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Home production – Enjoying the process or the product?

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Abstract

This paper tests a household production model on data from a Danish time use survey from 2001 using GMM 3SLS. Household production includes "process benefits" accruing from the pleasure of undertaking certain housework tasks. I find no significant evidence of "process benefits". An identification problem arises from the situation where households alternatively attach extra value to consuming home-produced goods. The outcome of these two types of benefits may in certain cases be observationally equivalent.

JEL-Codes: C31, D13, J22

Keywords: Household production, process benefits, consumption benefits, GMM 3SLS

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1 Introduction

The classical household production model (Gronau, 1977; 1980; 1986) states that individuals allocate their time between market work, housework and leisure based on the shadow price of the time they spend in the labour market. Consuming the output of household production is the sole source of utility from housework. Home produced goods are perfect substitutes for market goods, and the output of household production is usually thought of as a public good enjoyed within the family.

However, some housework activities carry additional benefits beyond their consumption value.[1] Beside the pure income/production side of work, working may provide pleasure, self esteem and a sense of identity to people. The benefits accruing from the activity per se have been named "process benefits" (Juster, 1985) or “joint production” (Graham and Green, 1984; Kerkhofs and Kooreman, 2003; Pylkkänen, 2002). Process benefits are close substitutes to leisure and are predominantly a private good enjoyed by the person undertaking the activity. One obvious example is childcare. The time spent caring for one’s children contributes to the output of household production, but (usually) parents also derive utility from caring for their children. Other examples are do-it-yourself spells and gardening which may also partially be considered as leisure activities. It is difficult to draw a line between what is housework and what is leisure, and there may be considerable heterogeneity in tastes for undertaking housework activities within and across households.

This paper investigates the question of what is work and what is pleasure in household production. The theoretical setup builds on a model by Kerkhofs and Kooreman (2003) which explicitly includes “joint production” or “process benefits”. Kerkhofs and Kooreman’s model is an extension of Gronau’s classical household production model. The model is tested empirically on a time use dataset of Danish households in 2001. Previous analyses on this model (Kerkhofs and Kooreman, 2003; Pylkkänen, 2002) have used the FIML estimator which relies on the assumption that the error terms are joint normally distributed. In this paper, I use the less restrictive GMM 3SLS estimator. Provided correct moment conditions and without any assumptions about the functional form for the error terms, GMM 3SLS is consistent and efficient. The model without “process benefits” in household production finds substitution between housework of husband and wife. When the model is extended to incorporate the leisure value of household production, I find weak, but insignificant, signs of the presence of process benefits for women.

The paper contributes to the discussion of household production models by suggesting that there may be a supplementary - or alternative – explanation for why households may choose a higher level of household production than what is implied by the classical household produc-

1 In this paper, the term “housework” is used for normal housework activities including do-it-yourself work, gardening, transport of children etc., but not childcare in itself.

tion model. Hence, I argue that across households, there may be a considerable heterogeneity in households' taste for their own home produced goods, and some households may attach a higher value to goods produced by one of the household members than other households. In this sense, the value of home produced goods is not comparable across households. I refer to these benefits as "consumption benefits". The outcome of a higher value of home-made goods may be difficult to distinguish empirically from "process benefits". I demonstrate graphically that household production outcomes with "process benefits" and with "consumption benefits", respectively, may be observationally equivalent. This raises an important identification issue which has not been addressed explicitly in the previous literature on household production models.

Even though the outcome of process benefits and consumption benefits may be equivalent in terms of the amount of household production, the different types of benefits are enjoyed by different persons in the household. Thus, if household production is driven by process benefits, the extra benefits are private benefits which are enjoyed by the person undertaking the household production activity. However, if the chosen level of household production is governed by consumption benefits, the extra utility from home production may be enjoyed by either of the spouses independently of who did the housework. In the first case (process benefits), the level of household production activities is driven by individual household members' tastes for housework. In the last case (consumption benefits), the allocation of household production activities within the family is determined by relative wages and productivity.

More knowledge about the motivation behind time allocation outside the market is crucial for our understanding of time allocation in the family. Understanding the mechanisms for the choice of household production is important for our understanding of female labour supply. Moreover, considerations about alternatives to household produced goods and services may depend on the nature of the extra benefits from household production. If there are large process benefits – that is, if part of household production is considered leisure – then the justification for supporting substitutes for household production seems less evident. However, if the choice of activities at home is governed by consumption benefits, then an increase in the quality of market alternatives may induce families to buy more services in the market. Ultimately, this may have positive implications for female labour supply and lead to productivity gains from increased specialization in society.

2 Theoretical model

According to Becker (1965; 1994), households combine time and market goods to consume some basic commodities that directly enter their utility functions. Gronau (1977) developed the classical household production model which is a cornerstone in household production theory. Gronau's model provides an essential development of Becker's framework by explicitly accounting for household production. According to Gronau (1977, p. 1104), "An intuitive distinction between work at home (i.e., home production time) and leisure (i.e., home consumption time) is that work at home (like work in the market) is something one would rather have somebody else do for one (if the cost was low enough), while it would be almost impossible to enjoy leisure through a surrogate. Thus, one regards work at home as time use that generates services which have a close substitute in the market, while leisure has only poor market substitutes." Essential assumptions in Gronau's model are that home produced goods are perfect substitutes for market goods and that home production is subject to diminishing marginal productivity. Diminishing marginal productivity is often thought to be due to fatigue or changes in input proportions. In Gronau's model, diminishing marginal productivity is also due to changes in the composition of housework as a person may increase housework by undertaking more activities with cheap market substitutes.

Gronau's central assumption of perfect substitutability between home-produced commodities and market goods has been the subject of some discussion. Critics have pointed out that people do not always spend their time exclusively on one activity at a time, see e.g. Pollak and Wachter (1975). On the contrary, some of the time spent in housework may partly be considered as leisure. Graham and Green (1984) extend Gronau's model with so-called "joint production" defined as housework also partly being leisure to account for this observation. Implicitly, this extension modifies the strong assumption of perfect substitutability between market goods and home products. Graham and Green (1984) use the American Panel Study of Income Dynamics (PSID) and find substantial "jointness" between home production time and leisure. Kerkhofs and Kooreman (2003) build on Graham and Green's idea of "joint production", but employ a different specification of the household production function. Their empirical application is based on Swedish time-allocation data from the 1984 wave of the HUS survey.

This paper builds on Gronau's household production model with the Kerkhofs and Kooreman (2003) extension. The analysis concentrates on households with two adult members. It is assumed that the household members share one common utility function, i.e. a unitary utility function. In the classical Gronau household production model, households derive utility from the consumption of market goods, X_M, commodities produced at home, Z, and leisure for the man and the woman, l_m and l_f, and it is assumed that market goods and goods produced in the household are perfect substitutes.

(1) $$U = U\left(X_M + Z, l_m, l_f\right)$$

Household production, Z, is a function of time spent in housework, h_m and h_f, for male and female respectively, and auxiliary inputs, X_Z. For example, Z could be a meal produced with time inputs of the man and/or the woman, h_m and h_f, and intermediate inputs as food products, X_Z:

(2) $$Z = Z\left(h_m, h_f, X_Z\right)$$

The household budget consists of non-labour income, y, and labour income, where w_m and w_f are hourly wages, and m_m and m_f are market labour supply in hours, for male and female respectively. This leads to the following budget constraint:

$$X_M + X_Z = y + w_m m_m + w_f m_f \quad (3)$$

Initially, it is assumed that both partners participate in the labour force. This assumption ensures that individual wages are observed. Evidently, this assumption may lead to selection bias in the sample. Selection problems are addressed in section 5.1.

Each member of the household has a personal time constraint. T is total time endowment (e.g. 24 hours on a daily basis).

$$h_i + l_i + m_i = T, \quad i = m, f \quad (4)$$

The household maximizes utility (1) subject to (2), (3) and (4), giving the following Kuhn-Tucker conditions:

$$\begin{aligned} &\frac{\partial Z}{\partial X_Z} = 1 \\ &\frac{\partial U}{\partial Z}\frac{\partial Z}{\partial h_m} = \frac{\partial U}{\partial l_m} = \frac{\partial U}{\partial Z}\frac{\partial Z}{\partial X_Z} w_m + \xi_m \\ &\frac{\partial U}{\partial Z}\frac{\partial Z}{\partial h_f} = \frac{\partial U}{\partial l_f} = \frac{\partial U}{\partial Z}\frac{\partial Z}{\partial X_Z} w_f + \xi_f \end{aligned} \quad (5)$$

where ξ_m and ξ_f denote shadow prices of the inequality constraints on labour time. If both partners participate in the labour force ($m_m > 0, m_f > 0$ and $\xi_m = \xi_f = 0$), then one can find an interior solution, and (5) simplifies into:

$$\begin{aligned} &\partial Z/\partial X_Z = 1 \\ &\partial Z/\partial h_m = w_m \\ &\partial Z/\partial h_f = w_f \end{aligned} \quad (6)$$

For the conditions in (6) to hold, it is important that the net marginal wage rate is exogenous. The interpretation of (6) is that an individual will choose a level of housework where her marginal product of time equals her net wage rate in the market. If the marginal product of housework is lower than her wage rate, she will choose to work more in the market (and perhaps buy household production in the market). The model predictions in (6) correspond to the classical household production model without “process benefits”.[2]

To allow for the possibility that undertaking housework can both enhance household production and function as a sort of recreation activity for the person doing the work, “process benefits” are included in the model. For example, gardening provides utility through two channels:

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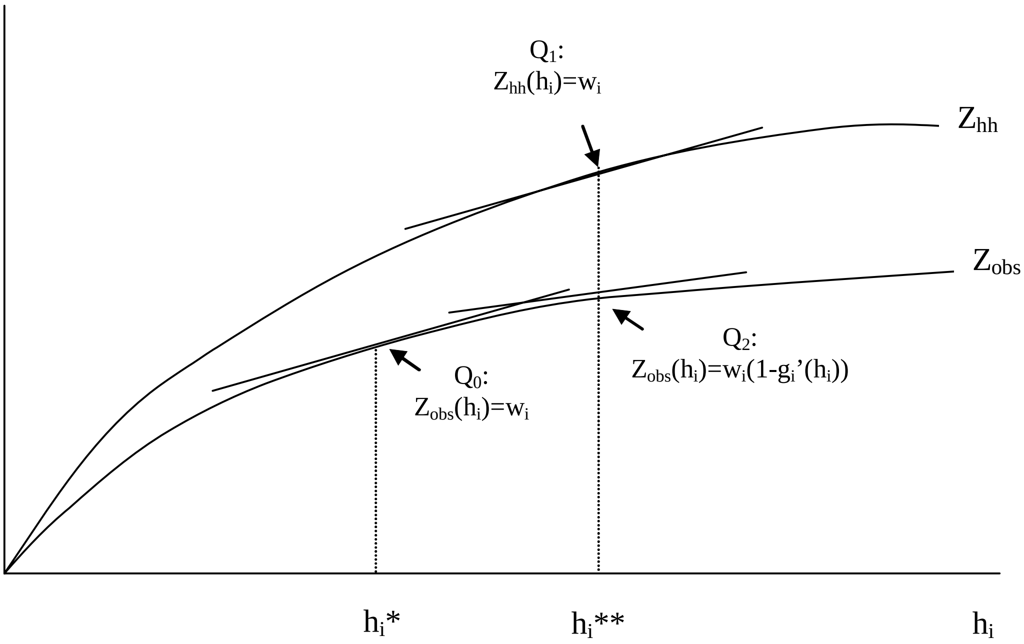
2 The optimum can be viewed as the result of a two-stage decision process. In the first stage, the household decides on its requested level of household production. In the second stage, the household decides how to allocate non-production time and the purchase of consumption goods. Therefore, the household production model can be analysed only with the help of the production function, whereas the utility function does not appear until in the second stage of the decision process. It is a both necessary and sufficient condition that the production function Z is strictly concave to ensure a local maximum.

First, gardening enhances the household product, Z, by creating a prettier garden. This can be enjoyed by both partners in the household as a public good. Secondly, gardening may be seen as a sort of leisure activity which provides utility to the person who does the gardening. The first effect is already in the model. The second feature can be included in the model in the following way: If a person spends hi hours on home production, he or she considers a certain part of this time, the "process benefit" $g_i(h_i)$, as a perfect substitute for leisure. The process benefit function g_i is assumed to be increasing, twice differentiable and concave in h_i, $g_i^{'} \leq 1$ and $g_i^{'} \rightarrow 0$ as $h_i \rightarrow T$, implying that the marginal utility of housework is decreasing in h_i. This is graphically represented in figure 1.

Figure 1
Household production function



Source: Own illustration.

The equilibrium for the situation without process benefits (the "classical" equilibrium) is found in Q^0. Next, the household utility function is extended to allow for process benefits:

(7) $$U = U\left[X_M + Z, l_m + g_m\left(h_m\right), l_f + g_f\left(h_f\right)\right]$$

Under the usual budget and time constraints, the first-order conditions are now:

(8) $$\begin{aligned} &\partial Z / \partial X_Z = 1 \\ &\partial Z / \partial h_m = w_m\left[1 - g_m{}'\left(h_m\right)\right] \\ &\partial Z / \partial h_f = w_f\left[1 - g_f{}'\left(h_f\right)\right] \end{aligned}$$

When taking process benefits into account, the model predicts that the individual members of the household will choose a housework level where the marginal product of their housework equals their wage rate times a correction factor, $0 \leq \left[1 - g_i^{'}(h_i)\right] \leq 1$. The correction factor reflects that part of individual housework activity may be perceived as leisure. The introduction of process benefits can explain why the chosen level of individual housework may be higher than predicted by the traditional labour supply model. When allowing for process benefits, the optimum is in Q^1 (figure 1).

Household production Z is an increasing function of i's work in household production, h_i, and the marginal product of h_i is decreasing with h_i. According to the classical household production model, person i chooses the number of hours of housework h_i^* where her marginal product in household production equals her wage rate, w_i, i.e. $\partial Z / \partial h_i = w_i$. However, for given wage w_i and given marginal production in household production, $\partial Z / \partial h_i$, we may observe that she works more in the household than the classical household production model would predict. If she instead works h_i^{**} hours in the household, where $h_i^{**} > h_i^*$, the difference between h_i^{**} and h_i^* may reflect that she derives utility in the form of leisure from performing the housework. The extent of these process benefits can be identified from observations on her wage and her household production.[3]

Identification

An important identification problem which has not been given any attention in the previous literature on household production models relates to the character of the "extra" benefits in household production. As discussed in the introduction to this paper, a higher level of household production than what is predicted by the classical household production model does not necessarily have to be ascribed to "process benefits". An alternative – or supplementary - explanation is that households may attach a higher value to goods produced by one of the household members rather than similar goods bought in the market. The value the household puts on home-made goods can be higher than the price they would get for them in a hypothetical market for home-produced goods.

The household-specific value of household production may be due to several factors which are discussed extensively by Chiswick (1982). First, some households may have a higher preference for home-made goods than others, and these preferences may also diverge within the household. Household members may simply prefer home-made goods to substitutes bought in the market. For example, both spouses in the household may attach a higher value to children for whom one or both of them have cared themselves. Secondly, household members may possess household-specific skills which are important in the production of goods

3 As pointed out by Kerkhofs and Kooreman (2003), if Z is strictly concave there is still a unique solution (a local maximum) to the problem. However, strict concavity of Z in h_m and h_f is a sufficient condition, but it is no longer a necessary condition, as both the left-hand and the right-hand side of the first-order conditions change when h_m or h_f changes. The model with process benefits allows for increasing returns to scale in household production provided the curvature of the g_i-function is sufficiently high. Thus, increasing returns to scale may make high specialization in the household attractive from a production efficiency point of view. But the additional process benefits from spending many hours in housework may be sufficiently low on the margin to offset the benefits from specialization. Therefore, it is possible to find a solution to the optimization problem with increasing returns to scale if the (negative) second-order derivative of the g_i function is (numerically) large enough to ensure that the combined utility of consuming and performing household production for each individual has a local optimum.

that they consume themselves. And thirdly, there may be fixed costs associated with household production which makes it difficult to delegate household tasks to persons outside the household.

The extra value of home produced goods is named "consumption benefits" in this paper. These benefits are not comparable across households. Consumption benefits are inherently different from "process benefits" since the former may be enjoyed by either of the spouses irrespective of who did the housework, while the latter can only be enjoyed by the person undertaking the household production activity. Thus, while "process benefits" through their leisure character are mainly private goods, "consumption benefits" are public goods. Some households may have a higher preference for home-made goods than others, and these preferences may also diverge within the household.

Figure 1 illustrates that household production with "process benefits" and with "consumption benefits", respectively, may be observationally equivalent. Assume we can observe the "market" value of household production, Z_{obs}. According to Gronau's classical household production model, person i is expected to work h_i^* hours in the household. But we observe that she works h_i^{**}. As argued above, the higher input of housework may be due to "process benefits", i.e. her individual pleasure of undertaking household production activities. Since household production generates this extra, leisure-like benefit, she is willing to increase her housework to a point where her marginal product of household production is lower than her wage rate.

Usually, one cannot observe the value of household production, but the household knows its own subjective value on home-produced goods. Suppose the household attaches an additional value to consuming home-made products beyond the "market" value, Z_{obs}. The "true" value of household production for the household equals Z_{hh}. The difference between Z_{hh} and Z_{obs} is defined as "consumption benefits". If individual i does not particularly enjoy working in the house (no process benefits), she chooses her optimal housework when $\partial Z_{hh} / \partial h_i = w_i$. Given the shape and position of the Z_{hh} curve, the optimal amount of housework is h_i^{**}. Thus, in this case, the two situations with "process benefits" and "consumption benefits", respectively, are observationally equivalent.

The distinction between "process benefits" and "consumption benefits" may seem of a somewhat theoretical nature. However, from a policy point of view it is important to establish the true source of the extra benefits from household production that lead to a level of housework higher than what the classical model predicts. Thus, women's traditionally high level of home production may arise not (only) from the fact that they enjoy housework, but also from the fact that the family as a whole attaches a high value to its output. Understanding the mechanisms behind the family's time allocation outside the market may give us a fuller picture of what drives female labour supply in the labour market.

Another identification issue stems from the fact that the *output* of home production, Z, usually unobserved, and often one does not observe the input of auxiliary goods, X_Z, either. The amount of household production therefore has to be based on information about the input of time in household production, and identification of the model is based on the first-order conditions. This poses a number of additional identification questions. These have already been thoroughly discussed in Kerkhofs and Kooreman (2003) where they point out that in general, the model has limited power for identification of process benefits in single earner households. In the following empirical application, the analysis is restricted to couples who are married or cohabiting.

3 Data

The data used to test the model empirically are from the Danish Time Use Survey for 2001 (DTUS). The DTUS complies with methodologies developed at the EU level for conducting time use surveys; see Bonke (2005) for a detailed description. For married and cohabiting respondents, the partner in the household was also asked to participate in the survey. There are two sources of information on time use. First, each respondent filled in a diary stating their activities at a detailed level every 10 minutes in two 24-hour days, one a week-day and the other a weekend day. Second, the questionnaire asked the respondents about their "usual" time use and some personal and household characteristics. Moreover, the survey data has been merged with information from register (administrative) information from Statistics Denmark on the respondent and partner, giving access to further personal and household information. The wage measure used in this paper is from the register data and is therefore not directly linked to the information given in the time use survey.

As mentioned, as well as keeping a time diary, respondents were asked about the time they *usually* spend on housework and in the labour market in a typical week. Usual housework time includes cleaning, laundry, shopping, cooking etc. and gardening, repairs, other do-it-yourself work and transportation of children, but not childcare per se. As always, the classification of childcare as housework is disputable, as discussed above. Since respondents were only asked one question on usual housework, childcare cannot be treated separately.

In general, it is observed that surveys asking about usual or normal time use have a smaller variance, but perhaps a more imprecise mean of time use, while diary information gives more precise means, but with a larger variance, see Juster and Stafford (1991). Based on this, usual time use rather than the diary information has been used to avoid the very serious infrequency problems in the latter.

In the following, I focus on a sample of households in which both husband and wife work full-time in the labour market.[4] Table 1 gives descriptive statistics of the sample.: One of the reasons for focusing on this sample is that hourly wage rates are determined with more precision for full-time workers in the data, and the determination of household production based on the wage rate is central in the theoretical model. When a person decides how much time to allocate to housework, the shadow price of time is obviously the wage rate *net* of taxes on

4 Full-time market work is defined as at least 30 hours work per week, including commuting time. Part-time work is not very prevalent in Denmark.

labour. In the data, I only have information on the gross wage rate. To arrive at a very crude estimate of net wages, a simple imputation of individual marginal tax rates has been performed. Details are given in the Appendix. Our dataset contains 596 couples. Figure 2 shows the distribution of housework and wages for men and women.

Table 1
Descriptive statistics

Variable	Mean	Std.	Min	Max
Male characteristics				
Housework, hours per day	1.63	0.91	0.43	5.00
Gross wage, DKK per hour	210	78	93	649
Age	42.51	9.73	22.00	66.00
Education in years	13.10	2.52	10.00	18.00
Female characteristics				
Housework, hours per day	2.21	1.00	0.43	5.00
Gross wage, DKK per hour	165	48	71	461
Age	40.48	9.51	20.00	61.00
Education in years	13.37	2.57	10.00	18.00
Household characteristics				
Homeownership	0.85	0.35	0.00	1.00
Dummy young children (0-6)	0.30	0.46	0.00	1.00
Dummy children 7-17	0.40	0.49	0.00	1.00
Number of children	1.01	1.01	0.00	4.00
Non labour income, 1000 DKK	23	65	0	1003
Dummy for garden	0.81	0.40	0.00	1.00
Number of square metres	133	41	48	350

Source: Danish Time Use Survey 2001, own calculations.

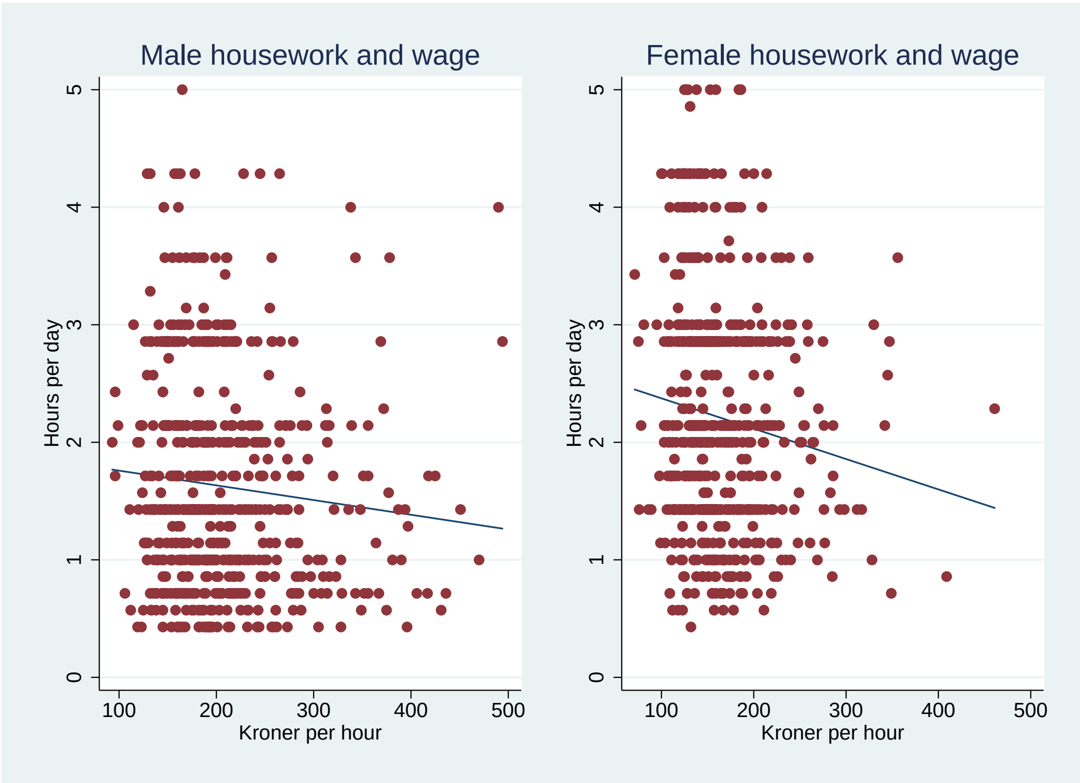
Out of the sample of full-time employed people, there is information on wage rates for both husband and wife for about ¾ of the couples. For both men and women, the correlation between housework (in hours per day) and wages (in DKK per hour) is small and negative, cf. figure 3.

Within married couples, both household production and wage rates are strongly correlated (the correlation between wife's and husband's wage is 0.34, and the correlation between wife's and husband's housework hours is 0.55). This may be explained by positive assortative mating (Becker, 1991; Weiss, 1997), the presence of children in the household, and/or correlation in preferences and other unobserved characteristics. Despite the strong correlation of housework within the family, I still find that women do the majority of household production. On average, women do 59 percent of the housework, and the median wife does 58 percent of the housework. In 7 percent of the households, the woman does less than half of the housework. The wife takes on more than 75 percent of the housework in more than 11 percent of the households.

Figure 2
Housework and wages for men and woman

Source: Danish Time Use Survey 2001, own illustration.

Figure 3
Housework and wages for men and women



Source: Danish Time Use Survey 2001, own illustration.

4 Empirical specification

The first-order conditions set out in (6) and (8) for the theoretical model without and with process benefits, respectively, are now investigated empirically. According to the theoretical model, household production is a function of housework time, h_m and h_f, and intermediate inputs into household production, X_Z. As discussed previously, time use surveys usually do not contain any measure of the output of household production, and due to the imperfect substitution possibilities of household production for comparable market goods, it is difficult to find comparable market prices for the output from household production. Furthermore, as there is no information on auxiliary goods used in household production, X_Z, the net product value function is used instead of the (gross) production function. To ensure comparability with Kerkhofs and Kooreman (2003), the net product value function, $\tilde{Z}$, is assumed to have the following functional form:

(9) $$\tilde{Z} = b_m h_m + b_f h_f + ½ c_{mm} h_m^2 + ½ c_{ff} h_f^2 + c_{mf} h_m h_f$$

b_m and b_f are strictly positive. The C-matrix,

$$C = \begin{pmatrix} c_{mm} & c_{mf} \\ c_{mf} & c_{ff} \end{pmatrix},$$

should be negative definite to ensure a well-behaved production function. Housework of the two spouses, h_m and h_f, can be substitutes or complements; substitutes if $c_{mf} < 0$ and complements if $c_{mf} > 0$. This parameterization of the model is convenient as it ensures that the production function possesses standard characteristics such as a positive marginal product which is decreasing in time inputs. Furthermore, the parametric formulation of the model allows for an investigation of substitutability versus complementarity of time inputs of the two spouses.

Based on equation (9), one can derive the marginal products of male and female housework time:

(10) $$\frac{\partial \tilde{Z}}{\partial h_m} = b_m + c_{mm} h_m + c_{mf} h_f$$
$$\frac{\partial \tilde{Z}}{\partial h_f} = b_f + c_{ff} h_f + c_{mf} h_m$$

Hence, the marginal productivity of housework time for a married man, h_m, depends on the parameters b_m, c_{mm} and c_{mf} as well as the level of both his own and his wife's housework. This is parallel for a married woman. First-order conditions when process benefits are not accounted for follow equation (6) combined with (10):

(11)
$$\frac{\partial \tilde{Z}}{\partial h_m} = w_m \Rightarrow b_m + c_{mm} h_m + c_{mf} h_f = w_m$$
$$\frac{\partial \tilde{Z}}{\partial h_f} = w_f \Rightarrow b_f + c_{ff} h_f + c_{mf} h_m = w_f$$

And first-order conditions when process benefits are taken into account are obtained by combining (8) and (10):

(12)
$$\frac{\partial \tilde{Z}}{\partial h_m} = w_m \left[1 - g_m'(h_m)\right] \Rightarrow b_m + c_{mm} h_m + c_{mf} h_f = w_m \left[1 - g_m'(h_m)\right]$$
$$\frac{\partial \tilde{Z}}{\partial h_f} = w_f \left[1 - g_f'(h_f)\right] \Rightarrow b_f + c_{ff} h_f + c_{mf} h_m = w_f \left[1 - g_f'(h_f)\right]$$

The household chooses a level of household production time for wife and husband depending both on these factors as well as wages and utility of housework as reflected in the g-function. Furthermore, individuals are heterogeneous in their marginal productivity of housework. It is assumed that b_m and b_f depend on household and individual specific characteristics captured in x_m and x_f, respectively:

(13)
$$\ln(b_m) = x_m'\beta_m + u_m$$
$$\ln(b_f) = x_f'\beta_f + u_f$$

This parameterization is also convenient since it secures positive marginal products of both spouses, as would be expected from a well-behaved production function. Combing (11) and (13), the system of equations for the model *without* process benefits expressed in errors is:

(14)
$$u_m = \ln(b_m) - x_m'\beta_m = \ln\left(w_m - c_{mm} h_m - c_{mf} h_f\right) - x_m'\beta_m$$
$$u_f = \ln(b_f) - x_f'\beta_f = \ln\left(w_f - c_{mf} h_m - c_{ff} h_f\right) - x_f'\beta_f$$

w_m, w_f, x_m, and x_f are assumed to be exogenous. To estimate the model *with* process benefits, it is necessary to specify a functional form for the process benefit function. As in Kerkhofs and Kooreman (2003) and Graham and Greene (1984), a specific functional form that captures the characteristics for g set out above is assumed:

(15)
$$g_i(h_i) = h_i \left[1 - \frac{1}{1+\delta_i}\left(\frac{h_i}{T}\right)^{\delta_i}\right], \quad i = m, f$$

where $\delta_m, \delta_f \geq 0$. If $\delta_m = \delta_f = 0$, the model corresponds to the classical household production framework. As $\delta_m, \delta_f \to \infty$, all household production time is perceived as leisure. Differentiating g_i (equation 15) with respect to h_i gives $g_i'(h_i) = 1 - (h_i/T)^{\delta_i}$; inserting this in (12) and combining with (13) leads to a system of equations with process benefits:

(16)
$$u_m = \ln(b_m) - x_m'\beta_m = \ln\left[\left(h_m/T\right)^{\delta_m} w_m - c_{mm} h_m - c_{mf} h_f\right] - x_m'\beta_m$$
$$u_f = \ln(b_f) - x_f'\beta_f = \ln\left[\left(h_f/T\right)^{\delta_f} w_f - c_{mf} h_m - c_{ff} h_f\right] - x_f'\beta_f$$

In the empirical analysis presented below, I estimate model (14) *without* and model (16) *with* process benefits, respectively.

5 Estimation and results

5.1 Classical household production - no process benefits

The estimations presented in this section focus on the classical household production model in (14). That is, when $\delta_m = \delta_f = 0$. The model is estimated by applying the efficient General Method of Moments for systems (GMM 3SLS). Kerkhofs and Kooreman (2003) estimated this system by maximum likelihood, which is the efficient estimator if the error terms are joint normally distributed. However, normality of the error terms is often a strong assumption. The advantage of GMM 3SLS is that consistent estimates are obtained under much weaker assumptions than estimation based on maximum likelihood, since it is not necessary to assume anything about the functional form of the distribution of the error terms. GMM is efficient is the error terms are not joint normally distributed which is the case with our dataset. See the Appendix for more details on the estimation procedure and the outcome of normality tests.

The imputed measure of net wages is used as a measure of the shadow price of time. Construction of net wages is described in the Appendix. The individual and household characteristics captured in the X -matrices consist of individual age and age squared, individual education dummies and dummies for the presence of younger and older children. In (14), h_f is endogenous in the first equation and h_m is endogenous in the second equation. Instruments for female household production, h_f, are her gross wage and gross wage squared, her age, her education (in years), the number of children, the number of square metres in the home and a dummy for whether the house has a garden. Equally, instruments for male household production, h_m, are his gross wage and gross wage squared, his age, his education (in years), number of children, number of square metres in the home and a dummy for whether the house has a garden. The moment conditions are constructed under the assumption that the error terms in each equation are uncorrelated with the instruments for the relevant equation. Both sets of instruments are jointly significant in explaining the variation in household production ($\chi^2 - value$ of 20.4 for the joint test of the four instruments), although the overall explanatory power of the estimation equations for the two instruments as measured by R^2 is rather low, $R^2 = 0.12$ for the instruments for female household production, and $R^2 = 0.05$ for the instruments for male household production (see Appendix 1).

Selection

The sample consists of couples where both spouses work more than 30 hours a week including commuting time. Thus, the sampling is based on labour market status which is endogenous in the model. This gives rise to selection bias. On the one hand, relatively home-productive individuals might be under-represented in the sample, since these individuals are relatively more likely not to have a paid job (and an observed wage rate). On the other hand, the personal characteristics which determine productivity in the market and thus enhance the chances of being employed may also lead to a relatively high productivity at home, so productivity at home and in the market might be positively correlated through various (observed as well as unobserved) characteristics that affect both productivities in the same direction. Thus people who are productive at home may be over-represented in the sample[5]. Consequently, the net direction of the selection bias is an empirical question and is difficult to predict ex-ante. Possible selection bias is treated by use of the Heckman selection procedure.: Participation in the labour market for husband and wife is estimated in a bivariate probit model. Details of the participation estimation are given in the Appendix. The inverse Mills ratio resulting from the labour supply estimation is added as an extra explanatory variable in the estimation of the model in (14). The estimation results for GMM are shown in table 2, column 1. The overidentifying restrictions test tests whether the instruments are uncorrelated with the error terms. The null hypothesis is accepted at a 5 percent significance level meaning that the instruments are indeed uncorrelated with the error terms.

Table 2
Estimation Results

	(1) no process benefits		**(2) process benefits**	
	Coefficient	t-value	Coefficient	t-value
Curvature male household productivity, c_{mm}	-7.730	-0.96	-10.712	-1.12
Curvature of female productivity, c_{ff}	-1.225	-0.51	4.237	0.84
Substitution factor, c_{mf}	-6.964***	-2.70	-5.093	-1.48
Male equation β_m				
Constant	4.063***	23.48	4.061***	23.01
Age	0.016**	2.11	0.017**	2.13
Age squared	0.000*	-1.79	0.000*	-1.82
Dummy high school	0.088*	1.96	0.087*	1.91
Dummy vocational education	0.049**	2.24	0.051**	2.28
Dummy short further education	0.050	1.41	0.050	1.40
Dummy medium further educ.	0.073***	2.65	0.076***	2.73
Dummy higher further education	0.158***	4.78	0.163***	4.91
Dummy young children	0.080***	3.48	0.081***	3.46
Dummy children 7-17	0.050***	2.56	0.046**	2.27
Homeownership	0.059***	2.56	0.058**	2.44
Inverse Mills ratio, male	0.133***	2.67	0.126**	2.44

5 Gronau and Hamermesh (2001) show that there is a positive correlation between the level of education and the demand for variety in time-use activities. Their interpretation is that people with higher levels of education have a higher productivity, not only in market work, but also in housework.

Table 2 Cont.
Estimation Results

	(1) no process benefits		(2) process benefits	
	Coefficient	t-value	Coefficient	t-value
	Female equation			
Age squared	0.000***	-4.29	0.000*	-1.95
Constant	3.690***	28.10	2.746*	1.66
Age	0.029***	4.60	0.038*	1.96
Dummy high school	0.040	1.21	0.040	0.91
Dummy vocational education	0.037*	1.95	0.047	1.42
Dummy short further education	0.061***	2.00	0.082	1.33
Dummy medium further education	0.075***	3.53	0.097*	1.82
Dummy higher further education	0.152***	4.96	0.185**	2.13
Dummy young children	0.022	1.26	0.030	1.15
Dummy children 7-17	-0.019	-1.06	-0.025	-0.85
Homeownership	0.024	1.24	0.036	1.15
Inverse Mills ratio, female	0.011	0.34	0.012	0.29
δ_f			0.3	

Note: * p=0.10; **, p=0.05; ***, p=0.01.
Source: Danish Time Use Survey 2001, own calculations.

Details of the overidentifying restrictions test are given in the Appendix. The estimation results with selection are documented in table 2. It appears that the selection parameter (inverse Mills ratio) is significant in the male equation, but not in the female equation. One explanation might be that the explanatory power of the estimation of female labour supply is rather low, see the Appendix.

5.2 Estimation with process benefits

In the previous section, it was assumed that there are no "extra" benefits related to household production. This section analyzes the consequences of relaxing this assumption by estimating the system in (16). Compared to the previous estimation of (14), this implies that the restriction that $\delta_m = \delta_f = 0$ is relaxed when allowing for process benefits. The optimization procedure tends to converge towards a corner solution where male process benefits are zero. As a consequence, δ_m was tied to zero, and δ_f was allowed to vary freely, cf. table 2, column 2. An optimum for the GMM estimation was found where $\hat{\delta}_f = 0.3$. The joint significance of the estimates was tested by using the GMM distance statistic which is χ^2 distributed with 2 degrees of freedom under the null hypothesis $\delta_m = \delta_f = 0$. Joint significance is not accepted, and the null hypothesis that $\delta_f = 0$ is accepted with a p-value of 0.26. Thus, there is no significant evidence of the presence of process benefits for women. See details of the tests in the Appendix. The estimate of c_{ff} is positive but insignificant.[6]

[6] As discussed above, increasing returns to scale (positive c_{ff}) is not necessarily a problem in the extended household production model that allows for process benefits. What matters for the optimization is that the

Table 3 shows sample means and standard deviations for predicted values of male and female housework productivity and value of household production with and without process benefits.

Table 3
Sample averages of predicted household production variables

	No process benefits (Model 1)		**Process benefits (Model 2)**	
	Mean	Std. dev.	Mean	Std. dev.
b_m	103.2***	23.3	104.0***	23.7
b_f	80.6***	12.8	65.5***	12.1
$Z/(b_m + b_f)$	79.8***	12.7	75.7***	12.9
$g_m(h_m)/h_m$	-	-	0.0	-
$g_f(h_f)/h_f$	-	-	0.52	0.06

Note: * p=0.10; **, p=0.05; ***, p=0.01.
Source: Danish Time Use Survey 2001, own calculations.

I insert the parameter estimate of $\hat{\delta}_f = 0.3$ into the g_i-function formulated in (15) and use the observation that the time spent in housework is around 10 percent of the total time for women. It appears that the mean value of household production is around 80 DKK per hour when process benefits are not taken into account and around 76 DKK per hour when process benefits are accounted for. Compared to average gross wage rates of 210 DKK per hour for men and 165 DKK for women and average marginal tax rates around 60 percent, average household production values of that size seem realistic. Moreover, it appears that female marginal productivity is around 66 rather than 81 DKK per hour when allowing for the wife's pleasure of doing housework, i.e. process benefits. Thus, the model with process benefits suggests that the observed high level of female housework is due to women's pleasure from working in the house rather than motivated for the household's demand for this product. I find that *on average* the fraction of housework that is also perceived as leisure is around 0.5.

For comparison, Kerkhofs and Kooreman (2003) estimated that $\hat{\delta}_m$=0.135 and $\hat{\delta}_f = 0.216$. Their estimates were not statistically significant either. Pylkkänen (2002) found significant estimates of $\hat{\delta}_m$=0.165 and $\hat{\delta}_f = 0.076$. Interestingly, Kerkhofs and Kooreman (2003) found female process benefits to be around 1½ times higher than men's process benefits, whereas Pylkkänen (2002) found the opposite result, that men's marginal pleasure of housework is almost the double of women's pleasure of undertaking housework. My results are in line with the estimates found by Kerkhofs and Kooreman (2003).[7]

contribution of the second order derivative of the g-function (which is negative) is large enough to counteract the contribution of the positive second-order derivative of the Z-function.

7 A natural question to ask is whether it is more likely to find process benefits in households where a larger part of household production could be perceived as partly leisure; e.g. families with young children. Out of the 596 full-time couples used in this analysis, a little more than ½ of the families had children below 17 years. Since this is a rather small sample, we have not investigated this question further.

5.3 Discussion

A future step to obtain a fuller picture of the process of allocating time to household production within the household would be to develop a model that incorporates the distribution of "power" within the household, i.e. a "collective" model as proposed by Chiappori (1988, 1992, 1997), or the intra-household allocation model proposed by Apps and Rees (1988, 1996, 1997). Such an extension seems desirable, but would inevitably enhance the empirical identification problems already present, given the limited information in the data about the value of household production, intermediate inputs and intra-household matters.

The analysis above investigates "process benefits" in household production. The analysis implicitly assumes that process benefits do not arise from performing market work. However, this is not necessarily the case. Hallberg and Klevmarken (2003) analyzed the Swedish HUS study of 1984 and 1993, where respondents were asked to state how enjoyable they found various activities on a scale from 0-10. Playing with one's own children and being in charge of one's children produced the highest enjoyment for both men and women measured on the popularity scale (around 8), closely followed by market work (around 7). Making dinner or repair and maintenance tasks were given a 6 on the scale, whereas cleaning the house got the lowest scores (around 3-4) among all activities. Thus, market work was considered nearly as enjoyable as being with one's own children and more enjoyable than most household chores.

Juster and Stafford (1985; 1991) found similar trends in American data. As a pragmatic solution to this conceptional problem, the estimates presented in our paper may be interpreted as a measure of the *relative* process benefits from carrying out household production compared to working in the market.

Certain household services as e.g. cleaning are sometimes purchased at an hourly price which is higher than people's own after-tax hourly wage. This indicates that different types of work vary in popularity. The phenomenon may also partly be explained by differences in productivity between individuals doing housework in their own homes and professionals. But in low-productivity jobs as cleaning, differences in productivity between professional cleaners and individuals cleaning their own house will hardly explain why people tend to buy cleaning in the market. For some well-educated people, the decision to buy services may be based on expected future rather than present income. Buying time through the purchase of domestic services may be invested in human capital investment through formal education or work experience.

The analysis in this paper focuses on married couples. The possible interaction between the demand for the exchange of household production and goods within married couples and the decision to marry or divorce is not treated in this paper. See Grossbard-Shechtman (1984) for a discussion. Furthermore, the model used in this paper does not treat the two partners' possible utility from coordination of leisure and household production activities (Burda et al., 2006).

6 Conclusion

The model in this paper builds on the classical household production model developed by Gronau (1977, 1980, 1986) with an extension allowing for “process benefits” (due to Juster, 1985) or “joint production” (Graham and Greene, 1984; Kerkhofs and Kooreman, 2003). The model is tested empirically on Danish time use data with interpretable results.

First, the model is estimated without process benefits, i.e. without allowing for the possibility that some of the activities which are characterized as household production also provide benefits per se for the person performing the activity. For this formulation of the model, housework by husband and wife show the expected diminishing returns to scale and his and her time in housework are q-substitutes. The results comply with the results from a previous study by Kerkhofs and Kooreman (2003) which used Full Information Maximum Likelihood (FIML) as estimation method. This paper suggests a more flexible estimation method, the efficient GMM 3SLS estimator, which does not rely on the error terms being normally distributed.

In a second step, the household production model with process benefits is estimated. There is some empirical evidence of the *presence* of process benefits in household production for women, but the effect is not significant. The results are in line with a previous analysis by Kerkhofs and Kooreman (2003).

In general, the model’s explanatory power is low. Housework of husband and wife are strongly correlated, and the exogenous explanatory variables can only explain a modest part of the variations in housework across households. Thus, there is probably considerable unobserved heterogeneity in housework.

The paper discusses alternative interpretations and identification issues related to the empirical results. The paper argues that possible “extra” benefits related to household production may be related to households having a higher preference for home-made products rather than household products bought in the market. These benefits are called “consumption benefits”. The paper shows graphically that “process benefits” and “consumption benefits” can be observationally equivalent. However, the benefits are inherently different in the sense that “process benefits” (in the form of leisure) are private goods, while “consumption benefits” are public goods which directly enhance the utility of both spouses, irrespective of who carried out the housework. This point has not been given any attention in the previous literature on household production models.

Appendix

Construction of net wages

The register data has information on gross hourly wages. I construct a net wage by imputing marginal tax rates based on the gross wage for a person who works full-time (1500 hours) for the whole year. Based on tax rules for marginal tax rates and labour market contributions for 2001, I set the marginal tax rate at 50 pct. for a person with a total gross wage income below 178,000 DKK (US$ 28,000). For total gross wage incomes between 178,000 DKK and 277,000 (US$ 45,000), the marginal tax rate is 55 percent, and for gross wage incomes beyond 277,000 DKK, the marginal tax rate is 68 percent.

Efficient GMM

The formulation of moment conditions for the efficient GMM 3SLS estimator follows Wooldridge (2001, ch. 14). The efficient GMM 3SLS estimator solves:

(A1) $$\min_{\theta \in \Theta} \left[\sum_{i=1}^{n} Z_i q_i(\theta) \right] (n^{-1} \sum_{i=1}^{n} Z_i' \hat{\hat{u}}_i \hat{\hat{u}}_i' Z_i)^{-1} \left[\sum_{i=1}^{n} Z_i q_i(\theta) \right]$$

Where Z is a matrix of instruments for the endogenous variables.

Instruments

In the first equation (A1), I instrument female household production by her wage, her wage squared, her age, her education in years, number of children, a dummy for whether the house has a garden and number of square metres in housing. I use the same procedure in the second equation where male household production is instrumented by his wage, his wage squared, his age, education in years, number of children, dummy for garden and number of square metres. Table A1 shows that the explanatory variables in both equations are jointly significant with a very low p-value for the χ^2 test, but the R^2's are rather low in both equations.

Table A1
3SLS (SUR) estimation of instruments for h_f (1st eq.) and h_m (2nd eq.)

	Coefficient	t-value
Female equation (instruments for equation 13a and 15a)		
Male wage	-0.007**	-2.37
Male wage squared	0.012*	1.65
Male age	0.008*	1.76
Male education in years	-0.033**	-2.29
Number of children	0.277***	6.68
Dummy for garden	0.167	1.56
Log (1 + # of square metres)	0.221	1.56
Constant	1.686**	2.43
R^2	0.12	
Chi^2	89.9	
p-value	0.000	
Male equation (instruments for equation 13b and 15b)		
Male wage	-0.004***	-2.68
Male wage squared	0.005**	1.97
Male age	0.003	0.83
Male education in years	0.012	0.88
Number of children	0.149***	3.86
Dummy for garden	0.229**	2.25
Log (1 + # of square metres)	-0.057	-0.42
Constant	1.911***	3.05
R^2	0.05	
Chi^2	33.7	
p-value	0.000	

Note: * p=0.10; **, p=0.05; ***, p=0.01.
Source: Danish Time Use Survey 2001, own calculations.

Selection

The regressions are based on our sample of households where both spouses are employed and the wage rate is observed. Using this selected sample potentially leads to biased results. I treat selection bias by use of the Heckman selection procedure where labour force participation of husband and wife is modelled through a bivariate probit model. The usual challenge is to find suitable instruments which are not included in the core model for the participation decision. Participation is modelled as a function of the logs of his and her age, education dummies for both, a dummy for home ownership, log family size, log number of young children (0-6 years), log number of cars and log non-labour income, cf. Table A2. The estimation is based on 1512 observations.

Table A2
Bivariate probit for participation in labour market

	Parameter	t-value
Male participation		
Log male age	-0.849*	-1.92
Log female age	-0.284	-0.64
Dummy high school, male	-0.386*	-1.96
Dummy short vocational, male	0.137	1.26
Dummy short further educ., male	0.301	1.29
Dummy medium further educ., male	0.343*	1.93
Dummy long further educ., male	0.051	0.27
Dummy high school, female	-0.146	-0.8
Dummy short vocational, female	0.123	1.11
Dummy short further educ., female	0.530*	1.88
Dummy medium further educ., female	0.178	1.22
Dummy long further educ., female	0.071	0.33
Dummy home owner	0.103	0.91
Log family size	1.006***	3.52
Log (1 + number of young children)	-0.382*	-1.91
Log (1 + number of children 7-17)	0.284	1.37
Log (1 + number of cars)	1.240***	5.84
Log (1 + non-labour income)	-0.399***	-12.93
Constant	2.753***	3.95
Female participation		
Log male age	0.639*	1.67
Log female age	-1.016***	-2.68
Dummy high school, male	0.448**	2.35
Dummy short vocational, male	0.166*	1.75
Dummy short further educ., male	0.166	0.91
Dummy medium further educ., male	0.133	0.93
Dummy long further educ., male	-0.128	-0.80
Dummy high school, female	-0.160	-1.00
Dummy short vocational, female	0.426***	4.51
Dummy short further educ., female	0.792***	3.64
Dummy medium further educ., female	0.702***	5.67
Dummy long further educ., female	0.843***	4.48
Dummy home owner	0.258***	2.60
Log family size	0.017	0.08
Log (1 + number of young children)	-0.143	-0.93
Log (1 + number of children 7-17)	0.355**	2.25
Log (1 + number of cars)	0.836***	4.32
Log (1 + non-labour income)	-0.304***	-14.21
Constant	0.030	0.05

Note: * p=0.10; **, p=0.05; ***, p=0.01.
Source: Danish Time Use Survey 2001, own calculations.

The Likelihood Ratio test shows that the explanatory variables are jointly significant. Based on the parameter estimates, I calculate inverse Mills ratios for each equation. The inverse Mills ratio for male participation is then added as an explanatory variable in the first equation in the core model, and the inverse Mills ratio for female participation is added as an explanatory variable in the second equation in the core model.

Overidentifying restrictions tests

I perform an overidentifying restrictions test in order to test whether the instruments are correlated with the error terms for the estimation models (1)-(3). Under the null hypothesis that the residuals are uncorrelated with the error terms, the value of the objective function of the GMM problem is χ^2-distributed with 14 degrees of freedom (equal to number of instruments minus number of explanatory variables). The value of the objective function in the two different models in section 5.1-5.2 is shown in Table A3. The value of the objective function is 19.31 with a p-value of 0.15 in the most restricted model (model 1) without process benefits. Thus, the null hypothesis that the instruments are uncorrelated with the error terms is accepted. Furthermore, the null hypothesis is accepted for model (2).

Table A3
Values of objective function in estimations

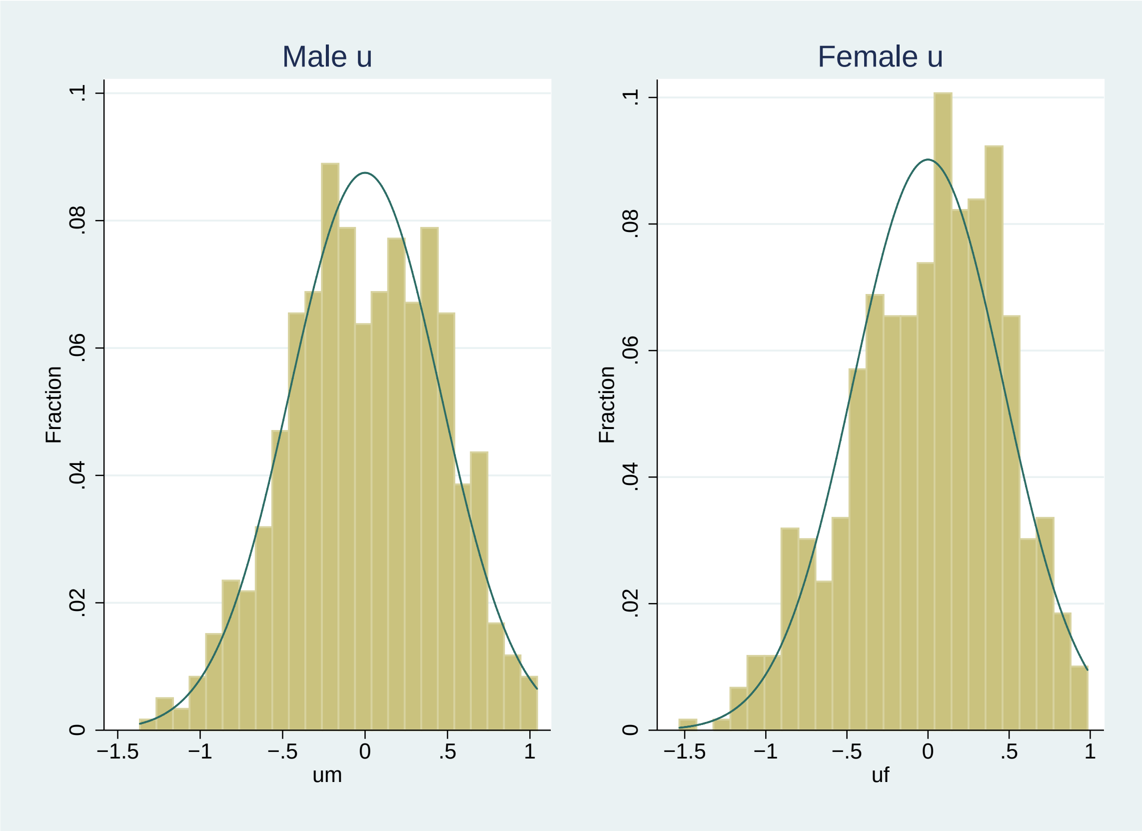
	Objective function	**p-value**
1) No process benefits	19.31	0.15
2) Process benefits	16.44	0.29

Source: Danish Time Use Survey 2001, own calculations.

Normality tests

Figure 4 shows histograms for the residuals from estimation (1). Normality tests (skewness-kurtosis test and Shapiro-Wilkinson test) for the residuals reject the null hypothesis that the error terms are normally distributed. Especially, the test for skewness contributes to the rejection which is also strongly suggested by Figure A1. Rejection of normality rules out the application of maximum likelihood based estimators as e.g. FIML and points to an estimator based on GMM as a consistent and efficient estimator under less restrictive assumptions about the error term.

Figure A1
Histograms for residuals from estimation (1)



Source: Danish Time Use Survey 2001, own illustration.

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