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VALUATION OF HOUSEHOLD PRODUCTION AT MARKET PRICES AND ESTIMATION OF PRODUCTION FUNCTIONS

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This paper estimates household production functions directly, considers their characteristics, and compares them with previous indirectly estimated functions. Interviews with 135 Missoula, Montana area married couple households provided the data. The results suggest that endogeneity and a previous lack of output and capital data which led to the use of the indirect methodology are not insurmountable problems. The results tend to confirm the feasibility of directly measuring household outputs since the production function results are reasonable. Directly estimated household production functions offer the possibilities for estimation of short-term household output changes and testing hypotheses about households' economic behavior.

INTRODUCTION

The importance of household production within our economy has made it a subject for ongoing scholarly analysis.[1,2] Many writers have suggested that direct measurement of household output is the most desirable method for valuing home production, and that direct measurement is difficult but feasible (See Goldschmidt-Clermont, 1993). In this paper we hope to advance the argument one step further by showing that direct output data can generate reasonable estimates of household production functions, and by showing the advantages of this approach. Past work has included two studies, Gronau (1980) and Graham and Green (1984) which have empirically addressed household production functions. Knowledge of hosuehold production functions can further the understanding of issues such as the economic roles of wives and husbands within the household and the degree to which the neoclassical theory of the firm applies to households. Both of these previous studies employed indirect methods in their estimates due to lack of

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[1]Household production may be defined as those goods and services which households produce for their own or others' consumption, but which alternatively might have been produced by someone else.

[2]Estimates of household production's magnitude generally range between one-third and two-thirds of national income as measured by the U.S. Department of Commerce. See Chadeau (1985) and Murphy (1982).

available output and capital input data and concern over endogeneity in direct methods. Time devoted to household production and certain socioeconomic characteristics of householders were the only production function variables for which directly measured data existed.

Background

Gronau (1980) estimated the parameters of the wife's marginal productivity function using cross-section data from the Michigan Panel Study on Income Dynamics on household labor time and a set of variables hypothesized to influence household productivity. These included wife's age and education, husband's education and wage rate, non-earned family income, number of children and age of the youngest, and number of rooms in the house. The purposes of the study were to provide an alternate estimate of the total value of household production and to identify variables determining wives' productivity in this activity.

Graham and Green (1984) expanded Gronau's work by estimating the parameters of a household production function. This approach allowed them additionally to consider returns to scale, the relative contributions of labor and market goods (i.e. a combination of capital goods and intermediate output such as food), and the relative contributions of wives' and husbands' labor. Like Gronau, they used a set of socioeconomic variables to measure productivity. Specifically, they assumed that age and years of education measured wives' and husbands' productivity, and that four dummies for the presence of children in various age brackets, family size, the number of rooms in the house, and a dummy indicating home ownership estimated general household productivity. They further assumed a Cobb–Douglas form and made estimates of its coefficients based on alternative assumptions about the jointness of household production time in yielding output and leisure enjoyment, comparative productivity in market and household output, returns to scale, and relative wife and husband productivities. While their results were very sensitive to the alternative assumptions made, they concluded that:

(1) there are not increasing returns to scale;
(2) household output's elasticity with respect to market goods exceeds the elasticity with respect to time;
(3) both spouses are more productive at market employment than at household production;
(4) there is considerable jointness between household production and leisure, particularly for wives.

Additionally, they estimated the value of household production under their alternative assumptions.

With data only on time use in household production, indirect estimation of household production functions and the use of these production functions to estimate the value of production is the best that can be done. Fitzgerald and Wicks (1990) discuss the advantages and demonstrate the feasibility of measuring household production directly instead of using the indirect labor value approach. As they point out, the key to successful direct measurement is the definition of output units. They were able to do this for the activities accounting for 85 percent of household production time. Using their methods, we defined and gathered data concerning the production of 49 different outputs for our study. Direct measurement of household output provides an alternative to Gronau's production function approach as a measure of that output.

Direct output data allows us to estimate household production functions. We can then test the key assumptions underlying the Gronau (1980) and the Graham and Green (1984) estimates—that the production function is the Cobb-Douglas form and that variables such as age and education are good measures of householders' and overall household productivity—and answer some additional questions. Among these are whether one production function adequately describes all types of household production, factor shares, input substitutability or complementarity, and household efficiency in resource allocation. We also discuss concerns about joint production and endogeneity of inputs in direct production function estimation.

DATA

We begin by discussing output and capital data. The measurement of all data except capital used the methods described in detail in Fitzgerald and Wicks (1990) with only several minor differences. In a new sample of households, we restricted ourselves to married couples to reduce the data requirements. For several types of output, e.g. home repairs and improvements, we presented interviewers with detailed lists of possible outputs to aid them in recalling amounts produced and time spent. As pointed out by Fitzgerald and Wicks (1990), the key to successful direct measurement is the disaggregated definition of output units. Personal interviews with a sample of 135 Missoula, Montana urban area married couple households provided most of the data. The households were selected using a preset geographic pattern. Interviews measured the time devoted to and the quantity produced of each of 49 kinds of household production as well as the values of a number of socioeconomic variables describing the household.[3] The 49 kinds of output included all of the output for which a measure other than the hours used in its production could be identified, for example, number of floors vacuumed, number of oil changes, etc. In total, they accounted for about 85 percent of the average total time devoted to household production. Baby sitting and related child care activities accounted for most of the remaining time. Table 1 lists the 49 kinds of output.

The authors have found that the key to quantifying household production by the output approach is to disaggregate the outputs sufficiently so that specific output units may be identified, e.g. floor vacuuming—one room's floor vacuumed one time; electrical repair—one electric appliance repaired one time. If a person

[3]This procedure allowed for joint production of different types of household output by quantifying the output and the inputs used in producing it for each type of household output considered one at a time. For instance, if a householder cleaned the kitchen cabinets and baby sat during the same hour of time, both would be counted as household production. This is consistent with the way inputs and outputs for a firm's joint production process would be measured. With the exception of child care, our interviews generally did not indicate that two or more outputs resulted from the same unit of labor time. As discussed subsequently, child care was excluded from the analysis because of lack of an output unit other than hours.

TABLE 1

DESCRIPTION AND MEANS OF VARIBLES
(Annual Output in Dollars)

Output Type	Sample Size	Annual Output	Husband's Hours	Wife's Hours	Capital $
Inside cleaning[a]	135	2,741	53	523	110
Outside cleaning[b]	130	872	50	17	358
Appliance repairs & maintenance[c]	107	575	20	6	263
Home furnishings & clothing	73	509	9	56	703
Home & yard repairs & improvements	113	2,122	36	8	732
Meals	135	6,929	92	821	1,447
All[d]	135	16,091	338	1,766	3,665

[a]Floor vacuuming; floor mopping; basin, tub, tile, commode cleaning; bed linen changing; bed making; garbage take-out; stove cleaning: elements and oven; defrosting refrigerator or freezer; cupboard cleaning; kitchen other surfaces cleaning; other rooms other surfaces cleaning; general pick-up.

[b]Window cleaning, garage cleaning, patio cleaning, lawn mowing, lawn raking, yard litter pick-up, snow shovelling, chimney sweeping.

[c]Electrical repair, plumbing repair, interior painting, exterior painting, vehicle cleaning, vehicle tune-up, vehicle lubrication (including oil change), tire changing, other vehicle repair, other appliance and equipment repair.

[d]Excludes person care (child feeding, child changing, child bathing, child transporting, other child care, care of sick, care of elderly); clothing care (washing and drying, ironing, mending, altering); and miscellaneous output (hunting, fishing, wild berry gathering, homegrown livestock, garden produce).

vacuumed three rooms of a house weekly, there would be 156 units of that output yearly. These units were then valued at the market price charged by vendors for like services. For instance, interviews with six Missoula area firms which performed electrical appliance repairs yielded an average of $27 per repair job net of any parts. For interior cleaning, vendors were asked to apportion their total charge for a cleaning session among the various services provided—e.g. vacuuming, cupboard cleaning—to determine the appropriate charge for each. The average value of vacuuming a room measured in this way was 42 cents. Accordingly, the output value of the room vacuumings in the above example would be $65.52. In the cases of broad output categories such as hobby and home furnishings production, the household respondents listed each item produced, the values of these items were priced at a sample of stores selling them, and an aggregate value of the items was summed for each respondent.

To facilitate the analysis we grouped the specified outputs into nine categories, six of which we included in our analysis. Table 1 lists the six. Child care was excluded because of our prior belief that there lacked output units other than hours, or hours multiplied by value per hour.[4] Clothing care and miscellaneous output were excluded because of the small sample size of households with positive entries. Interviews with samples of local firms furnished the market price of each

[4]A referee pointed out that even person care units are measurable. One person, e.g. one child below school age or one handicapped adult, could be the output unit. These units could be further subdivided into active and passive care. Market prices are available for this care. In retrospect, we should have measured the inputs. The authors are preparing a paper quantifying the person care component of household production using this method.

capital input item as well as the outputs. To allow aggregating both output and capital inputs, we defined a unit of each as a dollar's worth.[5]

For measuring household capital, an admittedly difficult task, each interview included a checklist which contained all capital items we could identify as used in household production. We included only capital items *per se*. Capital items are those previously manufactured items such as stoves and refrigerators not used up except by depreciation as they function as inputs. Outputs of the business sector to which households add further value are not capital. For instance, the food used in the home preparation of meals is not capital. Rather, since it is something which the household did not produce (with the exception of home gardening), its value was subtracted from the gross value of home produced meals to determine the portion of the value produced by the household as described in Fitzgerald and Wicks (1990). For major capital items such as stoves we measured the approximate current value based on quality, size, and age. With minor capital items such as screwdrivers, we determined merely whether the household had at least one of the items and valued it at half of its current market price new. Ignoring multiple units of capital items implicitly assumed the use of only one unit of a given type of capital, e.g. a hammer, at a time. Even if this assumption was not completely valid, the number of different capital items which a household owned was likely to be a good proxy for the total value of capital. We identified the capital items probably used in producing each type of output and summed the values of those capital items possessed by a household for potential use in each category of outputs analyzed. This procedure allowed the same item to be included as a capital input for a number of outputs. The household's capital stock was assumed to be available to both spouses. The amount of that capital stock applicable to a given category of household output was subsequently used as the capital input variable for estimating the production of that output.

Analysis

Direct Estimation

We first estimated household production functions using husband's time (h), wife's time (w), and capital (k) as inputs. Output was the husband's and wife's outputs added together. We estimated production functions for each of the six output categories for which sufficient data were available and for aggregate output. Table 1 shows the means for the variables aggregated by output type.

We elected to use a very flexible functional form for the production function, a translog. See Christensen, Jorgenson and Lau (1973). Heuristically, the translog is a second order Taylor's approximation for log output. It includes Cobb–Douglas as a special case. The advantage of the translog is that it allows for variable elasticities of substitution and varying returns to scale.[6] We estimated a

[5]This procedure introduces the possibility that variation in output prices could alter the measure of outputs. While this is not ideal, the alternative of using physical quantities of many kinds of disaggregated outputs would require a separate production function for each output type and interpretation of the results would thereby be considerably complicated.

[6]We present unrestricted translogs in Appendix Table 1. For the main results of the paper, we used a restricted form which is easier to interpret.

translog with the added restriction that returns to scale are the same at all output levels, that is the function was made homogeneous of degree λ. The parameter λ gives a single value to interpret for returns to scale. Specifically, the estimate form was:

$$y = a_0 + \lambda(a_w w + a_h h + a_k k) + a_{ww} w^2 + a_{hh} h^2 + a_{kk} k^2 + a_{wh} wh + a_{hk} hk + a_{wk} wk$$

where

$$y = \ln(\text{output} + 1),\ h = \ln(h+1),\ w = \ln(w+1).$$

The number one was added to allow use of households where one of the spouses had zero hours of work for that output type. Households where both spouses had zero hours for a particular type of output were excluded from the estimation for that output. Thus we are conditioning on the household spending some time on the output.[7] The values of h, w, and k were normalized by rescaling each to have mean zero after taking the log. This should have improved the approximation by the translog without affecting the value of any parameter except the constant. The imposed restrictions to ensure homogeneity were:

$$a_h + a_w + a_k = 1$$

$$a_{ww} + a_{wh} + a_{wk} = 0$$

$$a_{hh} + a_{wh} + a_{hk} = 0$$

$$a_{kk} + a_{wh + a_{hk}} = 0$$

These restrictions provide a gain in precision and facilitate presentation of results because we avoid the potential for scale to change with output. Table 2 presents the results.

In all of the equations, the coeffcient on wife's hours was significant at the one percent level. The coefficient for husband's hours was also significant at this level for all of the equations except meals, in which it was significant at the five percent level, and interior cleaning, where it was not significant. Capital, however, was significant only for exterior cleaning and for home repairs and improvements. The R^2 values are quite high for a cross-section, ranging between 0.34 and 0.72. Overall, the consistent pattern of results and good precision raise our confidence in our measures.[8]

[7]As shown in Table 1, nearly all households have positive output for inside and outside cleaning and meals, which account for 80 percent of the value of output. For the other three categories, there is a possible selection bias: households that choose to produce positive amounts may have unmeasured characteristics that raise demand or lower cost for these outputs. To the extent that these unmeasured characteristics correlate with our measured regressors, it biases our coefficient estimates. In the absence of instruments that predict who produces positive amounts and yet are uncorrelated with the residual level of production, the usual Heckman-type selection correction depends solely on assuming the correct distribution of the errors (Greene, 1990, pp. 139–150). Since we have no useful instruments, the usual correction is not a very attractive option. Thus we use the simple method and acknowledge the possible bias.

[8]We also estimated the functions using the unrestricted translog form. Appendix Table I presents these results. The identity and signs of the significant coefficients are similar to those in Table 2 showing the results of the homogeneous translog functions. Given the similarity, we chose to use the tighter, homegeneous form whenever possible in the following analysis.

TABLE 2

HOMOGENEOUS TRANSLOG HOUSEHOLD PRODUCTION FUNCTION ESTIMATES

	Output Type						
Parameter	Clean In	Clean Out	Appl. Repair	Home Furn.	Home Repair	Meals	All
α_w	0.744**	0.233**	0.321**	0.448**	0.269**	0.630**	0.648**
	(0.169)	(0.0334)	(0.0823)	(0.0894)	(0.0457)	(0.126)	(0.0878)
α_H	0.0444	0.586**	0.695**	0.472**	0.562**	0.134**	0.169**
	(0.174)	(0.0565)	(0.115)	(0.0918)	(0.0642)	(0.0638)	(0.0398)
α_k	0.212	0.181**	−0.016	0.080	0.169**	0.236	0.183
	(0.174)	(0.0665)	(0.123)	(0.156)	(0.0681)	(0.128)	(0.107)
λ	0.482**	1.28*	1.03	1.30	1.14	0.841	0.812
	(0.111)	(0.110)	(0.156)	(0.244)	(0.100)	(0.178)	(0.105)
α_{HH}	0.0533*	0.129	0.0898	−0.350	−0.119*	−0.0303	0.0211
	(0.0240)	(0.111)	(0.110)	(0.0858)	(0.0544)	(0.0329)	(0.0326)
α_{ww}	0.0252	0.0390	0.0602	0.0572	−0.0134	0.152**	−0.126
	(0.0412)	(0.0486)	(0.101)	(0.0722)	(0.0646)	(0.0421)	(0.157)
α_{kk}	0.00845	0.0901	−0.0296	−0.230	−0.191*	0.105	−0.147
	(0.0854)	(0.0809)	(0.118)	(0.134)	(0.0745)	(0.0852)	(1.226)
α_{HW}	−0.350	−0.154**	−0.116	−0.126**	−0.0292	−0.00829	−0.0312
	(0.0247)	(0.0300)	(0.0607)	(0.0447)	(0.0407)	(0.0023)	(0.0558)
α_{kw}	0.00986	0.115*	0.0558	0.0688	0.0426	−0.144*	0.157
	(0.0616)	(0.0494)	(0.0946)	(0.0881)	(0.0613)	(0.0619)	(0.186)
α_{Hk}	−0.0183	0.0249	0.0262	0.161	0.148**	0.0386	0.0101
	(0.0343)	(0.0695)	(0.0974)	(0.0888)	(0.0476)	(0.0398)	(0.0643)
σ^2	0.497	0.766	0.925	1.04	0.713	0.469	0.376
LogLikelihood	−97.20	−149.74	−143.52	−106.44	−122.04	89.22	−59.36
R^2	0.35**	0.65**	0.56**	0.53**	0.72**	0.34**	0.44**
N	135	130	107	73	113	135	135

*Indicates significance at 5 percent level.
**Indicates significance at 1 percent level.

Specification Tests

We performed a series of tests concerning the general question of whether the homogeneous translog function was the most appropriate production function, including an endogeneity test. We concluded that our specification was appropriate. The first of these tested the restrictions in a homogeneous translog function which will yield a Cobb-Douglas function, and rejected the Cobb–Douglas restrictions.[9]

The second test considered whether one production function adequately described the household production process or whether different functions for different categories of output were indicated. We pooled the 693 observations for the six output categories and estimated the coefficients for a homogeneous translog function.[10] We rejected the conclusion that all output types have common coefficients and made our other tests separately for the six output types.

[9]Log-likelihood ratio tests indicated rejection of a Cobb–Douglas function for inside cleaning, outside cleaning, home repairs, and meals. Appendix Table 2 shows the results.

[10]The log-likelihood ratio for the pooled model was −900.40. The sum of the log-likelihood ratios for the six separate models was −708.16. Minus twice the difference gave a chi-squared statistic of 384, exceeding the critical value of 55.7 at the 5 percent level.

Third, it is common to include age and education as variables in production functions for market output since they frequently influence labor productivity as assumed by Gronau (1980) and Graham and Green (1984). We tested whether age and education should be added as productivity multipliers on husband and wife time in household functions. (Appendix Table 3 shows the log likelihood tests.) For only one of the six output categories, home repairs and improvements, was it possible to reject the hypothesis that the zero restrictions on age and education are true. Only in the equation for home repairs were husband's and wife's age significant as multipliers of their labor hours. Education never made a difference. Perhaps it is the simple nature of most household tasks which made age and education unimportant. Age would probably have been significant for child care.

The fourth test concerned endogeneity. Direct estimation could suffer from endogeneity since output levels and input amounts are jointly chosen. We tested for endogeneity using an unrestricted translog model.[11] We used a Hausman-type test (Hausman 1978) developed for single equations by Spencer and Berk (1981).[12] Appendix Table 4 shows the appropriate Wald tests. Only meals and "All" exhibited endogeneity. The "All" results can be ignored on the grounds that the tests reported earlier show output should be disaggregated. The general lack of endogeneity is heartening, but we realize that the instruments we used for the test were not ideal.

Since meals showed endogeneity, we reestimated its production by two-stage least squares using the regressors listed in footnote 12 as instruments. While the two stage coefficients for other outputs were not wildly different from ordinary least squares, except that they lacked precision, the results for meals were unusual. The coefficients for wife's hours (w), husband's hours (h), and capital (k) are compared below:

	w	h	k
two stage least squares	1.40	1.35	0.93
ordinary least squares	0.12**	0.53**	0.22

**denotes significant at the 1 percent level

These odd results may stem from quality measurement problems with meals which should be addressed in subsequent household production studies.

Characteristics of Directly Estimated Production Functions

Having accepted separate translog functions excluding age and education for each output group as most appropriate on the basis of these three sets of tests, we then examined the characteristics of these functions. These included returns

[11] Testing for endogeneity in the restricted model with its non-linear estimation would have been difficult, and we did not think it would have added insight.

[12] Essentially, the test puts in predicted values for the potentially endogenous variables (input levels) along with other variables and tests whether the coefficients on the predicted values are zero. See Greene (1990, pp. 640–41) for a discussion. We used age, education, income, household size, number of children, and interactions as our exogenous regressors (instruments) for that test. Ideal instruments would correlate with inputs, but not output; for example input prices. Our instruments are imperfect proxies, but we think the results are still informative.

TABLE 3

MEAN FACTOR OUTPUT SHARES FOR HOMOGENEOUS TRANSLOG HOUSEHOLD PRODUCTION FUNCTIONS

Output Type	Factor Shares		
	Wives	Husbands	Capital
Clean in	0.74	0.04	0.21
Clean out	0.23	0.59	0.18
Appl. repair	0.32	0.70	−0.02
Home furn.	0.45	0.47	0.08
Home repair	0.27	0.56	0.17
All	0.63	0.13	0.24

to scale, factor shares, and input substitution elasticities. Most outputs—i.e. appliance repair, home furnishings, home repairs, and meals—show constant returns to scale as measured by a five percent confidence interval in λ. Outside cleaning had increasing returns perhaps as a result of better use of capital at higher output levels. Inside cleaning showed substantial decreasing returns to scale, a result without an obvious explanation.

To consider the relative importance of each input type—wife's labor, husband's labor, and capital—in the household production process, we estimated factor shares for each of the three by evaluating the first derivatives of the translog with respect to each of the three for each household assuming cost minimizing behavior by the household and then taking the means across households. Table 3 gives the figures. While the results indicate that wives' shares were the largest overall, the husbands' shares were larger for exterior cleaning, repairs, and furnishings. Capital's share was the smallest of the three, although it averaged 20 percent for the four categories except appliance repairs and maintenance, and home furnishings.

Generally, the inputs were substitutes in the production functions. Allen elasticities computed as described in Berndt and Christensen (1973) and Chan and Mountain (1983) provided the basis for determining substitute-complement relationships. As in computing factor shares, it was necessary to assume cost minimizing behavior by households since factor price data were unavailable. Table 4 shows the median Allen elasticities. We have used medians rather than means

TABLE 4

ALLEN ELASTICITIES ESTIMATED FROM HOMOGENEOUS TRANSLOG HOUSEHOLD PRODUCTION FUNCTIONS

Output Type	Median Elasticities					
	E_{ww}	E_{hh}	E_{kk}	E_{wh}	E_{wk}	E_{hk}
Clean in	−0.29	6.69	−3.50	0.74	0.97	0.55
Clean out	−0.87	−0.16	−1.57	0.47	0.00	0.87
Appl. repair	−2.00	−0.64	0.00	1.61	0.00	0.66
Home furn.	0.00	0.00	0.00	0.00	0.00	0.00
Home repair	−2.35	−0.49	−1.12	1.05	0.57	0.27
Meals	−0.39	−4.01	0.00	0.77	0.79	0.00

to avoid undue influence from extreme cases. If the Allen cross-elasticity is positive, the inputs are substitutes. Higher values indicate better substitutes. Husbands' and wives' times were quite good substitutes except in the case of home furnishings.

The results presented above demonstrate the feasibility of direct estimation of household production functions and indicate their properties. From these results it is possible to consider two additional topics, an evaluation of the indirect technique heretofore used to estimate household production functions and applications which can be made of directly estimated functions.

Comparison with Indirectly Estimated Household Production Functions

As earlier discussed, Gronau (1980) and Graham and Green (1984) must use various assumptions in conjunction with notable econometric techniques to estimate production functions indirectly.[13] Our already reported results test two of the assumptions, that the household production function is of the Cobb-Douglas form and that age and education measure wife's and husband's productivities. In neither case did the results support the assumptions. For only one of six output categories, home repairs and improvements, was age significant as a productivity parameter. Education was significant in no cases. In four of the six output categories for which we estimated translog production functions, it was not possible to accept the restrictions which yield a Cobb-Douglas function. That functional form fit only appliance repairs and maintenance, and home furnishings.

To test the validity of the assumption that the presence of children in various age categories, total family size, the number of rooms in the house, and whether or not the family owns its home measure general household productivity and to give a supplementary test of whether age and education measure individual productivity, we re-estimated the Graham-Green function including our directly measured output and input data.[14] Specifically, for all of our measured household output aggregated and for each of its six categories we regressed output on wife's household production time, husband's household production time, capital, and each of the other independent variables used by Graham and Green (1984) in their estimates. Appendix Table 5 shows the results. Only three of the 49 estimated household productivity coefficients were significant at a 5 percent confidence level, and none of the age or education coefficients was significant. These results do not support the validity of the assumptions necessary for the Graham-Green methodology.

It is also possible to compare some of Graham and Green's conclusions with the results of the directly estimated translog functions. When Graham and Green did not impose a restriction of constant returns to scale they found evidence of decreasing returns. Since they could not estimate confidence intervals for those results, they concluded that increasing returns do not exist. The directly estimated results generally indicated constant returns to scale. In the production functions

[13] Graham and Green (1984) p. 277 explicitly state that they believe that neither household production nor most of its inputs can be accurately measured.

[14] Comparison is imperfect because inputs are different. Graham and Green ignore capital but include intermediate inputs; we include capital but use value added which eliminates the intermediate inputs.

for four of the six output categories, the returns to scale parameter did not signficantly differ from one at the five percent confidence level. (See Table 2.) As mentioned earlier, inside cleaning showed significant decreasing returns, and outside cleaning showed significant increasing returns to scale.

The results from the direct estimates tend to confirm the Graham-Green conclusion that both wives and husbands are more productive in the marketplace than in the household. Our study's weighted averages of marginal product of labor (discussed below) and average product of labor in household production are less than average take home pay wage rates for both wives and husbands.

Application of Directly Estimated Household Production Functions

This section briefly considers an application of the type which might be made of directly estimated household production functions. This application is illustrative rather than a rigorous test of the proposition involved. It tests whether duties within the household tend to be allocated between the spouses in an economically efficient manner.

Specifically, we computed the following ratio, subsequently termed the productivity ratio, for as many households as our data allowed:

$$(1) \qquad \frac{W_w}{P_{wj}} \Big/ \frac{W_h}{P_{hj}} \quad \text{for } j = \text{various output categories}$$

where W = wage rate, P = marginal product in household production, subscript h denotes husband; w denotes wife.

We did not impute wages. Thus our results are for households where both spouses do some market work. This is the relevant sample to test a marginal efficiency proposition, but it obviously is a selected sample.

The ratio W/P is the opportunity cost of household production. If the ratio exceeds one, there is a loss of more than a dollar's worth of wage to make a dollar's worth of household production. However, the point is that the ratio should be equated across spouses, assuming that household production is fungible between spouses. If the ratio is higher for a husband, then his opportunity cost of household output is higher than the wife's, and she should make the next unit of it. Even if both are making too much household output, it tells where the opportunity cost is greater.[15]

The test considered the allocation of duties within the household. Here, neoclassical efficiency would dictate allocation according to comparative advantage. Each productivity ratio computed as explained above measured the comparative advantage of the wife to the husband at market employment as contrasted with the jth category of household production. We computed the mean of these wives'

[15]To see the second best nature of this condition, consider a simplified model in the spirit of Gronau (1980) wherein a husband wants to maximize income by choosing hours of market and home work. Break the problem into stages. In the first, the household wants to maximize labor income subject to producing a given level of home production. This problem yields the optimizing condition in the text, $W_w/P_w = W_h/P_h$, equalized opportunity cost of household production. In the second stage, the household selects the optimal amount of home production. This yields the conditions $W_w = P_w$ and $W_h = P_h$. One could reverse the stages and get the same result.

TABLE 5

MEAN COMPARATIVE ADVANTAGES OF WIVES AT MARKET WORK AS COMPARED WITH SELECTED CATEGORIES OF HOUSEHOLD PRODUCTION AND RELATIVE SHARE SPOUSAL RESPONSIBILITY FOR THOSE CATEGORIES

Household Production Category	Mean Comparative Advantage at Market Work	Mean Share of Household Production Hours	
		Wives	Husbands
Clean in	−1.79	85.6%	14.4%
Home furn.	0.55	73.3	26.7
Meals	0.56	61.6	38.4
Clean out	1.58	37.9	62.1
Home repair	2.98	19.9	80.1
Appl. repair	3.37	43.9	56.1

comparative advantages for each of our six household production categories. The first column of Table 5 shows the mean comparative advantage estimates. Columns two and three list the mean percentages of household hours devoted to each household production category respectively for husbands and wives. If duties were allocated by comparative advantage, then the portion of responsibility for an activity should have been inversely related to the comparative advantage at market employment compared with that activity. The results approximately, but not perfectly, met that efficiency condition. The ordering was exactly as expected for five categories, but the portion of total time devoted by wives to appliance repairs ranked fourth rather than sixth as comparative advantage would indicate.

SUMMARY AND CONCLUSIONS

The main purposes of this paper were to estimate household production functions directly, consider the characteristics of these functions, and compare them with previous indirectly estimated production functions. Interviews with 135 households in the Missoula, Montana urban area provided the data for the estimation, in particular the output quantities of the numerous types of household output, the wives' and husbands' labor hours, and the quantity of available capital. The translog production function form best fit the data. In general, there were different functions for different categories of output and constant returns to scale. The estimated factor share was the greatest for wives' labor, second for husbands' labor, and smallest for capital. Wives' and husbands' labor were usually substitutes. Direct estimation allowed statistical testing of these conclusions about the characteristics of household production functions.

We think our results confirm the feasibility of measuring household outputs. Our measures are good enough that we get reasonable production function results. In fact, if the production functions prove stable, they could themselves be used to approximate short term changes in household output, since household labor and capital are quicker to measure than household output. An earlier lack of output and capital data and endogeneity concerns provided an impetus for indirectly estimated production functions. Our results suggest that these are not insurmountable problems. Furthermore, using directly measured data to re-estimate others' earlier indirect functions produced results which were not consistent with many of the assumptions on which the indirect estimates were based.

Directly estimated household production functions offer the potential to aid in the testing of various hypotheses about the economic behavior of households. The preliminary application included in this paper suggests that households usually allocate duties between wives and husbands roughly according to comparative advantage. Other topics for possible consideration include the optimality of the composition of household production and the responses of households to marriage or having children.

APPENDIX TABLE 1

UNRESTRICTED TRANSLOG HOUSEHOLD PRODUCTION FUNCTION ESTIMATES

	Output Type						
Parameter	Clean In	Clean Out	Appl. Repair	Home Furn.	Home Repair	Meals	All
constant	−0.117 (0.0839)	0.0795 (0.105)	0.273 (0.195)	0.00808 (0.241)	0.320** (0.115)	−0.0678 (0.124)	0.00336 (0.0530)
α_W	0.379** (0.0534)	0.32** (0.0503)	0.686** (0.175)	0.625** (0.0890)	0.377** (0.0655)	0.529** (0.0715)	0.556** (0.0679)
α_H	0.0211 (0.0246)	0.689** (0.0646)	0.762** (0.0885)	0.735** (0.149)	0.689** (0.0544)	0.122 (0.0741)	0.130** (0.0316)
α_k	0.0307 (0.154)	0.160 (0.963)	−0.0419 (0.132)	0.0870 (0.227)	0.179 (0.102)	0.224 (0.151)	0.168 (0.103)
α_{HH}	0.0168 (0.0214)	−0.0168 (0.0317)	−0.148 (0.0946)	0.00426 (0.0486)	−0.0434 (0.0452)	0.0693** (0.0267)	0.0555 (0.930)
α_{WW}	0.0140 (0.0152)	0.0335 (0.0417)	−0.00292 (0.0679)	−0.0100 (0.0748)	−0.0836** (0.0297)	−0.0172 (0.0203)	0.00970 (0.0166)
α_{kk}	0.0215 (0.196)	−0.189** (0.0704)	0.0771 (0.0934)	0.153 (0.285)	−0.0748 (0.0737)	0.434 (0.378)	−0.424 (0.252)
α_{HW}	−0.0298 (0.0274)	−0.165** (0.6372)	−0.108 (0.0676)	−0.171** (0.0536)	−0.0579 (0.0435)	−0.0169 (0.0279)	−0.0273 (0.0597)
α_{kW}	0.168 (0.135)	−0.0387 (0.0697)	−0.0723 (0.119)	0.00051 0.117	−0.00291 (0.0920)	−0.189 (0.200)	0.0390 (0.219)
α_{Hk}	−0.0859 (0.0633)	−0.0278 (0.0772)	0.0147 (0.129)	0.0441 (0.164)	0.0247 (0.0669)	(0.054) (0.0712)	0.00584 (0.0951)
σ^2	0.508	0.730	0.932	1.08	0.713	0.485	0.381
R^2	0.372	0.708	0.597	0.557	0.748	0.341	0.463
N	135	130	107	113	73	135	135

*Indicates significance at 5 percent level
**Indicates significance at 1 percent level

APPENDIX TABLE 2

TEST OF RESTRICTION OF HOMOGENEOUS TRANSLOG HOUSEHOLD PRODUCTION FUNCTIONS TO COBB–DOUGLAS FORM

Output Type	Log Likelihood from Unrestricted Model (L_1)	Log Likelihood from Restricted Model (L_2)	$-2(L_2-L_1)$
Clean in	−97.20	−105.59	16.78*
Clean out	−149.74	−164.03	26.60*
Appl. repair	−143.52	−145.33	3.62
Home furn.	−106.44	−111.10	9.32
Home repair	−122.04	−127.17	10.25*
Meals	−89.22	−110.16	41.89*
All	−59.36	−59.95	1.18

*Indicates that restriction to Cobb–Douglas can be rejected at 5 percent significance level.

APPENDIX TABLE 3

TESTS OF RESTRICTIONS THAT AGE AND EDUCATION HAVE ZERO COEFFICIENTS IN HOMEGENEOUS TRANSLOG HOUSEHOLD PRODUCTION FUNCTIONS

Output Type	Log Likelihood from Unrestricted Model with Age & Education (L_1)	Log Likelihood from Restricted Model without Age & Education (L_2)	$-2(L_2-L_1)$
Clean in	−95.79	−97.20	2.82
Clean out	−149.21	−149.74	1.06
Appl. repair	−138.11	−143.52	10.80*
Home furn.	−105.21	−106.44	2.46
Home repair	−120.16	−122.04	3.76
Meals	−99.02	−89.22	2.39
All	−51.62	−59.36	14.58*

*Indicates that the hypothesis that the restrictions are true can be rejected at a 5 percent significance level; $X^2_{0.05}$ (4) = 9.48

APPENDIX TABLE 4

TESTS FOR ENDOGENEITY IN UNRESTRICTED TRANSLOG HOUSEHOLD PRODUCTION FUNCTIONS

Output Type	*F* test	Wald test
Clean in	0.389	3.51
Clean out	1.06	9.54
Appl. repair	1.16	10.5
Home furn.	0.311	2.81
Home repair	0.686	6.18
Meals	2.85*	25.6*
All	5.77*	51.7*

*Indicates significance at 5 percent level; F0.05 (9,120) = 1.96; $X^2$0.05(9) = 16.92.

APPENDIX TABLE 5

GRAHAM-GREEN TYPE HOUSEHOLD PRODUCTION FUNCTIONS RE-ESTIMATED USING DIRECTLY MEASURED INPUTS AND OUTPUTS

Independent Variable	Output Category						
	All	Clean In	Clean Out	Appl. Repair	Home Furn.	Home Repair	Meals
Constant	2.28	5.57*	5.26	1.25	3.38	−1.16	−1.96
	(1.60)	(2.50)	(3.15)	(4.92)	(10.5)	(3.04)	(2.49)
Wife's home production time	0.410**	0.239*	0.150	0.133	0.586*	0.202	0.070
	(0.100)	(0.108)	(0.0885)	(0.168)	(0.252)	(0.102)	0.059)
Husband's home production time	0.135*	−0.217	0.723**	0.698**	0.672	0.582**	0.0265
	(0.0.52)	(0.050)	(0.130)	(0.161)	(0.322)	(0.0898)	(0.0329)
Capital	0.374	−0.102	0.626*	−0.0328	−0.682	0.272	0.862**
	(0.223)	(0.288)	(0.252)	(0.284)	(1.01)	(0.168)	(0.259)
Wife's education	0.0745	0.328	−0.0192	−0.0398	2.50	−0.119	0.483
	(0.367)	(0.661)	(0.918)	(1.72)	(3.72)	(0.879)	(0.540)
Husband's education	0.411	0.671	−0.901	−0.677	−3.81	1.36	0.856
	(0.357)	(0.606)	(0.843)	(1.46)	(2.72)	(0.725)	(0.540)
Wife's age	−0.360	−0.361	−0.400	0.735	0.449	−0.139	0.883
	(0.246)	(0.345)	(0.638)	(0.960)	(1.51)	(0.541)	(0.186)
Wife's wage rate	−0.0676	−0.216	−0.382	−0.328	0.0217	−0.0412	−0.0455
	(0.131)	(0.222)	(0.302)	(0.533)	(0.984)	(0.220)	(0.186)
Husband's wage rate	−0.0494	−0.163	0.243	0.0699	1.60	0.583*	−0.132
	(0.0977)	(0.168)	(0.255)	(0.357)	(0.871)	0.278	(1.136)
Family size	0.769*	0.548	0.190	1.25	−0.291	1.30	0.883
	(0.369)	(0.638)	(0.947)	(4.92)	(2.45)	(0.849)	(0.523)
Children 0–2	−0.0395	−0.109	0.0924	−0.427	−0.841	−0.266	0.157
	(0.197)	(0.353)	(0.484)	(0.828)	(1.36)	(0.531)	(0.275)
Children 3–5	−0.0078	−0.105	−0.124	−0.788	−0.758	−0.151	−0.130
	(0.189)	(0.321)	(0.474)	(0.803)	(1.37)	(0.407)	(0.262)
Children 6–13	−0.155	0.0354	0.0768	−0.132	1.13	−0.854	−0.985
	(0.218)	(0.389)	(0.554)	(0.888)	(1.35)	(0.516)	(0.313)
Children 14–17	−0.407	−0.213	0.136	−1.27	−2.15	−0.103	−0.206
	(0.208)	(0.360)	(0.517)	(0.816)	(1.60)	(0.513)	(0.296)
Number of rooms	−0.118	0.129	−0.414	−0.0766	1.49	−0.609	−0.142
	(0.223)	(0.348)	(0.570)	(0.916)	(1.96)	(0.596)	(0.291)
Own or rent	0.456*	0.239	0.686	0.951	−1.32	0.899*	0.506
	(0.185)	(0.305)	(0.440)	(0.777)	(1.53)	(0.434)	(0.260)
Adjusted R^2	0.625**	0.010	0.717**	0.491**	0.068	0.752**	0.346**

*Significant at 1% level
**Significant at 5% level

References

Berndt, E. R. and L. R. Christensen, The Translog Function and the Substitution of Equipment, Structures, and Labor in U,.S. Manufacturing 1929–68, *Journal of Econometrics* 1, 81–114, 1973.

Chadeau, A. Measuring Household Activities: Some International Comparisons, *Review of Income and Wealth*, 31, 237–254, 1985.

Chan, M. W. Luke and D. R. Mountain, Economics of Scale and the Turnqvist Discrete Measure of Productivity Growth, *Review of Economics and Statistics*, 65, 663–667, 1983.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau, Transindental Logarithmic Production Functions, *Review of Economics and Statistics*, 55, 28–45, 1973.

Fitzgerald, J. and J. Wicks, Measuring the Value of Household Output: A Comparison and Direct and Indirect Approaches, *Review of Income and Wealth*, 36, 129–141, 1990.

Goldschmidt-Clermont, L., Monetary Valuation of Non-market Productive Time: Methodological Considerations, *The Review of Income and Wealth* 39, 419–433, 1993.

Graham, J. and C. Green, Estimating Parameters of a Household Production Function with Joint Products, *Review of Economics and Statistics*, 66, 277–282, 1984.

Greene, W. H. *Econometric Analysis*, 2nd ed., Macmillan, New York, 1990.

Gronau, R., Home Production—A Forgotten Industry, *Review of Economics and Statistics*, 62, 408–416, 1980.

Hausman, J. A., Specification Tests in Econometrics, *Econometrica*, 46, 1251–1271, 1978.

Murphy, M., Value of Non-Market Household Production: Opportunity Cost versus Market Cost Estimates, *Review of Income and Wealth*, 28, 29–43, 1982.

Spencer, D. E. and K. N. Berk, A Limited Information Specification Test, *Econometrica*, 49, 1079–1085, 1981.