Product (GDP). A National Academy of Sciences Panel (NAS Panel) points-out that the NIPA's (1) "use dollar prices as the metric for relative value"; (2) "value outputs at their marginal rather than their total value"; and (3) "derive these marginal values wherever possible from observable market transactions" (Abraham and Mackie, 2005, p. 23). Comparable practices for nonmarket activities should be followed.

Based on a procedure outlined by Pratt (Pratt, 2007), this paper uses U.S. data from 2006 to explore the determination of economy-wide implicit values for the time spent by household members in unpaid household activities. Estimates of detailed household production time from nearly 13,000 respondents in the American Time Use Survey for 2006 are combined with the 2006 U.S. National Input-Output table. Using the duality between time allocation and time valuation, these implicit values for household production time (1) use the same metric as the I-O flows accounts, namely transactions-based, GDP-denominated monetary units; (2) are, by definition, marginal values; and (3) are based on the same observed market transactions used in compiling NIPAs and the U.S. I-O table.

This analysis proceeds by describing the long-standing problem with the NIPAs and household production and discusses the difference between an accounting approach and the economic approach used here to value family care time. Next, it outlines the components of Input-Output and the American Time Use Survey (ATUS) used in the analysis. This is followed by a description of how the NIPA I-O account can be formulated as an equivalent mathematical program for the purpose of computing dual values. Finally, the ATUS data for 2006 is integrated with the NIPA 2006 I-O table, and dual values for work and work-related time are computed by industry and by occupation. Based on these dual value computations, imputed values for the care time provided to household members is estimated for employed ATUS respondents in different occupations.

2. The National Income and Product Accounts

That NIPA's have, from their inception, excluded estimates of household production is not a recent revelation (Reid, 1934). The growth of female paid labor force participation and the coincident re-emergence of the 'feminist' movement have, however, brought a renewed focus on the value of household production. Combined with current interests in valuing the environment, health, and education, there is renewed interested in measuring economic activity by way of nonmarket accounts. To address this issue, the NAS Panel strongly recommended "… the development of satellite accounts to report on selected activities not included in the conventional accounts" (Abraham and Mackie, 2005, p. 16). Among the excluded nonmarket accounts, work on developing household production satellite accounts has advanced the farthest (Ironmonger, 2001; Landefeld and McCulla, 2000). These household production satellite accounts have progressed substantially as part of the effort to measure household production and to properly reclassify many household expenditures from 'final consumption' to 'intermediate inputs' (Landefeld and Villones, 2007).

There have been many efforts to value household production (e.g., Bryant et al., 1992; Folbre, 2008; Hamdad, 2003; Ironmonger, 2001; Landefeld and McCulla, 2000; Landefeld et al., 2005; Trewin, 2000; Zick and Bryant, 1983, 1990). All of these have imputed a value to the time spent by households in nonmarket production activities using various imputation methods, with the opportunity cost, quality-adjust replacement cost, and housekeeper wage approaches being the most common. In addition to deciding on the appropriate imputed value to use, a determination must be made as to which nonmarket household activities this value will be applied, i.e., which activities are 'work'. All of these efforts rely heavily on the use of household activity accounts, mainly household time use information. Because these efforts depend heavily on imputations, the irksome issue of valuation remains. While utilizing information potentially available from household production satellite accounts, the research reported below addresses the NAS Panel's desire "to encourage social scientists to pursue the analysis of nonmarket activities and the development of corresponding data collection and accounting systems" (Abraham and Mackie, 2005, p. 10), by exploring a national approach to the valuation of household production.

In this analysis, valuation in the NIPA's is formally linked with time allocation from the ATUS using duality between work and work-related time and total market output. Formulating the U.S. national I-O table for 2006 as a mathematical program allows for the computation of dual values. In traditional I-O analysis, these values are commonly known as multipliers. This mathematical reformulation allows for the augmentation of time use data to the national I-O table and the subsequent dual valuation of time spent in market work and work related activities. Once this formal dual linkage between market valuation and time allocation is made, nonmarket time use can be valued through its relationship to market time.

2.1 Accounting versus economic valuation

Most of us are, by nature, accountants. It is more natural for us to think in terms of total expenditures than in terms of marginal costs. It is more natural for us to consider the cost of raising children as the grand sum of all the associated expenditures that are made rather than as the value of what is 'given up'. Using an imputed value, which is based on a replacement wage, or quality-adjusted replacement wage, as a substitute for the parental time devoted to children in an expenditure summation, resides squarely in the realm of accounting and has been used by most studies of household time. Using an opportunity cost of time for the parents moves the cost calculation more towards an economic perspective, but summing these costs is still accounting. The NAS Panel suggests using a "productivity-adjusted replacement cost instead to value time inputs to home production" (Abraham and Mackie 2005, p 75), leaving us firmly in an accounting framework and potentially adding large values to the long-standing national accounting totals.

An alternative approach, used in this paper, is to compute an aggregate, economy-wide opportunity cost, rather than an individual or household opportunity cost. This value is not intended to be summed, but stands on its own as a market value indicator. This implicit value is based on time-use interactions with inter-industry and industry-household monetary relationships that are already contained in the NIPAs. These economy-wide opportunity costs indicate the economy-wide marginal valuation of nonmarket household production time, much like Input-Output multipliers are used to indicate the economy-wide output stimulating impacts of final demand spending. Economic developers, business managers, labor leaders, and even politicians can grasp the multiplier concept and understand how the same concept can be applied to time devoted to nonmarket activities. The values derived from this approach are not opportunity costs for individuals or even households, but opportunity costs for the aggregate economy, be it a nation, a region, or a community. They are the total foregone market output value resulting from removing time from market activity and devoting it to nonmarket activity. This involves all the multiplier effects that we know are at work in the market sectors. It does not measure the value of non-market care time directly, but, rather, provides an economy-wide estimate of its opportunity cost.

3. The conceptual components

3.1 Input-Output (I-O)

National Input-Output accounts are one of the three major branches of a nation's national economic accounting; the other two are capital finance accounts and balance sheets. I-O tables quantitatively trace the flows of goods and services among an economy's industries and households and can be considered as "a foundation for the NIPA's" (Abraham and Mackie, 2005, p. 40). The U.S. Bureau of Economic Analysis (BEA) collects and disseminates the data that make-up the U.S. national I-O tables (http://www.bea.gov/index.htm). It must be stressed at the outset of the empirical section of this paper that the use of data from the U.S. I-O tables and from the ATUS is done in a 'descriptive' rather than a 'prescriptive' mode. Wassily Leontief, the father of modern I-O, more than once used "describe" and "quantitative picture" in his motivations for constructing I-O tables (for example, see Leontief, 1953, p. v, and Leontief, 1965, p. 35). Also, though a highly aggregated form of the NIPA's is used here (13 market industries), the basic BEA data lends itself to a much higher degree of detailed disaggregation[2], allowing for the creation of "the 200-inch telescope" (Leontief, 1965, p. 35) that modern day economic analysis requires.

3.2 Time use

The establishment of the American Time Use Survey offers great promise in advancing the valuation of nonmarket household production. The NAS Panel stated that, "Time is the most quantitatively significant input to both market and nonmarket production. One cannot begin to understand economically oriented nonmarket activity without knowing how a population spends its time"(Abraham and Mackie, 2005, p. 43). A number of countries have conducted time use studies in recent years, including Australia (Trewin, 2000), Canada (Statistics Canada, 1998), and the United Kingdom (Holloway et al., 2002). Canada and Australia have used these to estimate the value of unpaid household work. These computations resulted in 34% and 48% increases in GDP for Canada and Australia, respectively.

In January 2003, the U. S. Bureau of Labor Statistics (BLS) initiated the ATUS. The ATUS uses the Current Population Survey (CPS), a rich, continuous survey of households covering 300 variables, as the sampling

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[2] Through 2006, the IMPLAN U.S. I-O tables (Minnesota IMPLAN) allowed up to 509 sectors. After 2006, they follow BEA's new categories and will be reducing the number of industry sectors to 440. The BLS Occupational Employment Statistics (OES) program produces employment estimates for over 800 occupations.

frame. One randomly chosen adult (15 or older) in each CPS household is asked to complete a detailed time diary for his/her activities over the previous 24 hours. The diary day can be a weekday, weekend day, or holiday. The numbers of respondents for 2003-2007 were 20,720, 13,973, 13,038, 12,943, and 12,248, respectively. Weights associated with the ATUS participants are structured to produce nationally representative estimates. Weights are also provided, allowing responses from all years to be aggregated into a single data set. For this analysis, the 12,943 respondents from the 2006 ATUS are used. These respondents belong to households that represent a total of 71,211 individuals. The BLS publishes a news release with verbal and tabular summaries of each year's ATUS responses (http://www.bls.gov/tus/). For this analysis, I use work and work-related time. This time use category captures time spent working, doing activities as part of one's job, engaging in income-generating activities (not as part of one's job), and looking for jobs and interviewing. "Working" includes hours spent doing the specific tasks required of one's main or other job, regardless of location. Work done by self-employed as well as wage and salary workers is coded here. "Work-related activities" include activities that are not obviously work but are done as part of one's job, such as having a business lunch or playing golf with clients.

4. Method of analysis

For this analysis, the U.S. economy is partitioned into thirteen industrial and service sectors. The fundamental I-O system can be represented as:

$$AX + Y = X \quad (1)$$

$$Y = X - AX \quad (2)$$

$$Y = (I - A)X \quad (3)$$

$$X = (I - A)^{-1}Y \quad (4)$$

where:

X is a 13 x 1 vector of total market output
Y is a 13 x 1 vector of final demands
A is a 13 x 13 matrix of 'direct requirements',
AX is a 13 x 1 vector of intermediate demands,
I is a 13 x 13 identity matrix,
(I-A) is the 13 x 13 'Leontief' matrix, and
$(I-A)^{-1}$ is the 13 x 13 'Leontief'Inverse.

The familiar output multipliers are column sums of the Leontief Inverse and represent the cumulative industry output responses to exogenous changes in final demands, Y. Leontief's output multipliers have been (Isard, 1960) and continue to be (Hughes, 2003) routinely employed in the analysis of economy-wide impacts of activities in sectors ranging from agriculture and manufacturing to tourism.

In mathematical optimization, the concept of duality is a highly developed relationship between an optimization problem, the 'primal', and its alternative, but equivalent, 'dual' problem. Duality in the Input-Output (I-O) accounts is a mathematical certainty. The best place to go for an economic interpretation of duality in the context of a mathematical program is the classic 1958 economic textbook by Dorfman, Samuelson, and Solow.

> "The foregoing considerations show the intimate connection between the problem of valuation, i.e., that of determining the resource values *u*, on the one hand, and the problem of allocation, i.e., that of finding an optimal production program, on the other…. In fact we shall see that the two problems are mathematically identical" (Dorfman, et al., 1958, p. 174).

At the crossroad of economics and optimization, this means that a typical economic allocation problem, where the desire is to find an optimal *allocation* of scarce resources, has an equivalent economic *valuation* problem that optimizes the 'dual', or implicit, values of those scarce resources. These two views, *allocation* and *valuation*, of the same economic process are mathematically and economically equivalent. It is this particular dual relationship, between the allocation of resources and the values of these same resources, on which the following analysis of unpaid household time is built. That the NIPA's, in their I-O format, comprise a mathematical program is well-known (Brink and McCarl, 1977; ten Raa, 2005). Dual values computed from these tables give us the now-familiar final demand multipliers that have become common knowledge and accepted economic wisdom.

The I-O system of Leontief equations can be recast as a linear program (LP), with an objective function (5), the Leontief technical coefficients and right-hand-side constraints (6), and non-negativity (7).

$$\text{Maximize} \quad \Sigma X \quad (5)$$

$$\text{s.t.} \quad (I-A)X = Y \quad (6)$$

$$X \geq 0 \quad (7)$$

In this form, the system has an objective of maximized total market output (Σ X), thirteen variables, X, representing individual industry outputs, and thirteen constraints, Y, representing final demand for each industry's output. The choice of objective allows the dual values to be expressed in the same dollar values used for GDP. However, it should be pointed-out that this system, by way of its accounting structure, has only one solution, the observed market outcome, regardless of the objective. Given that we are concerned with a description of the system's marginal attributes, rather than predictions of larger changes, the choice of objective function serves solely to determine the units of the dual values. As is more customary for LP formulations, the fundamental accounting equalities (6) are changed to less-than inequalities (9).

$$\text{Maximize} \quad \Sigma X \tag{8}$$

$$\text{s.t.} \quad (I-A)\,X \leq Y \tag{9}$$

$$X \geq 0 \tag{10}$$

By incorporating a new set of variables that represents the actual levels of final demand that are met when the system is solved, Y_{actual} , and an additional set of thirteen inequality constraints that require actual final demand to be less than or equal to the originally observed final demands, the extended LP formulation now has thirty-nine variables, X's, Y's, and Y_{actual}'s, associated with the inequality constraints, and twenty-six constraints.

$$\text{Maximize} \quad \Sigma X \tag{11}$$

$$\text{s.t.} \quad -(I-A)\,X + Y_{actual} = 0 \tag{12}$$

$$Y_{actual} \leq Y \tag{13}$$

$$X, Y_{actual} \geq 0 \tag{14}$$

When this LP is solved, the optimal solution values for X are the same as the I-O industry output values in the original I-O formulation and observed in the original I-O accounts. The optimal LP dual values for the final demand constraints (13) are identical to the I-O output multipliers. What then is the advantage of using the LP formulation?[3] Once the basic I-O problem is formulated as a mathematical program, additional constraints and variables can be added to the basic I-O structure. This additional information need not be in the same GDP dollar units as the objective function or final demand constraints in the original I-O problem. For this analysis, these additional constraints will involve the physical units of time use and availability in the I-O economy. This approach is similar to one suggested by Gershuny (1987). It captures the 'chain of provision' of time use for an economy through the inter-industry relationships in the I-O. Rather than attempting to measure the direct and indirect time uses, the I-O/LP structure allows the direct and indirect time use chain to be embodied in the direct and indirect monetary flows of the I-O and in the direct and indirect time use relationships embodied in the LP time constraints.

4.1 Integrating the American Time Use Survey

Demographic information is available about the industry of employment and the occupation of employment for respondents in the ATUS, thereby permitting the bridging of time use data and the U.S. national I-O accounts. To assess the representativeness of the industry/occupation profile of the 2006 ATUS respondents, an industry/occupation matrix is constructed for the respondents and is graphically and statistically compared to the BLS national estimates of employment by occupation and industry. In 2006, BLS estimated from its Occupational Employment Statistics (OES) National Employment Matrix that there were 144,430,000 employed persons in the U.S. (BLS, 2006). These OES estimates are constructed from a sample of about 1.2 million establishments. The unweighted employment of sampled establishments makes up approximately 65 percent of total national employment.

Table 1 lists and Figure 1 graphs the relative percentages of employment, by industry and by occupation, from both the BLS national estimates and the ATUS survey respondents. The BLS estimates and the ATUS survey produce very similar employment–by-industry and employment–by-occupation distributions. The correlation coefficient between the BLS national estimates and the ATUS respondents for industry sectors, at .98, is very high, as is the .99 for occupations. Tests of the differences in variances for these two distributions indicate no significant difference between the variances of relative employment by industry for the BLS national estimates and the ATUS survey. Conducting a spatial test for differences in two-way variances, by industry and occupation, between BLS and ATUS (Wong and Lee, p. 147) that uses the relative percents as spatial weights, the null hypothesis of equal two-way variances in these two distributions is not rejected.

The 8,250 employed respondents in the 2006 ATUS engaged in work and work-related activities an average of 5.71 hours per day, which is 40 hours per week, or 2,084 hours per employed person per year. This would imply a total work and work-related commitment of over 301 billion hours in 2006. Using

[3] Some researchers legitimately point out that the linear structure of I-O and LP are too restrictive for household production analysis (Folbre, 2006, p. 50). It should be noted here that the LP structure of this problem is simply a result of the inherent linear structure of the national I-O accounts. Any non-linear mathematical program that embodies the I-O structure could also be chosen. The choice of mathematical structure would ultimately rest on the form of the relationships that time use researchers discover.

nationally-representative weighted ATUS estimates of average work and work-related time use and the BLS estimates of the number of persons employed in each of the 13 economic sectors used in this analysis, total employed hours in each sector are estimated and related to the individual industry outputs from the U.S. I-O table. These are reported in Table 2.

Table 1. Relative percentage of employees by industry and occupation: BLS and ATUS

Industry \ Occupation	Management, Business, and Financial	Professional & Related	Service	Sales & Related	Office & Administrative	Farming, Fishing, & Forestry	Construction & Extraction	Installation & Maintainance	Production	Transportation & Material Handling	
Agriculture, Forestry,	0.721	0.033	0.062	0.006	0.061	0.553	0.010	0.011	0.023	0.048	1.53
Fishing, and Hunting	0.764	0.012	0.061	0.012	0.061	0.533	0.024	0.036	0.012	0.036	1.55
	0.060	0.054	0.004	0.006	0.038	0.000	0.172	0.050	0.024	0.069	0.48
Mining	0.012	0.061	0.000	0.000	0.036	0.000	0.121	0.048	0.048	0.024	0.35
Transportation and	0.503	0.203	0.215	0.094	1.254	0.003	0.116	0.345	0.222	2.207	5.16
Utilities	0.436	0.230	0.145	0.085	1.297	0.024	0.109	0.364	0.182	1.588	4.46
	1.172	0.138	0.044	0.073	0.432	0.003	5.557	0.391	0.126	0.198	8.13
Construction	0.836	0.133	0.061	0.121	0.497	0.012	3.855	0.424	0.109	0.279	6.33
	1.791	1.444	0.181	0.433	1.032	0.035	0.233	0.559	4.699	0.931	11.34
Manufacturing	1.782	1.709	0.109	0.400	1.079	0.061	0.145	0.558	4.279	0.606	10.73
Wholesale and	1.083	0.705	0.457	7.515	2.316	0.044	0.100	0.643	0.465	1.440	14.77
Retail Trade	1.042	0.776	0.364	7.067	2.073	0.061	0.073	0.618	0.545	1.285	13.90
	0.493	0.756	0.070	0.288	0.470	0.000	0.008	0.272	0.066	0.051	2.47
Information	0.703	0.800	0.024	0.376	0.509	0.000	0.012	0.230	0.036	0.048	2.74
Financial	2.679	0.439	0.232	1.736	1.891	0.000	0.054	0.125	0.035	0.074	7.26
Activities	3.188	0.461	0.315	1.879	1.891	0.000	0.036	0.061	0.024	0.085	7.94
Professional and	2.198	3.214	1.964	0.386	1.619	0.008	0.121	0.194	0.233	0.357	10.29
Business Services	2.315	3.321	2.085	0.315	1.600	0.000	0.109	0.109	0.206	0.327	10.39
Education and	1.747	11.050	4.602	0.091	2.578	0.002	0.092	0.170	0.137	0.260	20.73
Health Services	1.988	13.588	4.836	0.024	2.836	0.000	0.097	0.206	0.121	0.291	23.99
Leisure and	1.069	0.503	5.451	0.572	0.416	0.002	0.022	0.088	0.087	0.200	8.41
Hospitality	0.752	0.412	4.727	0.533	0.267	0.000	0.036	0.121	0.085	0.097	7.03
Other	0.390	0.625	1.753	0.303	0.483	0.001	0.025	0.761	0.330	0.236	4.91
Services	0.473	0.764	2.121	0.303	0.570	0.000	0.036	0.497	0.267	0.242	5.27
Public	0.795	1.046	1.451	0.019	0.913	0.015	0.073	0.103	0.048	0.055	4.52
Administration	1.212	1.358	1.576	0.012	1.018	0.012	0.002	0.061	0.012	0.024	5.29
BLS	14.701	20.210	16.487	11.520	13.502	0.665	6.583	3.712	6.494	6.125	100
ATUS	15.503	23.624	16.424	11.127	13.733	0.703	4.657	3.333	5.927	4.933	100

Source: Bureau of Labor Statistics, National Industry-Specific Occupational Employment and Wage Estimates (BLS) and the authors' computations from 2006 American Time Use Survey (ATUS).

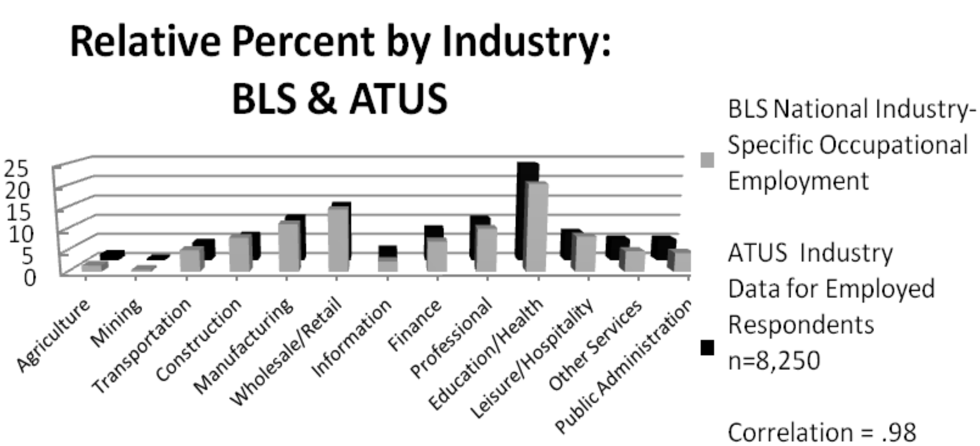

Figure 1. Relative percentages of employed persons by industry and occupation: Bureau of Labor Statistics Industry-Specific Occupational Employment Data and the American Time Use Survey

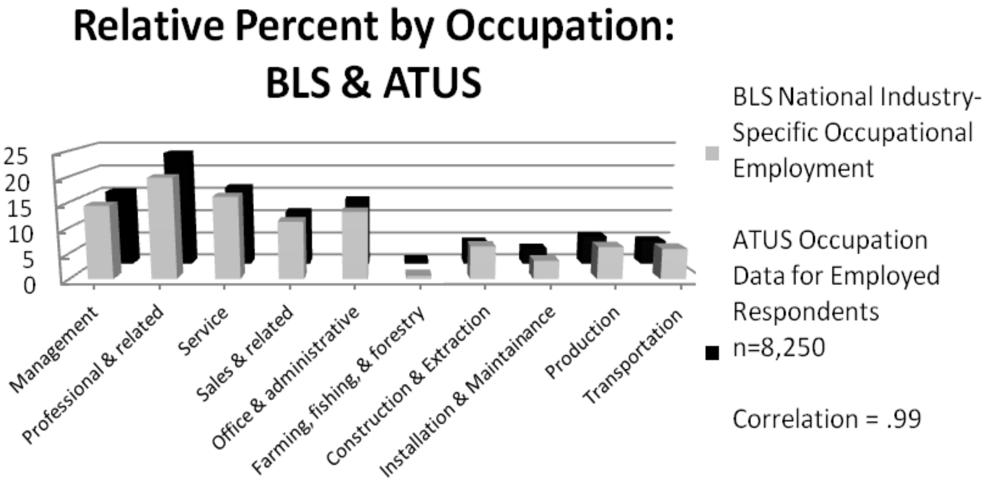

Figure 1 (continued). Relative percentages of employed persons by Industry and Occupation: Bureau of Labor Statistics Industry-Specific Occupational Employment Data and the American Time Use Survey

Table 2. Employment, output, hours of employment, and ratios, by industry sector.

Industry Sector	Employment (thousands)	Output (mil $)	Hours (thousands at 5.71/day)	Hours Per $1,000 Output	Output ($)/Hour	Dual Values - Output Multipliers
Agriculture, Forestry, Fishing, and Hunting	2,208	323,443	4,601,803	14.23	70	2.06
Mining	687	431,679	1,431,811	3.32	301	1.56
Transportation and Utilities	7,455	1,165,330	15,537,338	13.33	75	1.60
Construction	11,747	1,403,033	24,482,510	17.45	57	1.89
Manufacturing	16,377	6,354,130	34,132,125	5.37	186	2.18
Wholesale and Retail Trade	21,327	2,476,430	44,448,667	17.95	56	1.54
Information	3,574	1,184,529	7,448,752	6.29	159	1.87
Financial Activities	10,491	3,069,216	21,864,818	7.12	140	1.61
Professional and Business Services	14,867	2,623,391	30,985,058	11.81	85	1.67
Education and Health Services	29,939	2,226,056	62,397,367	28.03	36	1.48
Leisure and Hospitality	12,146	874,035	25,314,086	28.96	35	1.76
Other Services	7,087	1,575,054	14,770,371	9.38	107	1.39
Public Administration	6,525	1,068,139	13,599,079	12.73	79	1.20
Total	144,430	24,774,467	301,013,785			
Average				13.54	107	1.68

Sources: Bureau of Labor Statistics, National Industry-Specific Occupational Employment and Wage Estimates, 2006 (BLS), and author's analysis of the American Time Use Survey, 2006.

Education and Health Services has the largest employment and thus the largest estimated labor hours input. Manufacturing has the largest output. Mining, a relatively small sector with respect to employment and output, and Manufacturing, a relatively large sector by all measures, have the smallest values of employed time per $1,000 of output, while Education and Health, a large sector, and Leisure and Hospitality, a modestly sized sector, have the largest values of employed time per $1,000. This is due primarily to the greater capital investment per worker in Mining and Manufacturing and to the higher staffing levels generally required in service industries. Some academics have termed the inability to substitute capital for labor in the service sectors as a "cost-disease" (Baumol, 2001).

The last column of Table 2 reports the I-O output multipliers for each of the 13 individual industries. Manufacturing, with an output multiplier of 2.18, has the largest value. Agriculture, Construction, Information, and Leisure and Hospitality also have large multipliers. Public Administration, with an output multiplier of 1.20, has the smallest value. Other Services, Education and Health Services, Wholesale and Retail Trade, and Mining also have small multipliers. These multipliers indicate the total change in national market output which is associated with a one dollar change in final demand for a specific industry. Larger multipliers indicate that a higher level of output is associated with a unit of final demand than smaller multipliers. The mathematical programming formulation of the I-O table produces identical multipliers in the form of dual values for the final demand constraints. For dual value computations, the LP formulation and solution of the I-O table is mathematically equivalent to the traditional Leontief matrix (4).

5. Results

Dual values for work and work-related time by industry and by occupation of employed persons produce universally large values. When the output impact of inter-industry linked work and work-related time is considered, as it is in the LP formulation, this is not surprising. One hour of work and work-related time devoted to a single industry or occupation is linked to market value output in other industries as well. For occupations, the values are also large, and may not conform to prior expectations with regard to order. For example, Professional & Related occupations generally rank near the top with respect to earnings, but rank at or near the bottom with respect to their economy-wide marginal output value. Management, Business, and Financial occupations generally rank at the top with respect to earnings, but rank in the midrange of duality values. Installation and Maintenance occupations generally rank in the midrange of earnings, but rank at the very top, by a substantial margin, when inter-industry linkages are considered.

5.1 By industry

Using the demographic information available about industry of employment for respondents in the ATUS combined with the BLS national employment estimates, an estimate of national work and work-related hours for each of the individual thirteen industry sectors is made. Table 3, column 1, reports these industry-specific average work and work-related hours for ATUS respondents.

Transportation and Utilities has the largest work and work-related time estimate at 6.72 hours on the average day, or 47 hours per week. The Leisure and Hospitality industry, at 4.96 hours on the average day, or approximately 35 hours per week, is the smallest. Generally, the production sectors (Agriculture, Mining, Transportation, Construction, and Manufacturing) have larger-than-average work and work-related hours, while the service industries, with the exception of Public Administration have smaller than average work and work-related hours.

Table 3. Work and work-related hours and dual values, by industry sector.

Industry Sector	Work & Work-Related Hours on Average Day (7 days)	Dual Values of Work and Work-Related Time $/Hour
Agriculture, Forestry, Fishing, and Hunting	6.61	99
Mining	6.48	381
Transportation and Utilities	6.72	93
Construction	6.18	99
Manufacturing	6.29	245
Wholesale and Retail Trade	5.90	81
Information	5.40	246
Financial Activities	5.70	176
Professional and Business Services	5.62	117
Education and Health Services	5.27	57
Leisure and Hospitality	4.96	67
Other Services	5.06	165
Public Administration	6.08	88

Source: Bureau of Labor Statistics, National Industry-Specific Occupational Employment and Wage Estimates, 2006 (BLS), and the authors' computations from 2006 American Time Use Survey.

Industry-specific work and work-related time constraints are then added to the LP formulation of the U.S. national I-O. Dual values for these constraints are computed for each industry sector individually and are reported in the second column of Table 3.

At the margin, one hour of work has the impact on total U.S. market output level given by the dual value. Like an I-O multiplier, this dual value takes into account all the inter-industry monetary linkage effects in the original I-O account. It also takes into account the direct and indirect time-use relationships embodied in the time use constraints. For example, the lowest dual value of $57 for Education and Health Services indicates that the marginal hour of work and work-related time in this sector is associated with an economy-wide output of $57. When an hour of work and work-related time is taken away from, or committed to, Education and Health Services, total U.S. output is estimated to fall, or rise, $57 dollars, by way of the direct and indirect linkages among the 13 sectors. This is not a wage estimate or an individual's opportunity cost, but an economy-wide, output denominated, opportunity cost estimate. Similarly, the largest dual value of $381 for Mining represents an economy-wide marginal output value of work and work-related time in this sector.

5.2 By occupation

The availability of detailed occupation data in the ATUS allows for a much more nuanced time-use valuation. As in the computation by industry, estimates from the ATUS for the number of work and work-related hours by occupation can be used to generate total hours for each of the industry/occupation pairs. An individual constraint is then added to the LP formulation of the U.S. I-O for each occupation and a dual value for each of the ten occupations is computed. This constraint implies that work and work-related time can be substituted freely across industries within occupations. Table 4, column 1, reports the occupation-specific average work and work-related hours for ATUS respondents employed in each occupation.

Table 4. Work and work-related hours per day and dual values, by occupation

Occupation	Work & Work-Related Hours per Day (7 days)	Dual Value ($/hour)
Management/Bus./Fin.	6.41	200
Professional & Related	5.72	98
Service	4.89	107
Sales & Related	5.57	160
Office & Administrative	5.08	377
Farming, Fishing, Forestry	6.87	244
Construction & Extraction	6.20	143
Installation & Maintenance	6.59	704
Production	6.05	579
Transportation & Material Handling	6.59	174

Source: Author's computations using U.S. 2006 I/O table and 2006 ATUS survey.

Farming, Fishing, and Forestry occupations have the largest work and work-related time estimate at 6.87 hours on the average day, or 48 hours per week. Service occupations, at 4.89 hours on the average day, or approximately 34 hours per week, have the smallest. Using these estimates, dual values for work and work-related time, by occupation can be computed.

The occupation-based work and work-related time dual values are similar in magnitude to the industry-based values. The occupation-based dual values range from a low of $98/hour in Professional and Related occupations to a high of $704/hour in Installation and Maintenance. This indicates the important trade-offs between industry linkages, as reflected by the multipliers, and time use. These dual values are not wage proxies or estimates, nor even individual employee opportunity costs. They are economy-wide opportunity costs denominated in terms of the total output impact of an hour of employment in each occupation category.

5.3 Family care

The foregoing analysis demonstrates the establishment of a valuation linkage between the NIPA's, in their fundamental I-O format, and work and work-related time use statistics available in the ATUS. The ultimate goal is to establish this linkage between the NIPA's and family-provided care time. The strength and form of this relationship is an empirical issue that warrants significant research beyond the scope of this paper. To demonstrate the potential for linkage, a very simple form of relationship is estimated and used below, fully recognizing that "we should try to develop a better understanding of the nonlinearities, discontinuities, and surprises that are inherent in the production of human capabilities" (Folbre, 2006, p. 50).

Table 5. Average hours spent in primary activities for 8,250 employed respondents to 2006 American Time Use Survey.

Activity	Hours per Day (7 days)
Personal Care (including sleep)	9.10
Eating and Drinking	1.22
Household Activities	1.51
Purchasing Goods and Services	0.76
Care of Household Members	0.48
Care of non-Household Members	0.19
Work and Work-Related	5.71
Educational	0.32
Organizational and Religious	0.27
Leisure and Sports	4.18
Telephone	0.08
Other Activities	0.17

Source: Author's computation from 2006 ATUS.

Table 5 reports the average daily time estimates for employed respondents in the 2006 ATUS, using the list of primary activities measured in the ATUS. Personal Care, which includes sleeping time, at 9.10 hours on the average day, is the largest time use for this group. Work and work-related activities, including travel time, at 5.71 hours per average day, and leisure and sports, at 4.18 hours per day, are the next largest time uses. For employed respondents, all seven other categories total only 5.01 hours. Care time of household members averages 0.48 hours per day and care time for non-household members averages 0.19 hours. To establish a linkage between the dual valuation of work and work-related time and care time for household members, the relationship between household member care time (not including personal care time) and work and work-related time is estimated by simple regression using demographic and survey information available for the employed respondents in the ATUS.

Work and work-related time per day, in minutes, for employed respondents is the dependent variable. The independent variables consist of: a constant; the time the respondent devotes to care of household members per day (minutes); whether the diary day is a weekend or holiday (binary); the age (years), gender (binary), education level (years), and full or part-time employment status (binary) of the respondent; whether there is a child less than 5 years old and whether there is a spouse or unmarried partner in the household (binary); and the occupation category of the respondent (slope shifting binary). The results of this analysis are reported in Table 6.

Table 6. Regression results for work and work-related time of employed respondents as a function of demographic variables and household member family care time.

Variable	Units	Coefficient	*t*-statistic	
Constant	Minutes	371.69	27.77	
Care HH members	Minutes	-0.35541	-5.19	Caring for and helping household members (base equals Man't, Bus. and Fin. occupations)
Weekend day	Binary	-309.711	-62.88	Diary day, 0=weekday 1=weekend
Holiday	Binary	-191.06	-10.62	Diary day, 0=not holiday 1=holiday
Age	Years	-0.7029	-3.44	Respondent's age
Child present	Binary	27.802	3.87	Child less than 5 years old in Household
Spouse or partner present	Binary	6.31	1.17	Spouse or unmarried partner present in household
Education	Scale	2.0319	2.08	Highlest level of school completed, 1=less than 1st grade, 16=Phd
Work Status	Binary	118.64	18.97	Full or part-time status, 0=part 1=full
Gender	Binary	-34.262	-6.67	Respondent's gender, 0=male 1=female
Professional & Related	Minutes	-0.16064	-2.01	Slope shifter for Professional and related occupations
Service	Minutes	-0.0954	-1.04	" " for Service occupations
Sales	Minutes	0	0	" " for Sales occupations
Office & Administrative	Minutes	-0.00717	-0.07	" " for Office and adminisrative support
Farming/fishing/forestry	Minutes	0.241	0.23	" " for Farming, fishing, and forestry
Construction & Extraction	Minutes	-0.2176	-1.28	" " for Construction and extraction
Installation/maint/repair	Minutes	-0.3638	-1.83	" " for Installation, maintenance, and repair
Production	Minutes	-0.1262	-0.88	" " for Production
Transportation	Minutes	-0.1496	-0.71	" " for Transportation and materials handling

S = 223.143; R-Sq = 36.7%; R-Sq(adj) = 36.6%; n = 8,250 employed respondents to the 2006 ATUS.

The demographic and contextual information about the ATUS respondents appears to play a significant role in determining the connection between work and care time. Whether the survey was taken on a weekday, when most respondents are more likely to engage in work, or weekend day and whether the survey day is a holiday are very important determinants of time devoted to work and work-related activities. On average, a weekend day reduces the average work and work-related time by 310 minutes, or 5.16 hours. Holidays bring a reduction of 191 minutes or 3.18 hours. Full- or part-time employment status, the respondent's level of education, and whether a spouse or partner is present all have positive impacts on work and work-related time. Full-time work status adds 119 minutes per day. Each grade of school completed adds 2 minutes of work and work-related time per day, and the presence of a spouse or unmarried partner adds 6.3 minutes per day. The presence of children less than 5 years old in the household also has a positive impact, adding 28 minutes of respondent work and work-related time. The respondent's age and being female both have negative impacts. A year of age reduces a respondent's work and work-related time by 0.7 minutes and being female reduces it by 34 minutes per day.

Care time devoted to household members is negatively associated with work and work-related time of employed ATUS respondents. For every minute devoted to care of household members, there is a negative 0.36 minute base impact on work and work-related time. This relationship applies to Management, Business, and Financial occupations. The impact associated with each of the other occupation categories is estimated separately as a shifter from the coefficient for Management, Business, and Financial occupations. While the statistical significance of the respondents' occupations are generally lower than the other demographic and contextual variables, the coefficients for Professional and Related occupations and for Installation, Maintenance, and Repair occupations can be used to adjust the base impacts of time devoted to the care of household members. For example, for each minute of time devoted to the care of household members by respondents in Professional and Related occupations, there is an additional 0.16 minute negative impact on work and work-related time. For this occupation, there is a total of 0.52 minutes negative impact, the 0.36 base plus the 0.16 occupation-specific impact. Similarly, for respondents in Installation, Maintenance, and Repair occupations, there is a total of 0.72 minutes negative impact, the 0.36 base impact plus the 0.36 occupation-specific impact.

Using these base and adjusted occupation coefficients, the dual values for work and work-related time reported in Table 4 for each occupation can also be adjusted. For example, for Management, Business, and Administrative occupations, each hour of family care time is associated with a negative 0.36 hours in work and work-related time. Adjusting the work and work-related dual value of $200, from Table 4, results in an adjusted dual value of $71 for Management, Business, and Administrative occupations. An hour of family care time, which is associated with 0.36 hours of work and work-related time, converts to $71 of national output. An increase of one hour of time devoted to the care of household members by respondents employed in Management, Business, and Administrative occupations results in a $71 decrease in total output.

Similarly, for Professional and Related occupations, an hour of family care time is associated with a negative 0.52 units of work and work-related time; the 0.36 unit base plus a 0.16 unit slope shifter for this occupation. For these, the adjusted dual value is $51. For Installation, Maintenance, and Repair occupations, the adjusted dual value is $506. Adjusted dual values for all the occupations are reported in Table 7.

Table 7. Dual values for household member family care time, by occupation.

Occupation	Work and Work-Related Dual Value ($/hour)	Regression Coefficient	Adjusted Family Care Hours per Hour of Work & Work Related Time	Adjusted Dual Value ($/hour)
Management, Business, & Financial	200.16	-0.36	-0.36	71
Professional & Related	98.10	-0.16	-0.52	51
Service	107.15	-0.10	-0.45	48
Sales & Related	159.75	0.00	-0.36	57
Office & Administrative	376.70	-0.01	-0.36	137
Farming, Fishing, Forestry	244.14	0.24	-0.11	28
Construction & Extraction	143.24	-0.22	-0.57	82
Installation & Maintainance	703.89	-0.36	-0.72	506
Production	578.96	-0.13	-0.48	279
Transportation & Material handling	174.48	-0.15	-0.51	88

5.4. Discussion

This paper establishes a bridge between the household allocation of time and a national economic valuation of that time. It (1) uses GDP dollars as the measuring rod, (2) computes multiplier-like values which are marginal, and (3) introduces no new prices or imputations in the valuation. The data used for this analysis are public information, freely available, easily accessible, and transparent. Rather than generating valuations that are intended to be used to adjust the value of GDP directly, multiplier-like, economy-wide, marginal values are computed. This leaves the current NIPA's intact and liberates the construction of satellite accounts from the potentially heavy and contentious burden of valuation by imputation. Satellite accounts could then focus more on establishing sound accounting principles applicable to household production and on establishing the form of the fundamental relationships involved.

5.5. Questions for Future Research

There is a large and growing body of literature that seeks to investigate the determination of trade-offs between work and work-related time and family care time. This literature supports both a gendered and family-centric approach (Bianchi, 2006; Folbre et al., 2005; Jacobs and Gerson, 2004; Picchio, 2003; Zimmermann and Vogler, 2003). One general consideration has emerged: "Focusing on families rather than individuals provides a fuller, potentially more fruitful lens for making sense of the changing balance of paid work, family work, and leisure time" (Jacobs and Gerson, 2004, p. 41). The ATUS, unfortunately, is structured on an individual response basis. There is, however, family member demographic information available by way of the CPS-ATUS linkage. A potentially fruitful future avenue to investigate would be to use the family member information from the CPS sources for the time allocation of both employed and not-employed respondents. Similarly, determination of the complete expression of the undoubtedly complex relationships among family, rather than individual, time uses from time use surveys would also be a major contribution to the proper specification of the basic relationships involved. Time uses of employed and not-employed persons need to be considered simultaneously in a family or household context.

6. Conclusion

Nancy Folbre (2008) poses the fundamental question that must be asked before valuing the nonmarket activities of households: 'value to whom?' She notes that, "The value that parents place on their own time is likely to differ from its value to society as a whole" (Folbre, 2008 p. 122). The preceding analysis has formally linked valuation in the NIPA's with time allocation in the ATUS. It does this from the point of view of economy-wide economic valuation, the national accounts, not from an individual, a family, or a household perspective. The nation is the 'who'. Dual values for work and work-related time by industry and by occupation of employed persons produce universally large values. Adjusting these values for a work and work-related time/family-care time trade-off still results in large values. The marginal value of family care time to the national economy is large and should not be ignored or presumed to be zero in policy analyses.

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