Household Production in the Family – Work or Pleasure?

Mette Gørtz*

Work in progress

Abstract

According to the classical household production model, an individual decides how much time to spend in household production based on the shadow price of his/her time spent in the labour market. This prediction has sometimes been criticized based on the reflection that some housework activities provide extra benefits beyond the consumption value of household production. The extra utility may be in the form of leisure which is (primarily) enjoyed by the person undertaking the activity, so-called "activity benefits". Examples of this include childcare, gardening and do-it-yourself projects. This paper investigates the question of what is work and what is pleasure in household production. We apply a household production model which explicitly incorporates "activity benefits" to model the joint allocation of time for husband and wife. The model is tested on data from a Danish time use survey from 2001 which has information on time spent in household production for both partners in some 600 Danish households. On the empirical side, the paper suggests using a GMM 3SLS estimator instead of the more restrictive Full Information Maximum Likelihood (FIML) estimator which has been used in previous empirical studies. We do not find significant evidence of "activity benefits" for men in household production, but we do find some weak signs of the presence of such extra benefits for women. The paper provides an extensive discussion of the identification issues involved. One important problem is that the benefits identified are not necessarily related to the household production *activity*, but might just as well be due to the fact that households may attach extra value to goods produced by themselves rather than by someone else, i.e. "consumption benefits". We show that the outcome of "activity benefits" and "consumption benefits" may be observationally equivalent.

Keywords: Household production, GMM, FIML

JEL classification: C31, D13, J22

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*) CAM, Department of Economics, University of Copenhagen, and AKF, Institute for Local Government Studies – Denmark. Address for correspondence: AKF, Nyropsgade 37, DK-1602 Copenhagen V, Denmark. E-mail: meg@akf.dk

1 Introduction

According to the classical household production model, an individual decides on how much time to spend in household production based on the shadow price of his/her time spent in the labour market. Thus, household members derive utility from consuming the output of household production. Implicitly, this implies that home produced goods are perfect substitutes for market goods. The output of household production is usually thought of as a public good.

An important consideration when debating what determines individual allocation of time between the market and household production is the idea that some housework activities may provide extra benefits beyond their consumption value.[1] One obvious example is childcare. The time spent caring for one's children contributes to household production, but (usually) parents also derive utility from spending time with their children. Other examples include do-it-yourself spells, gardening etc. which some people may partially consider as leisure activities. The discussion underlines that it is difficult to draw a line between what is housework and what is leisure.

In general, it is widely recognized that people like to work. Beside the pure income/production side, work is perceived as giving pleasure, self esteem and a feeling of identity - in short, utility - to people. For example, in the Swedish HUS study of 1984 and 1993, respondents were asked to state how enjoyable they found various activities on a scale from 0-10, cf. Hallberg and Klevmarken (2003). The answers to these questions indicate that 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.[2] This concept has been named "process benefits" (Juster, 1985) or "joint production" (Graham and Green, 1984, Kerkhofs and Kooreman, 2003). In this paper, we will choose an alternative name, "activity benefits", for the phenomenon. Activity benefits are close substitutes to leisure and are therefore predominantly a private good enjoyed by the person undertaking the activity.

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[1] In this paper, we use the term "housework" for all types of activities that lead to a higher household product, including do-it-yourself work, gardening, child care etc.

[2] An indication of the fact that different types of work differ in popularity for individuals is people's purchases of household services which they are unwilling to do themselves - e.g. cleaning - at an hourly pay which is sometimes higher than their own after-tax hourly wage. Part of the explanation for this phenomenon is differences in productivity between individuals doing housework in their own homes and professionals. However, in low-productivity jobs like cleaning, differences in productivity between professional cleaning assistents and individuals cleaning their own house will hardly explain why people tend to buy cleaning in the market.

A supplementary - or alternative – explanation for why households may choose a higher level of household production than what is suggested by the classical household production model is that households may attach a higher value to goods produced by one of the household members rather than to similar goods bought in the market. In this sense, the value of home produced goods is not comparable across households. Some households may have a higher preference for home-made goods than others, and these preferences may also diverge within the household. For example, the household may attach a higher value to spending leisure time with children whom they have raised themselves. The higher value of home made goods may also be due to the household members possessing skills that are specific to housework in their own house. While the effect of a higher value of home-made goods may be difficult to distinguish empirically from the "activity benefits" above, they are inherently different since this extra utility from home production may be enjoyed by either of the spouses independently on who did the housework. We shall refer to these benefits as "consumption benefits" in the following. We illustrate in the paper that household production outcomes with "activity benefits" and with "consumption benefits" respectively may be observationally equivalent. This raises an important identification issue.

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 "activity benefits". The model is an extension of Gronau's classical model (Gronau, 1977, 1980, 1986). The model is tested empirically on a time use dataset of Danish households in 2001. We estimate our two-equation model using a GMM 3SLS estimator, and we compare the results with the results found using a FIML estimator which was used in Kerkhofs and Kooreman (2003). Given our data, we find that the residuals are not normally distributed and consequently FIML is an inconsistent estimator under the assumption of normality. Provided correct moment conditions and without any assumptions about the functional form for the error terms, GMM 3SLS is consistent and efficient. Thus, the paper contributes by suggesting a less restrictive estimation method than previous analyses in this field.

For the model without "activity benefits" in household production, we find complementarity between housework of husband and wife. We find no significant evidence of activity benefits for men, but we do see a weak sign of the presence of activity benefits for women (p-value=0.12). We also illustrate that the model may be able to establish the *presence* of activity benefits, but the model is not convincing in identifying the actual *size* of these benefits. We discuss the interpretation and the identification issues related to the results, in particular under what circumstances we are able to distinguish "activity benefits" from "consumption benefits" in the results.

2 Theoretical model

In classical economic theory, households maximize utility over a bundle of goods purchased in the market subject to a budget constraint. Becker (1965, 1994) developed this framework by assuming that households combine time and market goods to consume some basic commodities that directly enter their utility functions. For example, consuming a meal is not valued only as the costs of buying food; one has to add the value of the time spent consuming the meal. Likewise, the utility of going to the theatre is not merely the price of the theatre tickets, but also the time spent enjoying the play.

Gronau (1977) developed the classical household production model which is a cornerstone in household production theory. The model provides an essential development of Becker's framework by explicitly accounting for household production. According to Gronau, "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. Often, diminishing marginal productivity is thought to be due to fatigue or changes in input proportions. In Gronau's model, diminishing marginal productivity is also due to the fact that as an individual increases housework, the composition of housework changes as he/she undertakes 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. One point of criticism is 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, it will often be the case that part of the time people spend on housework can partly be considered as leisure. This observation is the background for Graham and Green's (1984) extension of Gronau's model where they introduce so-called "joint production" which they define as housework also partly being leisure. 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) continue the development of a household production model which explicitly deals with the problem of household activities which are partly work, partly leisure activities. Kerkhofs and Kooreman (K&K) 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. K&K look at both single and two-person households.

This paper uses the K&K model as a starting point. The analysis concentrates on households with two adult members. We assume 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. As in the classical Gronau model, it is assumed that market goods and goods produced in the household are perfect substitutes.

$$U = U(X_M + Z, l_m, l_f) \tag{1}$$

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:

$$Z = Z(h_m, h_f, X_Z) \tag{2}$$

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 gives the following budget constraint:

$$X_M + X_Z = y + w_m m_m + w_f m_f \tag{3}$$

It is assumed that both partners participate in the labour force. This assumption ensures that we have observations on individual wages. Evidently, this assumption also entails the risk of selecting households with both spouses having a relatively high productivity in the market and/or low productivity in household production. Thus, individuals with high productivity at home could be *underrepresented* in the sample. On the other hand, 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, suggesting that individuals with high productivity are *overrepresented* in the sample. It is difficult to determine the net direction of the selection bias in advance. We return to the discussion of selection problems in section 5, but note that our results apply for the large group of households where both spouses are in full-time employment.

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

$$h_i + l_i + m_i = T, \quad i = m, f \tag{4}$$

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

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

where $?_m$ and $?_f$ 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 $?_m$=$?_f$ =0), then we will find an interior solution, and (5) simplifies into:

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

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. The conditions in (6) are referred to as the so-called dichotomy in Kerkhofs and Kooreman (2003). For the dichotomy property to hold, it is important that the net marginal wage rate is exogenous. Moreover, the model does not take labour supply decisions into account. Thus, the model takes the non-random sub-sample of two-earner households as given. We would need to specify a utility function if we were to develop a full structural model including an endogenous labour supply choice.

The interpretation of (6) is that an individual will choose a level of housework where her marginal product of time equals her 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 where the "activity benefits", i.e. the utility in the form of leisure value to the person performing the activity, are zero.

In the following, we include the possibility of "activity benefits" in the model. Thus, we 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. For example, garden work provides utility through two channels: First, it enhances the household product, Z, which can be enjoyed by both partners in the household. Secondly, it may be seen as a sort of leisure activity for the person who works in the garden. This feature is included in the model in the following way: If a person spends h_i hours on home production, he or she considers a certain part of this time, $g_i(h_i)$, as a perfect substitute for leisure. The activity benefit function g_i is increasing, twice differentiable and concave in h_i, $g_i'=1$ and g_i'? 0 as h_i? T, meaning that the marginal utility of housework is decreasing in h (see figure 1).

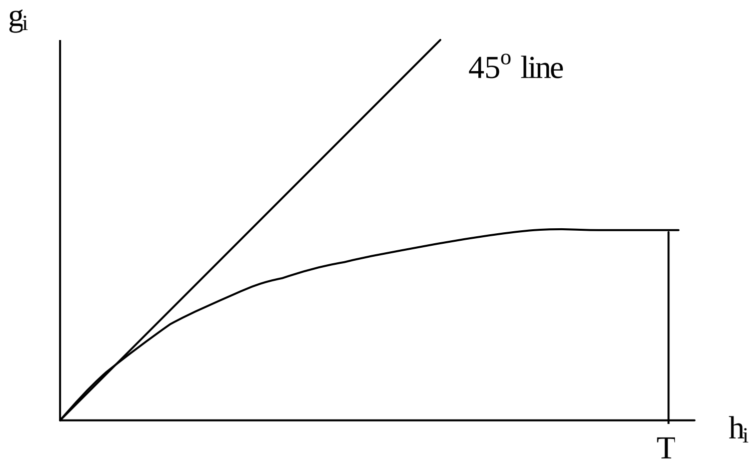

Figure 1: Activity benefit function for individual i

Introducing activity benefits, we get the following extended utility function for the household:

$$U = U(X_M + Z, l_m + g_m(h_m), l_f + g_f(h_f)) \qquad (7)$$

In this setting, the dichotomy property still holds. The partial optimization problem for household production changes into:

$$\max_{0\leq h_m, h_f \leq T;\ X_Z \geq 0} Z(h_m, h_f, X_Z) + w_m g_m(h_m) + w_f g_f(h_f) - w_m h_m - w_f h_f - X_Z \qquad (8)$$

And the first-order conditions are then:

$$\begin{aligned} \partial Z / \partial X_Z &= 1 \\ \partial Z / \partial h_m &= w_m(1 - g_m'(h_m)) \\ \partial Z / \partial h_f &= w_f(1 - g_f'(h_f)) \end{aligned} \qquad (9)$$

Compared to the predictions in (6), we see that with the inclusion of activity benefits, the individual members of the household will choose a housework level where the marginal product of their housework equals their wage rate corrected for the part of individual housework activity which is perceived as leisure. By taking account of activity benefits, we achieve an explanation of why the chosen level of individual housework is sometimes higher than what the traditional labour supply model would predict. This is illustrated in figure 2 below. Individual i's hourly wage rate is w_i. 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 will choose to increase her work in household production until the point, h_i^*, where her marginal product in household production is equal to her wage rate, $\partial Z / \partial h_i = w_i$. 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 we observe that she works h_i^{**} hours in the household, where $h_i^{**} > h_i^{*}$, we may interpret the difference between h_i^{**} and h_i^{*} as a consequence of her deriving utility in the form of leisure from performing the housework. We may therefore identify the extent of this extra utility – activity benefits – from observations on her wage and her household production.

If Z is strictly concave, we still have a unique solution (a local maximum). 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. Thus, (7) allows for increasing returns to scale in household production provided the curvature of the g-function is sufficiently high. To formulate this more intuitively, we can find a solution to the optimization problem with increasing returns to scale if the dis-utility of performing housework rises fast enough when h_i increases to ensure that the combined utility of consuming and performing household production for each individual has a local optimum.

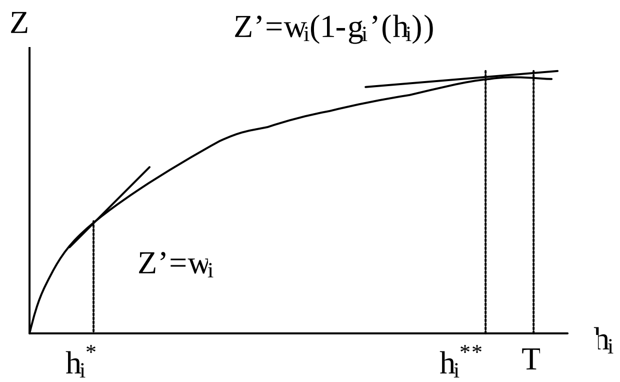

Figure 2: Household production as a function of input of time, h_i

Identification

Usually, we observe neither the *output* of home production, Z, nor the input of auxiliary goods, X_Z. 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 identification questions.

An important identification problem which has not been given much attention in the 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 household production than what the classical household production model predicts does not necessarily have to be ascribed to "activity benefits". An alternative explanation may be that households attach a higher value to goods produced by one of the household members rather than similar goods bought in the market, and that the value the household puts on home-made goods is higher than the price they would get for them in the market. This higher value of household production may be due to several factors. Household members may have a higher preference for home-made goods. Or household members may possess household-specific skills which are important in the production of goods that they consume themselves; see Chiswick (1982) for a discussion of the value of a housewife's time. In this sense, the value of home produced goods is not comparable across households. For example, both spouses in the household may attach a higher value to spending leisure time with children for whom one or both of them have cared themselves. These benefits are inherently different from the "activity benefits" described above since they may be enjoyed by either of the spouses irrespective of who did the housework. We name them "consumption benefits". Thus, while the "activity 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 3 illustrates that household production with "activity benefits" and with "consumption benefits" respectively may be observationally equivalent. Assume we can observe the true value the household puts on their own household production, Z_{obs}. According to Gronau's classical household production model, we expect person i to work h_i* hours in the household. But we observe that she works h_i**. As we argued above, the higher input of housework may be due to "activity benefits", i.e. the 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, we can not observe the value of household production, but the household can. Suppose we think that the value of household production is Z_{obs} and again, we expect hi* where $\frac{\partial Z_{obs}}{\partial h_i} = w_i$. However, the household attaches an additional value to consuming home-made products, i.e. "consumption benefits", so $Z=Z_{hh}$. Suppose individual i does not particularly enjoy working in the house, so there are no activity benefits. She therefore chooses her optimal housework where $\frac{\partial Z_{hh}}{\partial h_i} = w_i$. In our example, this corresponds to an optimal housework of h_i**. We therefore see that the two cases with "activity benefits" and "consumption benefits", respectively, may be observationally equivalent. This raises an important identification issue which we shall return to in the empirical part of the paper.

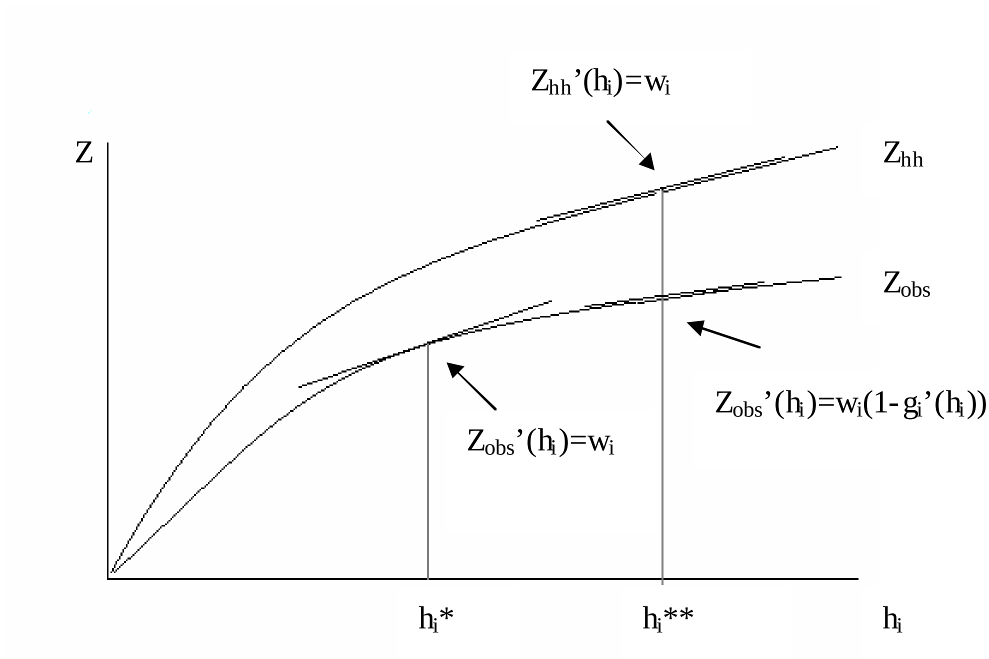

Figure 3: Identification in household production model

A number of additional identification issues may arise. These have already been thoroughly discussed in Kerkhofs and Kooreman (2003), and we shall only refer the main points from this discussion. First, we only observe allocations which are optimal for input vectors (w_m,w_f,y). Non-labour income, y, influences labour supply, but since we only observe households where both spouses have a paid job, we assume that we can identify unique optimal allocations (h_m^*,h_f^*,X_Z^*) based on observations of (w_m,w_f).

Secondly, since X_Z is not observed, we have to formulate our first-order conditions in terms of the *net* product value function, $\widetilde{Z}(h_m, h_f)$, where:

$$\widetilde{Z}(h_m, h_f) \equiv \max_{X_Z \geq 0} Z(h_m, h_f, X_Z) - X_Z \qquad (10)$$

Values of X_Z that could be in agreement with a maximization of the net product $\widetilde{Z}(h_m, h_f)$ would also have to satisfy the first of the first-order conditions in (9). It is assumed that (10) has a unique finite, non-zero solution for all pairs of (h_m,h_f). It is therefore also assumed that $\partial Z / \partial X_Z$ is continuously differentiable. A sufficient condition is that the marginal product of auxiliary goods is a strictly decreasing function of X_Z, is greater than one for $X_Z=0$, and eventually falls below one when X_Z is increased for all (h_m,h_f).

Another question is whether we can find different functional forms of the housework activity benefit specification with observationally equivalent outcomes in terms of housework, wages etc. Kerkhofs and Kooreman (2003) provide evidence that in general, the *presence* of activity benefits is identified. Moreover, if the activity benefit functions are restricted to some parametric function as e.g. the functional form chosen in section 4, it is generally also possible to establish the *magnitude* of the activity benefits for couples. K&K point out that in general, the model has limited power for identification of activity benefits in single earner households. In the following, we restrict the analysis to couples.

3 Data

The data 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. We have detailed information about time use of both spouses for a good 1700 couples. 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. The questionnaire also contained questions about personal and household characteristics. This background information is combined with information from register (administrative) information from Denmarks Statistics 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 normally spend on housework and in the labour market in a typical week. Housework time includes normal housework such as cleaning, laundry, shopping, cooking etc. and gardening, repairs, other do-it-yourself work and child care. As always the classification of child care as housework is difficult, as discussed above. Since respondents were only asked one question on usual housework, we cannot break out child care separately.

In general, it is observed that surveys asking about 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). We have chosen to use normal time use rather than the diary information to avoid the very serious infrequency problems in the latter.

Table 1 shows the time spent in household production for couples, broken down by the work status of the two partners. We define full-time market work to be at least 30 hours per week, including commuting time. Thus a respondent may be unemployed in the survey week and still report more than 30 hours per week of market work. Part-time work is not very prevalent in Denmark so that “not full-time” generally means “out of the labour force” (particularly for men). The “neither full-time” group is mostly made up of older, presumably retired, couples. Table 1 shows familiar patterns with men doing less housework than women who have the same work status. One should also note that there is a wide within category dispersion in household production, as shown by the standard deviations.

	Male household production, minutes/day			Female household production, minutes/day		
	Mean	Std.	Median	Mean	Std.	Median
Both (#=804)	93.2	65.1	85.7	134.0	74.8	128.6
Female (#=112)	118.5	80.9	85.7	111.9	65.8	90.0
Male (#=342)	80.6	58.6	68.6	155.7	100.8	128.6
Neither (#=343)	109.8	92.6	85.7	161.7	100.6	128.6

Table 1: Household production and labour market status (full-time or not)

In the following, we focus on the sample of households in which *both* husband and wife work full-time in the labour market. The load of housework (including child care) for full-time couples naturally depends on the number and ages of children within the household. Table 2 presents time use broken down by child status for the full-time households. We see that the load of housework increases with the number of children, also when we condition on both partners being in full-time work.

	Male household production, minutes/day			Female household production, minutes/day		
	Mean	Std.	Median	Mean	Std.	Median
No children (#=349)	80.5	54.9	68.6	116.6	65.1	102.9
1 child (#=180)	90.8	63.6	85.7	128.0	63.4	120.0
2 children (#=207)	104.8	64.5	85.7	150.7	68.6	128.6
3+ (#=68)	129.7	94.3	111.4	187.6	120.1	171.4

Table 2: Household production and number of children

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 labour. In the data, we only have information on the gross wage rate. To arrive at a very crude estimate of net wages, we performed a simple imputation of individual marginal tax rates.[3] In our estimation of the model, we present results with both the imputed net wage and the gross wage rate.

Figure 4 shows the distribution of housework and wages for men and women. Out of the sample of full-time employed people, we have information on wage rates for both husband and wife for 629 couples. This is the dataset used in the econometric estimations below. For both men and women, the correlation between housework (in hours per day) and wages (in kroner per hour) is small and negative. For men, the OLS-estimate from regressing housework on net wage is -0.0014 (t-value is -0.73) which is not significant. For women, the OLS-estimate is -0.012 (t-value is -3.35), which implies that for two randomly selected women with a difference in hourly wage of 10 kroner, the woman with the highest wage rate will work approximately 7 minutes less in the house per day. This is without controlling for any individual or household characteristics.

[3] The imputation of the marginal tax rate was based on the gross wage for a person who works full-time for the whole year. Details are given in the Appendix. We also tried to calculate individual specific marginal tax rates based on register information about total gross income, but unfortunately our net wage rate estimates based on these imputed marginal tax rates seem to be very noisy and the relationship between gross and net wages seems somewhat difficult to explain.

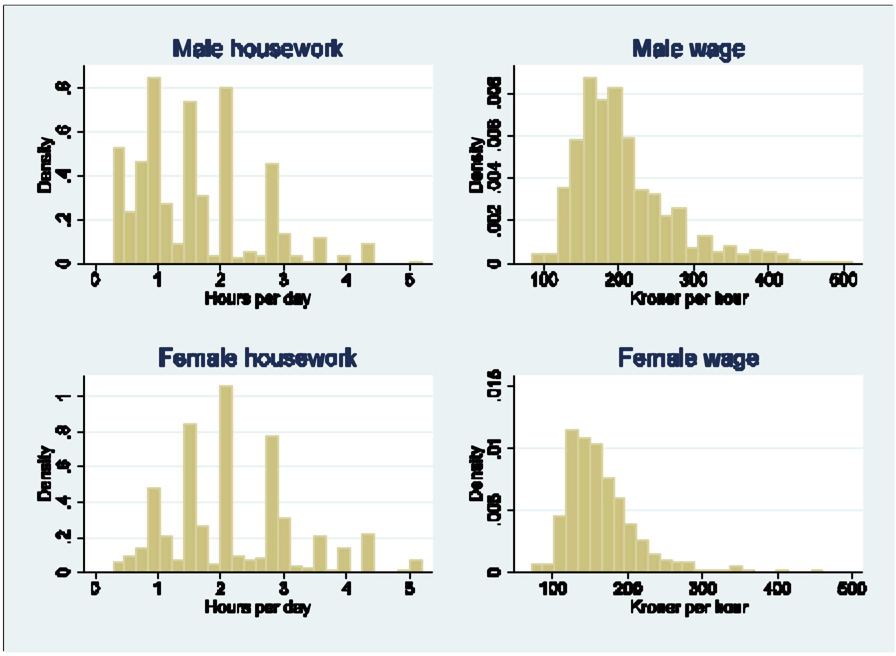

Figure 4: Housework and wages for men and women

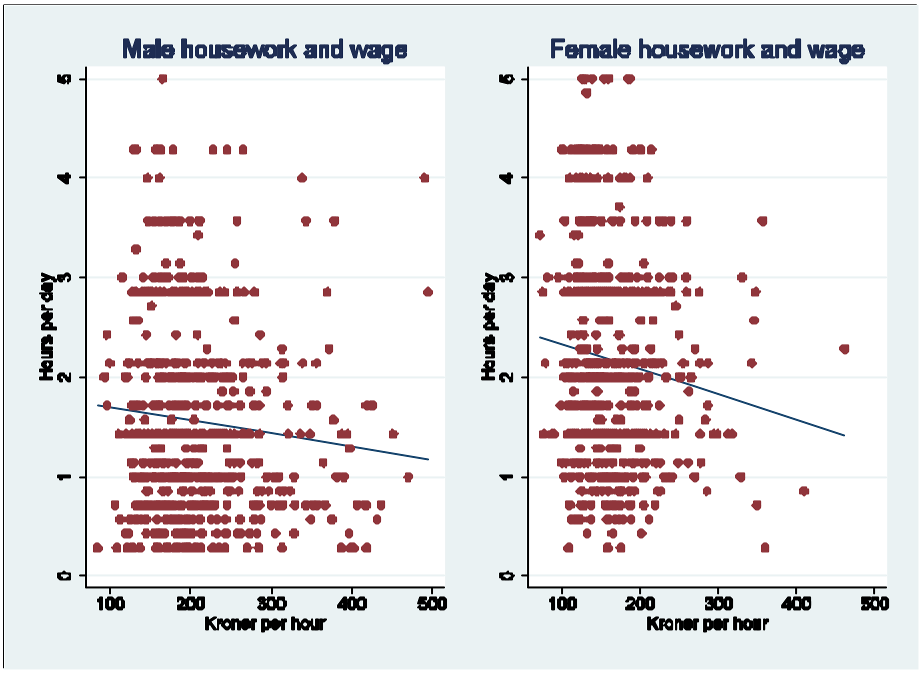

Figure 5: Housework and wages for men and women

Both household production and wage rates show a strong positive correlation for the two spouses in figure 6. This is probably partly due to positive assortative mating, i.e. the well-established observation that people seem to find a partner that looks very much like themselves in terms of observable characteristics as background, age, education, wage rates etc. See Becker (1991) or Weiss (1997) for a discussion. The positive correlation in household production is also very likely to be due to the presence of children in the household (which is obviously strongly correlated between the partners).

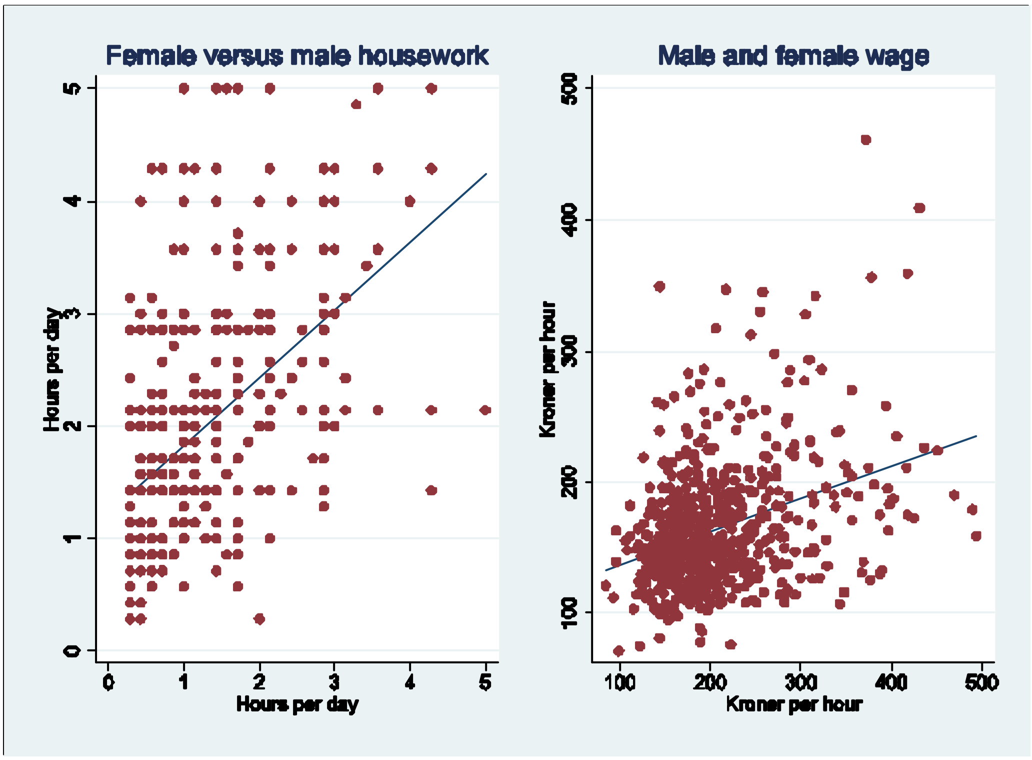

Figure 6: Intra-household correlation in household production and wages

Despite the strong correlation of housework within the family, we still find that women do the majority of the household production, see figure 7. 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.

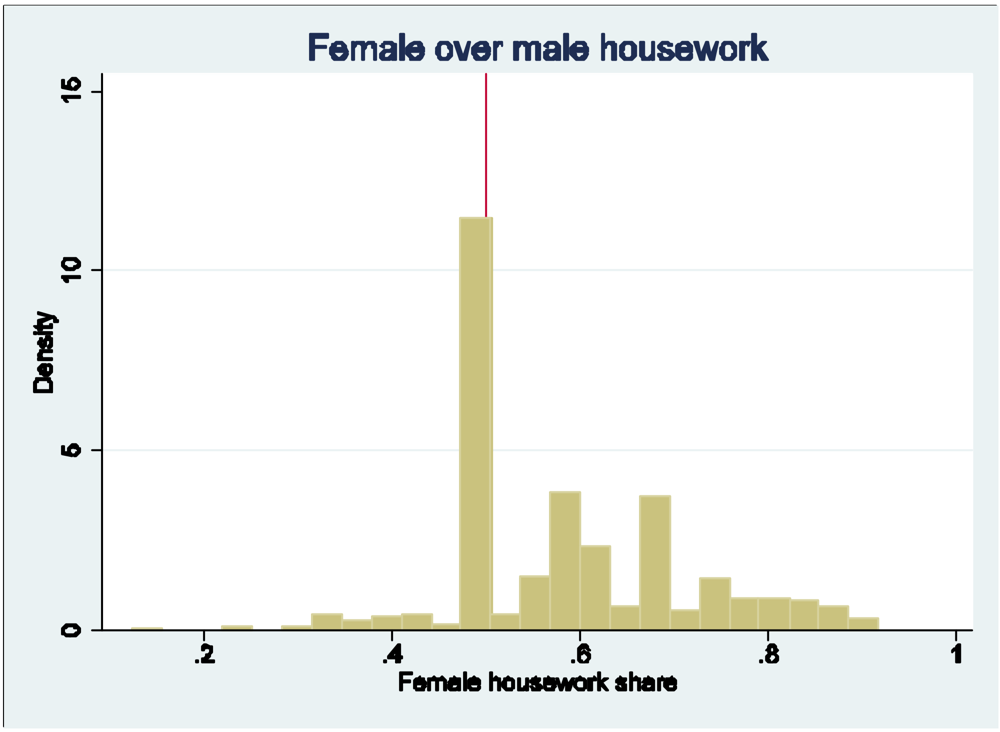

Figure 7: Female share of household production within the family

4 Econometric specification

In the following, we empirically investigate the theoretical first-order conditions (6) and (8). In the theoretical model, we assumed that 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 we have no information on auxiliary goods used in the production of household production, X_Z, we analyse the net product value function, $\tilde{Z}$, below instead of the (gross) production function found above:

$$\tilde{Z} = b_m h_m + b_f h_f + ½ c_{mm} h_m^2 + ½ c_{ff} h_f^2 + c_{mf} h_m h_f \qquad (11)$$

b_m and b_f are strictly positive. The C-matrix, $C = \begin{pmatrix} c_{mm} & c_{mf} \\ c_{mf} & c_{ff} \end{pmatrix}$, has to 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. As mentioned above, we concentrate on households where both spouses are employed. First-order conditions (for employed people) when activity benefits are *not* accounted for are:

$$\begin{aligned} \partial\tilde{Z}/\partial h_m &= b_m + c_{mm}h_m + c_{mf}h_f = w_m \\ \partial\tilde{Z}/\partial h_f &= b_f + c_{ff}h_f + c_{mf}h_m = w_f \end{aligned} \tag{12}$$

And first-order conditions when we *do* take activity benefits into account are:

$$\begin{aligned} \partial\tilde{Z}/\partial h_m &= b_m + c_{mm}h_m + c_{mf}h_f = (1 - g_m'(h_m))w_m \\ \partial\tilde{Z}/\partial h_f &= b_f + c_{ff}h_f + c_{mf}h_m = (1 - g_f'(h_f))w_f \end{aligned} \tag{13}$$

Furthermore, we assume that individuals are heterogeneous in their marginal productivity of housework. Thus, we let b_m and b_f depend on household and individual specific characteristics captured in x_m and x_f, respectively:

$$\begin{aligned} \ln(b_m) &= x_m' b_m + u_m \\ \ln(b_f) &= x_f' b_f + u_f \end{aligned} \tag{14}$$

Therefore, 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. Parallel for a married woman. 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.

For the model *without* activity benefits, the system of equations expressed in errors is:

$$\begin{aligned} u_m &= b_m - x_m' b_m = \ln(w_m - c_{mm}h_m - c_{mf}h_f) - x_m' b_m \\ u_f &= b_f - x_f' b_f = \ln(w_f - c_{mf}h_m - c_{ff}h_f) - x_f' b_f \end{aligned} \tag{15}$$

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

$$g_i(h_i) = h_i\left(1 - \frac{1}{1+d_i}\left(\frac{h_i}{T}\right)^{d_i}\right), \qquad i = m, f \tag{16}$$

Where $d_m, d_f \geq 0$. If $d_m = d_f = 0$, we are in the classical household production framework. As $d_m, d_f \to \infty$, all household production time is perceived as leisure. After differentiating g_i with respect to h_i, we arrive at a system of equations with activity benefits:

$$\begin{aligned} u_m &= \ln(b_m) - x_m' b_m = \ln((h_m/T)^{d_m} w_m - c_{mm}h_m - c_{mf}h_f) - x_m' b_m \\ u_f &= \ln(b_f) - x_f' b_f = \ln((h_f/T)^{d_f} w_f - c_{mf}h_m - c_{ff}h_f) - x_f' b_f \end{aligned} \tag{17}$$

5 Estimation and results

5.1 Classical household production model - no activity benefits

In this section, we concentrate on the classical household production model in (15). That is, we assume $d_m = d_f = 0$. Kerkhofs and Kooreman (2003) estimated this system by maximum likelihood, which is the efficient estimator if the error terms are joint normally distributed:

$$\begin{pmatrix} u_m \\ u_f \end{pmatrix} | \, x_m, x_f \sim N(0, \Sigma_{uu}) \qquad (18)$$

We follow the specification of the non-linear likelihood function for a linear system of equations in a Full Information Maximum Likelihood model as can be found in Davidson and MacKinnon (1993, chapter 18). See appendix A2.

Normality of the error terms is often a strong assumption. Alternatively, we can apply the General Method of Moments (GMM) for systems, i.e. the GMM 3SLS estimator. The advantage of GMM 3SLS is that we obtain consistent estimates under much weaker assumptions, since we do not have to assume anything about the functional form of the distribution of the error terms. We use the efficient GMM estimator for a system of equations formulated in Wooldridge (2001, chapter 14). See appendix A3.

In estimating the system in (15), we use our imputed measures of net wages for the wage rates as net wages are the most correct measure for the shadow price of time. Results with the gross wages are shown in appendix 4. The individual and household characteristics captured in the X-matrices consist of individual age, individual education in years, dummies for homeownership, the presence of younger and older children and non-labour income. We can think of (15) as h_f being endogenous in the first equation and h_m being endogenous in the second equation. As instruments for female household production, h_f, we use her gross wage, her gross wage squared, her age, her age squared, and her education (measured through five education dummies). Thus, we assume that the error term in equation 1 is uncorrelated with these instruments. As instruments for male household production, h_m, in the second equation we use his gross wage, his gross wage squared, his age, his age squared and his education (measured through five education dummies). Our moment conditions are therefore constructed under the assumption that the error terms in equation 2 are uncorrelated with the instruments. The reason for using gross wages as instruments (rather than net wages as above) is that they have higher explanatory power of h_m and h_f and thus serve as stronger instruments. Both sets of instruments are jointly significant in explaining the variation in household production, although their explanatory power as measured by R^2 is low (see appendix A3). On the other hand, these instruments make us accept the null hypothesis of the overidentifying restrictions test that the instruments are uncorrelated with the error terms. More details about choice of instruments are given in appendix A3. The estimations results for GMM 3SLS and FIML are shown in table 3 below.

	GMM 3SLS	t-value	FIML	t-value
c_{mm}	-272.116	-2.15	-643.542	-1.52
c_{ff}	-88.629	-3.53	-1597.810	-1.75
c_{mf}	14.143	0.76	-422.431	-0.95
Male equation				
Constant	5.322	8.78	7.159	7.99
Age	0.002	0.93	0.002	1.16
Education, years	0.158	1.25	0.025	0.49
Homeownership	0.120	1.91	0.166	3.26
Dummy young children	0.218	3.92	0.200	4.54
Dummy children 7-17	0.079	1.70	0.127	3.13
Non labour income	0.004	0.32	0.020	1.72
Female equation				
Constant	5.670	17.10	8.340	15.66
Age	0.004	2.19	0.002	1.36
Education, years	-0.209	-2.41	-0.153	-1.68
Homeownership	0.115	2.87	0.180	3.60
Dummy young children	0.161	4.29	0.203	4.60
Dummy children 7-17	0.109	3.72	0.145	3.67
Non labour income	0.022	2.75	0.028	2.55

Table 3: Estimation results for GMM 3SLS and FIML

Apart from the elements in the C-matrix, the two sets of estimates show similar characteristics. The signs and sizes of the coefficients estimated are of the same order of magnitude. Based on the residuals from the FIML estimation, we reject individual normality of the error terms (and therefore also joint normality).[4] Therefore FIML is inconsistent.[5] GMM 3SLS is consistent if the moment conditions apply. Moreover, in our case without normally distributed error terms, GMM 3SLS is efficient among

[4] Details on normality tests and histograms for the residuals from the FIML estimation can be found in appendix A.2.

[5] For normally distributed disturbances, GMM 3SLS has the same asymptotic distribution as the FIML estimator, which is in this case asymptotically efficient among all estimators, cf. Greene (2003, chapter 15). Moreover, Hausman (1975, 1983) shows that the FIML estimator is also an IV estimator.

estimators which rely only on moment conditions. In the rest of this paper, we apply GMM 3SLS when estimating the household production model.

The estimates of c_{mm} and c_{ff} are negative, as assumed, and significant. We find a positive (though insignificant) estimate of c_{mf} which is an indication of complementarity between housework of husband and wife. In this respect, our results deviate from Kerkhofs and Kooreman (2003) who found that male and female home-production are q-substitutes. The C-matrix is negative definite (the eigenvalues of the C-matrix are negative) which is in agreement with a well-behaved production function in the classical household production model.

5.2 Activity benefits – allowing for the pleasure of housework

In the previous section, it was assumed that there are no "activity benefits" in household production, i.e. that the activity benefit parameters, $d_m = d_f = 0$. In this section, we look at the consequences of allowing for activity benefits. We performed a grid search within a range of "reasonable" activity benefit parameters (d_m and d_f between 0 and 1.5). The GMM problem was difficult to solve for high values of d_f where b_f became negative for low observations of h_f or h_m. In order to obtain estimates in the grid search, we took out observations where h_f or h_m were less than 20 minutes per day. We therefore performed the activity benefit estimations with a subset of 596 observations as compared to the original dataset used above of 629 observations. The objective function for the GMM problem was consistently minimized in the region where $d_m < d_f$, and we found an optimum for $\hat{d}_m = 0.7$ and $\hat{d}_f = 1.3$. We tested the joint significance of the estimates by using the GMM distance statistic, cf. Wooldridge (2001, chapter 8), which is c^2 distributed with 2 degrees of freedom under the null hypothesis $d_m = d_f = 0$. We found that we cannot reject the null hypothesis that both parameters are equal to 0 at a p-value of 0.10. However, for d_m restricted to 0, we found an optimal value of $\hat{d}_f = 0.8$ with a p-value of 0.12. We use this result to conclude that there is some evidence of the *presence* of activity benefits for women, although the *size* of activity benefits is poorly estimated since values for d_f within the range of 0.4 and upwards produce almost the same value of the objective function. See details of the tests in Appendix 5.

Inserting the parameter estimate of $\hat{d}_f = 0.8$ into the g-function formulated in (14) and using the observation that the time spent in housework is around 10 percent of the total time for women, we find that on average the fraction of housework that is also perceived as leisure is close to 90 percent. If we instead enter $\hat{d}_f = 0.4$, we find that on average around ¾ of women's housework time is a substitute for leisure. This seems like an unlikely high leisure value of household production.

The result of the estimation with the value of $\hat{d}_f = 0.8$ found by grid search is shown in the appendix table A3. The estimate of c_{ff} is negative but, as we discussed above, increasing returns to scale (positive c_{ff}) is not necessarily a problem in the extended household production model that allows for activity benefits. What matters for the optimization is that the 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, see appendix 6.

To conclude on the above, there is some evidence of activity benefits for women in our sample of full-time employed couples, but the estimates are imprecise and insignificant even at a 10 percent level. A natural question to ask is whether it is more likely to find activity benefits in households where a larger part of household production could be perceived as partly leisure. This could be the case for families with children where a relative high proportion of time use is child care. Out of the 629 full-time couples used in this analysis, 370 families had children below 17 years. Since this is a rather small sample, we will not present the results for the families with children dataset.

5.3 Interpretation of results

In order to interpret the parameter estimates in table 3, we reformulate the model in reduced form:

$$\begin{aligned} h_m &= \frac{1}{c_{mm}} w_m - \frac{c_{mf}}{c_{mm}} h_f - \frac{1}{c_{mm}} \exp(x_m' b_m + u_m) \\ h_f &= \frac{1}{c_{ff}} w_f - \frac{c_{mf}}{c_{ff}} h_m - \frac{1}{c_{ff}} \exp(x_f' b_f + u_f) \end{aligned} \tag{19}$$

An increase in female housework by one hour will increase male housework by $-\frac{\hat{c}_{mf}}{\hat{c}_{mm}} = -\frac{14.143}{(-272.116)} = 0.05$ hours. And an increase in male housework by one hour will increase female housework by $-\frac{\hat{c}_{mf}}{\hat{c}_{ff}} = -\frac{14.143}{(-88.629)} = 0.16$ hours. A male wage increase of 10 DKr per hour decreases his daily time in household production with $\frac{1}{\hat{c}_{mm}} * 10 = -\frac{1}{272.116} * 10 = 0.037$ hours or around 2 minutes per day, while a similar wage increase for the wife decreases her daily time doing housework with

$\frac{1}{\hat{c}_{ff}}*10 = -\frac{1}{88.629}*10 = 0.11$ hours or 7 minutes per day. Thus, women's time in housework is more sensitive to wage changes which is reasonable since women's average housework is higher than men's and therefore corresponds to a flatter segment on the household production curve. Having children affects both male and female household production positively. Homeownership also has a positive effect, and age is positively correlated with housework. Education has opposite effects on male and female housework. While education increases his housework (althought the effect is not significant), more educated women tend to do less housework. This apparent paradox probably also is a sign of positive assortative mating in education. Thus, women with a higher education marry men with a higher education. This also suggests that his and her housework are substitutes on the margin.

5.4 Discussion

The analysis above investigates "activity benefits" in household production. It is argued that one can not compare one hour worked at home with one hour worked in the market without taking into account the activity benefits of performing household production. It is hereby implicitly assumed that there are no activity benefits connected to performing market work. However, this is not necessarily the case. As argued in the introduction, Hallberg and Klevmarken (2003) analyzed the Swedish HUS study of 1984 and 1993 and found that 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, we may interpret the estimates as a measure of the *relative* activity benefits from carrying out household production compared to working in the market.

In figure 3, we illustrated how a household production model with "activity benefits" or with "consumption benefits" may be observationally equivalent. We will therefore try to interpret our results in a "consumption benefit" framework. Suppose the value of household production is Z_{hh} for the household, j, producing it. If Z_{hh} is higher for household j than another household would attach to the production by household j, then X_M and Z_{hh} cannot be perfect substitutes. We assume that we can observe the value other households put on household production by household j, Z_{obs}. We may formulate the relationship between Z_{obs} and the "true" value of household production for household j, Z_{hh}, as a form of multiplicative "premium" for home-made products. Since we cannot observe X_Z, we concentrate on net household production, $\tilde{Z}$:

$$\tilde{Z}_{hh} = k*\tilde{Z}_{obs}, \quad \text{where } \tilde{Z}_{obs} = \tilde{Z}(h_m, h_f) \qquad (20)$$

In optimum, we find that:

$$\frac{\partial \widetilde{Z}_{hh}}{\partial h_i} = k * \frac{\partial \widetilde{Z}_{obs}}{\partial h_i} = w_i \Rightarrow$$
$$\frac{\partial \widetilde{Z}_{obs}}{\partial h_i} = \frac{1}{k} * w_i \qquad (21)$$

Comparing this with (9) where $\frac{\partial \widetilde{Z}_{obs}}{\partial h_i} = (1 - g_i\,'(h_i)) * w_i$, we find that:

$$\frac{1}{k} = (1 - g_i\,'(h_i)) \qquad (22)$$

With our empirical specification of the model, (22) is equivalent to:

$$\frac{1}{k} = \left(\frac{h_i}{T}\right)^{d_i} \Leftrightarrow k = \left(\frac{T}{h_i}\right)^{d_i} \qquad (23)$$

In this simple parameterization where both spouses attach the same premium, k, to household production, (23) implies that if $d_m = 0$ then $d_f = 0$. This is not the case in our empirical estimations. From (23) we also note that $\frac{d_f}{d_m} = \frac{\ln(T/h_m)}{\ln(T/h_f)}$ in the case where the extra benefits are in the form of "consumption benefits".

To illustrate, suppose we have $\hat{d}_f = 0.4$ which is not too far from the empirical results above, and we use the observation that around 10 percent of women's time is devoted to housework. Then $\hat{k} \approx (1/0.1)^{0.4} \approx 2.5$, implying that the value for the household of household production is 2.5 times larger than what we would expect based on observed household production, if we assume that there are no "activity benefits". Above, we noted that d_i is estimated with a high standard error. If we instead assumed $\hat{d}_i = 0.1$, we would find $\hat{k} \approx (1/0.1)^{0.1} \approx 1.25$.

The above discussion does not allow us to determine whether there are "activity benefits" or "consumption benefits" in play but is primarily intended to illustrate the identification problems. A more comprehensive modelling would include the possibility of the two partners having different preferences for household production. This would probably accommodate our empirical finding that $\hat{d}_m \neq \hat{d}_f$.

A further 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). We postpone this challenge for future analysis.

Our selection 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*, we might experience an *under-representation* of more home-productive individuals in the sample, since these individuals are relatively more likely not to have a paid job. *On the other hand*, it might be that the personal characteristics which determine productivity in the market and thus enhance the chances of being employed also lead to a relatively high productivity at home. Thus, we might see an *over-representation* of people who are productive at home in the sample. Gronau and Hamermesh (2001) show that there is a positive correlation between the level of education and demand for variety in time-use activities. They interpret this result as evidence that people with higher levels of education have a higher productivity, not only in market work, but also in housework. The net direction of the selection bias is difficult to predict.

Although the possible selection bias is potentially important, we postpone the treatment of this matter for future analysis. Selection is only a problem if we generalize our results beyond the group of full-time employed. The results found above still apply for the full-time employed. We note that the labour force participation rate is very high for both women and men in Denmark, and the incidence of part-time employment is low.

6 Conclusion

In this paper, we build on the classical household production model developed by Gronau (1977, 1980, 1986) with an extension allowing for "activity benefits" ("process benefits" due to Juster, 1985, or "joint production" due to Kerkhofs and Kooreman, 2003). We estimate the parameters of the model empirically on Danish time use data with interpretable results.

First, we estimate the model without "activity benefits", i.e. without allowing for the possibility that some of the activities which we characterize as household production also provide benefits per se for the person performing the activity. For this formulation of the model, we find that housework by husband and wife show the expected diminishing returns to scale and that his and her time in housework are complements. In this respect, our results differ from a previous study by Kerkhofs and Kooreman (2003) who found that housework by husband and wife are q-substitutes.

Secondly, we estimate the household production model with activity benefits. We find some evidence of the *presence* of activity benefits in household production for women, but the effect is not significant on a 10 percent level (p-value is 0.12). Furthermore, we find that the *size* of the extra benefit is measured with a large imprecision. The results are in line with previous analyses by Graham and Green (1984) and Kerkhofs and Kooreman (2003).

In the paper, we discuss alternative interpretations and identification issues related to our results. We note that the model only deals with activity benefits in household production, while possible intra-household differences in the taste for market work are ignored. Moreover, we argue that 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. We call these "consumption benefits" to be able to distinguish them from "activity benefits". We illustrate that these two types of benefits can be observationally equivalent. However, the benefits are inherently different in the sense that "activity benefits" (in the form of leisure) are private goods, while "consumption benefits" is a public good which directly enhances the utility of the two spouses, irrespective of who carried out the housework.

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. We leave this question for future research.

Appendices

A.1 Data

Table A1 contains summary statistics for the selection of 629 households where both spouses work in the labour market and where the wage rate is observed in the data.

Variable	Mean	Std.	Min	Max
Male characteristics				
Housework, hours per day	1.56	0.93	0.29	5.00
Wage, DKr per hour	210.81	78.06	84.00	649.00
Age	42.57	9.76	22.00	66.00
Education in years	13.10	2.52	10.00	18.00
Female characteristics				
Housework, hours per day	2.16	1.01	0.29	5.00
Wage, DKr per hour	164.24	47.79	71.00	461.00
Age	40.58	9.58	20.00	61.00
Education in years	13.34	2.56	10.00	18.00
Household characteristics				
Homeownership	0.85	0.36	0.00	1.00
Dummy young children (0-6)	0.29	0.45	0.00	1.00
Dummy children 7-17	0.39	0.49	0.00	1.00
Non labour income, 1000 DKr	23.41	63.87	0.00	1003.14
Number of observations	629			

Table A1: Summary statistics

Construction of net wages

Net wages are constructed on the basis of gross wage rates for a full-time person who works 1500 hours per year. Based on rules on marginal tax rates and labour market contributions for 2001, we assume that a person with an imputed total gross wage income below 178,000 DKr (US$ 28,000) pays around 50 percent in marginal tax, for total gross wage incomes between 178,000 DKr and 277,000 (US$ 45,000), the marginal tax rate is 55 percent, and for gross wage incomes beyond 277,000 DKr, the marginal tax rate is 68 percent.

A.2 Full Information Maximum likelihood (FIML)

Likelihood functions in FIML

The likelihood function for the non-linear FIML estimator is, according to Davidson and MacKinnon (1993) (formula 18.85):

$$
\begin{aligned}
& l(q,\Sigma) = \sum_{i=1}^{n} l_i(q,\Sigma) = \\
& -\frac{ng}{2}\log(2p) + \sum_{i=1}^{n}\log\left|\det J_i\right| - \frac{n}{2}\log\left|\Sigma\right| - \frac{1}{2}\sum_{i=1}^{n} h_i(Y_i, X_i, q)\Sigma^{-1}h_i(Y_i, X_i, q)' \\
& \textit{where} \qquad (24) \\
& h_i(Y_i, X_i, q) = U_i, \qquad \mathrm{U_i} \sim \mathrm{NID}(0,\Sigma) \\
& \mathrm{J_i} \equiv \partial h_i(q)/\partial Y_i
\end{aligned}
$$

Thus, central assumptions behind FIML are that the error terms follow a normal distribution, and are homoskedastic (and serially independent). Y_i is 1xg, Γ is gxg, X_i is 1xk (where k is the number of explanatory variables), U_i is 1xg, and Σ is gxg. In our case with a two-equation model, g=2.

Normality tests

Figure A1 shows histograms for the residuals from the FIML estimation. Normality tests (skewness-kurtosis test and Shapiro-Wilkinson test) for the residuals reject the null that the error terms are normally distributed. Especially, the test for skewness contributes to the rejection which is also suggested by figure A1.

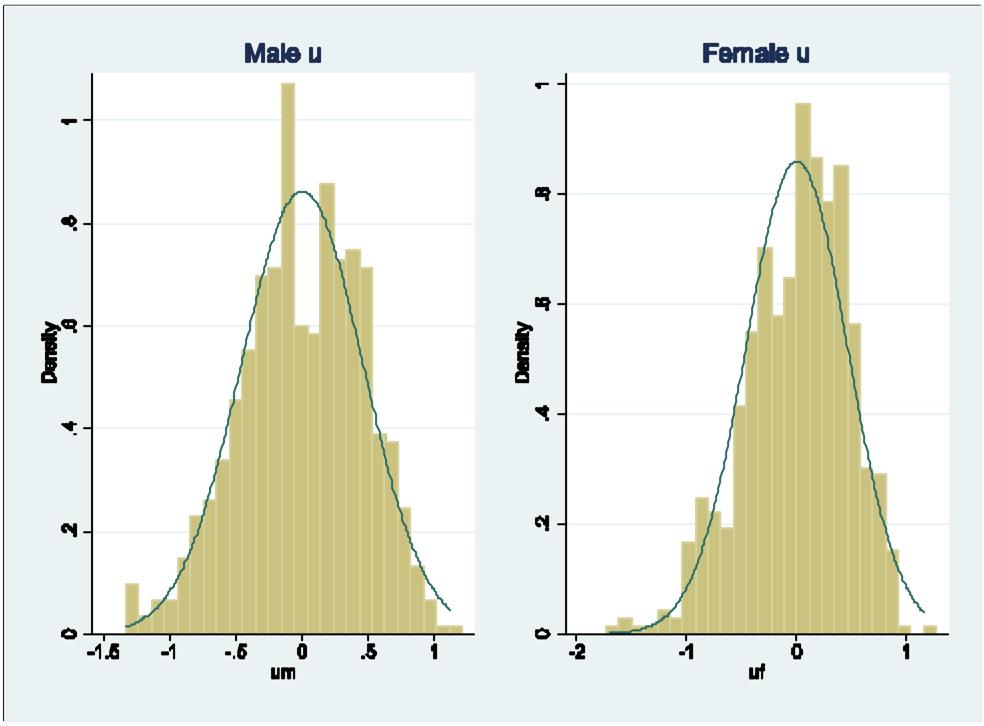

Figure A1: Distribution of residuals from FIML estimation

A.3 GMM-3SLS

In formulating our moment conditions for the GMM-3SLS estimator, we follow Wooldridge (2001, ch. 14). The efficient GMM-3SLS estimator solves:

$$\min_{q\in\Theta}\left[\sum_{i=1}^{n} Z_i q_i(q)\right]^T (n^{-1}\sum_{i=1}^{n} Z_i'\hat{\hat{u}}_i\hat{\hat{u}}_i'Z_i)^{-1}\left[\sum_{i=1}^{n} Z_i q_i(q)\right] \qquad (25)$$

Where Z is a matrix of instruments for the endogenous variables. In the first equation, we instrument female household production by her wage, her wage squared, her age, her age squared and education dummies. In the second equation, we use the same procedure and instrument male household production by his wage, his wage squared, his age, his age squared and education dummies. Table A2 shows that the explanatory variables in both equations are jointly significant with a very low p-value for the c^2 test. The R^2's are low in both equations. With these instrument, we can accept the null in the overidentifying restrictions test that the instruments are uncorrelated with the error terms.

	Coefficient	t-value
Female equation		
Female wage	-0.007	-2.09
Female wage squared	0.010	1.4
Female age	0.117	3.6
Female age squared	-0.001	-3.51
Female education 2	0.096	0.52
Female education 3	-0.142	-1.47
Female education 4	-0.293	-1.87
Female education 5	-0.122	-1.13
Female education 6	-0.351	-2.31
Constant	0.719	1.05
R^2	0.050	
Chi^2	38.550	
p-value	0.000	
Male equation		
Male wage	-0.004	-2.78
Male wage squared	0.005	2.04
Male age	0.084	2.86
Male age squared	-0.001	-2.85
Male education 2	0.023	0.14
Male education 3	0.118	1.34
Male education 4	0.044	0.31
Male education 5	0.166	1.49
Male education	0.151	1.16
Constant	0.406	0.66
R^2	0.029	
Chi^2	21.080	
p-value	0.012	

Table A2: SUR estimation of instruments for h_m and hf

Overidentifying restrictions tests

In order to test whether the instruments are uncorrelated with the error terms, we perform the overidentifying restrictions test. 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 8 degrees of freedom (equal to number of instruments minus number of explanatory variables). The value of the objective function in the optimum is 7.05. Thus we accept the null hypothesis that the instruments are uncorrelated with the error terms.

A.4 Results with gross wages

In the paper, we used imputed net wages (see appendix A1) as the net wage is in principle the most correct measure of the shadow price of time. In order to arrive at the imputed net wages, we had to use a rather crude method to impute the marginal tax rates. This imputation might add to measure error of the wage rate which people use when deciding how to allocate their time. For comparison, we present the regression results with gross wages in table A3.

	GMM-3SLS	t-value
c_{mm}	-786.285	-3.11
c_{ff}	-469.875	-3.01
c_{mf}	-22.996	-0.26
Male equation		
Constant	6.476	12.21
Age	0.003	1.13
Education, years	0.158	1.39
Homeownership	0.130	2.24
Dummy young children	0.220	4.44
Dummy children 7-17	0.093	2.17
Non labour income	0.008	0.64
Female equation		
Constant	7.260	17.65
Age	0.004	2.16
Education, years	-0.219	-2.30
Homeownership	0.145	3.10
Dummy young children	0.198	4.82
Dummy children 7-17	0.129	3.84
Non labour income	0.025	2.68

Table A3: Regression results with gross wages

A.5 Jointness

We test the joint significance (2 restrictions) of the activity benefit parameters by a c^2 test with 2 degrees of freedom. The value of the objective function is 11.45 under the null hypothesis (restricted version) and 8.84 for the unrestricted estimation. Thus, the value of the J-test which is the reduction in the objective function from going from the restricted to the unrestricted version of the model is around 2.6. The critical value of the $c^2(2)$ distribution is 4.61 for a significance level of 0.10. The null hypothesis is therefore accepted, and we reject joint significance of the activity benefit parameters.

We also tested the significance of the activity benefit parameters individually. If we restricted $d_f \equiv 0$ and performed a grid search for d_m, we found the optimum for $\hat{d}_m = 0$. On the other hand, if we restricted $d_m \equiv 0$, we found an optimum for $\hat{d}_f = 0.8$ where the value of the objective function is 9.06. The value of the J-test is then around 2.4 with a p-value=0.12. The critical value of the $c^2(1)$ distribution is 2.71 for a significance level of 0.10. Thus, we are close to concluding that our estimate of d_f is significant. Figures A2 and A3 below illustrate that the the objective function is almost flat for a broad range of values of d_m and d_f respectively, so the activity benefit parameters are estimated with great imprecision. Table A4 below shows the estimation results under the null (restricted version) and for $\hat{d}_f = 0.8$.

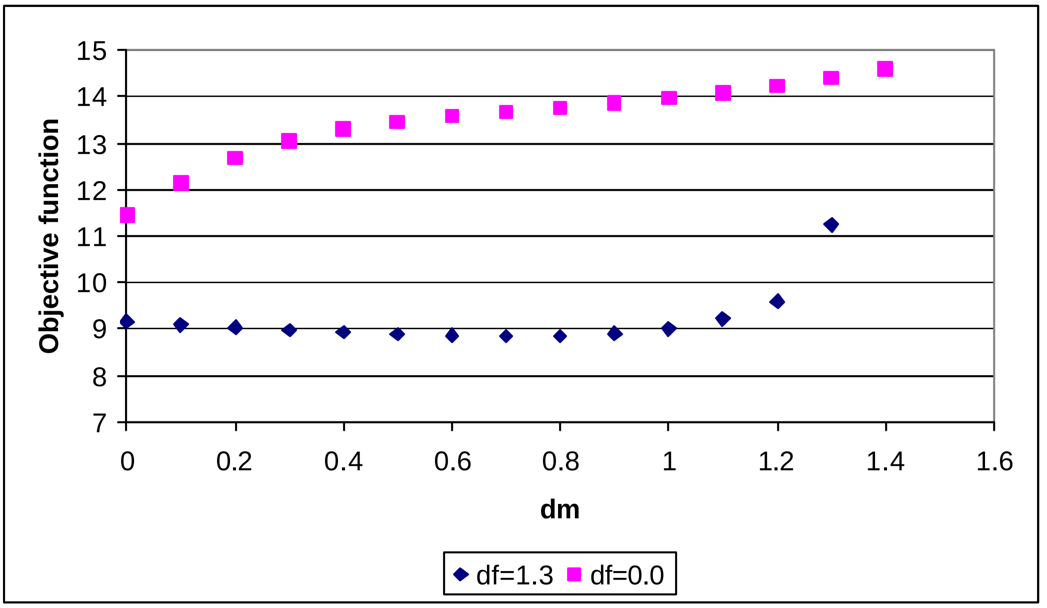

Figure A2: Values of objective function for fixed levels of d_f

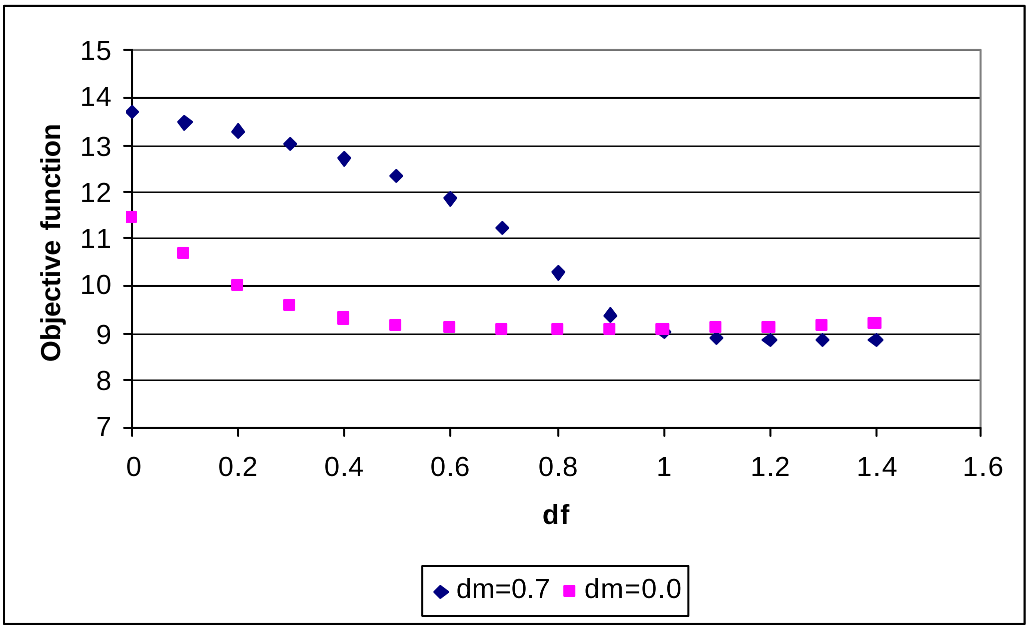

Figure A3: Values of objective function for fixed levels of d_m

	No activity benefits		Activity benefits for women	
c_{mm}	-270.804	(-2.15)	-278.280	(-1.99)
c_{ff}	-99.981	(-3.11)	-11.402	(-2.04)
c_{mf}	18.602	(0.92)	4.219	(1.66)
Male equation				
Constant	5.446	(9.09)	5.593	(10.26)
Male age	0.003	(1.09)	0.003	(1.38)
Male education	0.143	(1.19)	0.115	(1.10)
Dummy home owner	0.088	(1.47)	0.086	(1.50)
Dummy for children	0.174	(3.41)	0.176	(3.61)
Dummy for teenagers	0.056	(1.24)	0.065	(1.63)
Non labour income	0.011	(0.99)	0.012	(1.11)
Female equation				
Constant	5.746	(15.35)	3.595	(6.65)
Female age	0.003	(1.89)	0.004	(1.56)
Female education	-0.196	(-2.21)	-0.273	(-2.37)
Dummy home owner	0.094	(2.23)	0.140	(2.34)
Dummy for children	0.136	(3.62)	0.177	(3.50)
Dummy for teenagers	0.115	(3.68)	0.161	(3.66)
Non labour income	0.019	(2.36)	0.028	(2.40)

Note: t-values in parentheses.

Table A4: Results for model without and with activity benefits

A.6 Finding an optimum with increasing returns to scale

In the household production model without activity benefits, we have to assume decreasing returns to scale, i.e. $\widetilde{Z}''(h_m), \widetilde{Z}''(h_f) < 0$ or - for the specific functional form of net household production - $c_{mm}, c_{ff} < 0$ as a necessary condition for finding an optimum. However, increasing returns to scale is not in conflict with finding an optimum in the model with activity benefits. Thus, $c_{mm}, c_{ff} < 0$ is a sufficient but not a necessary condition. What matters for the possibility of finding an optimum is the curvature of the activity benefit function, $g(h_i)$. In order to find an optimum for one of the spouses in the house, the following condition must be fulfilled for the model in its general form:

$$\begin{aligned}
&\partial \frac{\widetilde{Z}'(h_i)}{(1-g_i'(h_i))} / \partial h_i < 0 \Rightarrow \\
&\frac{\widetilde{Z}''(h_i)*(1-g_i'(h_i)) + \widetilde{Z}'(h_i)*g_i''(h_i)}{(1-g_i'(h_i))^2} < 0 \Rightarrow \\
&\frac{g_i''(h_i)}{(1-g_i'(h_i))} < -\frac{\widetilde{Z}''(h_i)}{\widetilde{Z}'(h_i)}
\end{aligned} \tag{26}$$

Using our specific functional form for $\widetilde{Z}$ and applying the above condition to both male and female, this implies that:

$$c_{mf} > \max\left(-\frac{b_m}{h_f}, -\frac{b_f}{h_m} \right) \tag{27}$$

References

Apps, P. (2003): Gender, Time Use and Models of the Household. *IZA Discussion Papers*, No. 796. IZA, Bonn.

Apps, P., and R. Rees (1997): Collective Labour Supply and Household Production. *Journal of Political Economy*, Vol. 105, Issue 1 (Feb., 1977), pp. 178-190.

Apps, P., and R. Rees (1996): Labour Supply, Household Production and Intra-family Welfare Distribution. *Journal of Public Economics*, Vol. 60, pp. 199-219.

Apps, P., and R. Rees (1988): Taxation and the Household. *Journal of Public Economics*, Vol. 35, No. 3, April 1988, pp. 355-369.

Aronsson, T., S.-O. Daunfeldt and M. Wikström (2001): Estimating intrahousehold allocation in a collective model with household production. *Journal of Population Economics*, 14, pp. 569-584.

Becker, G. S. (1991): *A Treatise on the Family*. Cambridge, Mass. Harvard University Press. Cambridge, Massachusetts. London, England.

Becker, G. S. (1965): A Theory of the Allocation of Time. *The Economic Journal*, Vol. 75, No. 299 (Sep., 1965), pp. 493-517.

Bonke, J., and J. McIntosh (2005): Household time allocation – Theoretical and empirical results from Denmark. *electronic International Journal of Time Use Research*, Vol. 2, No. 1, pp. 1-12.

Bonke, J. (2005): Paid and unpaid work - diary information versus questionnaire information. *Social Indicator Research*, Vol. 70, pp. 349-368.

Chiappori, P.-A. (1997): Introducing Household Production in Collective Models of Labor Supply. *Journal of Political Economy*, Volume 105, Issue 1 (Feb., 1997), pp. 191-209.

Chiappori, P.-A. (1992): Collective Labour Supply and Welfare. *Journal of Political Economy*, Volume 100, Issue 3 (Jun., 1992), pp. 493-467.

Chiappori, P.-A. (1988): Rational Household Labor Supply. *Econometrica*, Vol. 56, Vol. 1, January 1988, pp. 63-90.

Chiswick, C.U. (1982): The Value of a Housewife's Time. *The Journal of Human Resources*, Vol. 17, No. 3 (Summer, 1982), pp. 413-425.

Davidson, R., and J.G. McKinnon (1993): *Estimation and Inference in Econometrics.* Oxford University Press.

Graham, J.W., and C.A. Greene (1984): Estimating the Parameters of a Household Production Function with Joint Products. *The Review of Economics and Statistics*, Vol. 66, No. 2 (May, 1984), pp. 277-282.

Greene, W.H. (2003): *Econometric Analysis.* Fifth edition. Prentice Hall. Pearson Education International.

Gronau, Reuben (1986): Home production – A survey. In Ashenfelter and Layard (ed): *Handbook of Labor Economics.* Elsevier, Holland.

Gronau, Reuben (1980): Home Production – A Forgotten Industry. *The Review of Economics and Statistics*, Vol. 62, No. 3 (Aug., 1980), pp. 408-416.

Gronau, Reuben (1977): Leisure, Home Production, and Work – the Theory of the Allocation of Time Revisited. *Journal of Political Economy,* Vol. 85, No. 6 (Dec., 1977), pp. 1099-1124.

Gronau, R. and D.S. Hamermesh (2001): The Demand for Variety: A Household Production Perspective. *NBER Working Paper*, No. 8509. National Bureau of Economic Research. Cambridge, MA.

Hallberg, D. and A. Klevmarken: Time for children: A study of parent's time allocation. *Journal of Population Economics* (2003) 16: pp. 205-226.

Hausman, J. (1983): Specification and Estimation of Simultaneous Equations Models. In Z. Griliches and M. Intriligator (eds.): *Handbook of Econometrics*. Amsterdam, North Holland.

Hausman, J. (1975): An Instrumental Variable Approach to Full-Information Estimators for Linear and Certain Nonlinear Models. *Econometrica*, 46, 1978, pp. 1251-1271.

Juster, F.T. and F.P. Stafford (1991): The Allocation of Time: Empirical Findings, Behaviourial Models, and Problems of Measurement. *Journal of Economic Literature*, Volume 29, Issue 2 (June, 1991), pp. 471-522.

Juster, F.T. (1985): Preferences for Work and Leisure. In F.T. Juster and F.P. Stafford, (eds.): *Time, goods, and well-being*. Ann Arbor, Institute for Social Research, University of Michigan.

Kerkhofs, M. and P. Kooreman (2003): Identification and Estimation of Household Production Models. *Journal of Applied Econometrics*. 18, pp. 337-369.

Pollak, R.A., and M.L. Wachter (1975): The Relevance of the Household Production Function and Its Implications for the Allocation of Time. *Journal of Political Economy*, 1975, vol. 83, No. 2.

Weiss, Y. (1997): The Formation and Dissolution of Families: Why marry? Who marries whom? And what happens upon Divorce. In M.R. Rosenzweig and O. Stark (eds.): *Handbook of Population and Family Economics*. Elsevier Science B.V..

Wooldridge, J.M. (2001): *Econometric analysis of cross section and panel data.* Massachusetts Institute of Technology.