

# WORKING PAPERS IN ECONOMICS

The Heckman Procedure for Estimating Static  
Disaggregate Labour Supply Functions: An  
International Comparison of Estimates for  
Married Women

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No. 93

March, 1987

DEPARTMENT OF ECONOMICS



The University of Sydney  
Australia 2006

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\* I am indebted to Richard Blundell, Viv Hall, Warren Hogan, Pak-Wai Lin, Margaret Patterson, John Piggott, and Alan Woodland for their constructive comments on this research. Nguyen van Anh provided very capable research assistance.

### Abstract

This paper undertakes a cross-country comparison of nine recent studies which estimate disaggregate labour supply functions for married women in a static framework using the Heckman method of correcting for sample selectivity bias. Comparison of the empirical results for the reduced form equations and the derived estimates of the underlying structural parameters shows that despite significant inter-country variations in aggregate labour force participation rates, and in the definitions of key variables, the derived uncompensated and compensated wage elasticities are remarkably robust.

## 1. Introduction

When the labour force participation rate in the population under review is less than 100%, bias in sample selection may arise when attempting to estimate disaggregate labour supply functions. It is potentially a serious problem for the analysis of labour supply patterns amongst married women. Their participation rates vary considerably across countries and are rarely close to 100%; some examples to be seen in Table 1 are discussed further below.

The Heckman (1979, 1980) method for correcting such bias has been widely applied though little attention has been given to the results of cross-country comparisons. Such comparison would be useful for several reasons. First, estimates of the underlying structural parameters such as the various measures of labour supply elasticities would be on a comparable basis. Second, valuable insights into the impact of institutional factors on labour supply patterns might be obtained. Third, useful information on cross-country differences in preferences should also be revealed.

The present paper examines nine recent studies which have followed the Heckman approach. The data sets cover the USA (2 studies), Canada, Australia, Holland, France, Spain, West Germany, and Sweden. Hence a substantial range of comparisons may be tested. The Heckman approach is set down briefly in section 2 and the nine studies are described in the third section. Section 4 contains summary empirical results from the studies, with attention focussed on the participation decision, offered wages, and hours of work respectively. In section 5 wage and income elasticity estimates are derived for each study and compared with previous estimates discussed in the Killingsworth (1982, chapter 4)

survey. Some concluding comments are offered in the final section. The major conclusion is that the Heckman procedure has permitted fresh insights into the market work patterns of married women as bias-adjusted estimates indicate that their labour supply is considerably more elastic than previously thought, a result which is remarkably robust across a large number of countries despite the quite disparate data bases used.

## 2. The Basic Model and the Heckman Procedure

Heckman's is a second generation static framework, i.e. one in which issues such as sample selectivity bias are allowed for. It has become the standard framework used by researchers who do not want to be restricted to a specific direct utility function when using a cross-sectional data base which contains neither longitudinal panel data nor expenditure data. Longitudinal panel data would facilitate fitting a dynamic life cycle model such as has been done by Heckman and MaCurdy (1980), while expenditure data would facilitate fitting a life cycle consistent model as in Blundell and Walker (1983).

This framework is the three equation static model developed by Heckman (1979, 1980). It has been well documented in the literature<sup>1</sup> and only a brief summary is provided here.

The theoretical framework is described by three equations:

$$W_{oi} = \alpha(X_{oi}) + u_{oi} \quad (1)$$

$$W_{ri} = \beta(X_{ri}) + u_{ri} \quad (2)$$

$$H_i = \max(0, h(W_{oi} - W_{ri})) \quad (3)$$

where  $W_o$ ,  $W_r$  and  $H$  are the natural logarithm of the offered wage (i.e. the market wage), the natural logarithm of the reservation wage (i.e. the shadow wage at zero hours of work), and the depth of

participation (i.e. hours of work) respectively; subscript  $i$  referring to the  $i^{\text{th}}$  married woman.  $X_0$  and  $X_r$  are vectors of characteristics;  $X_0$  consists of human capital characteristics, while  $X_r$  contains both human capital and demographic characteristics.  $\alpha$  and  $\beta$  are vectors,  $h$  is a function, while  $u_0$  and  $u_r$  are the random error components of the system. It is assumed here that  $X_0$  and  $X_r$  both contain a constant term,  $\alpha$  and  $\beta$  are linear in their parameters,  $h$  is a constant, and the error terms  $u_0$  and  $u_r$  are joint normal variables which are independent across observations.

Equation (3) indicates how hours of work are related to the offered and reservation wages. Only those women who have offered wages in excess of their reservation wages will work, and the hours they work are assumed to be linearly related to the difference between  $W_0$  and  $W_r$ .

For working women, Heckman rewrites equation (3) as

$$\begin{aligned} H_i &= h(W_{0i} - W_{ri}) \\ &= h(\alpha \cdot X_{0i} - \beta \cdot X_{ri}) + h(u_0 - u_r) \\ &= \delta \cdot X_{hi} + u_h \end{aligned} \quad (4)$$

where  $X_h$  is the union of  $X_0$  and  $X_r$ ,  $\delta$  is the vector of coefficients associated with  $X_h$ , and  $u_h = h(u_0 - u_r)$ .

The major empirical issue which Heckman addresses is that testing of this model is hampered by two facts; a significant proportion of the population is not in employment, and reservation wages are not directly available for any women. This means that  $W_0$  is unobserved for women who are not working while  $W_r$  is unobserved for all women. That is, the dependent variable in (1) is observed only for working women, while the dependent variable for (2) is not observed at all.

The Heckman procedure is to base estimation of the parameters of (1), (2) and (3) on a random sample of working women, but to allow for sample selectivity bias by taking into account the limited information available on non working women. The reduced form regression functions of (1) and (3)<sup>2</sup> for a random sample of working women are

$$W_{oi} = \alpha \cdot X_{oi} + \sigma_{oh} \cdot \lambda_i + u_{oi} \quad (5)$$

$$H_i = \delta \cdot X_{hi} + \sigma_{hh}^{1/2} \cdot \lambda_i + u_{hi} \quad (6)$$

$\sigma_{oh}$  is the ratio of the covariance between  $u_{oi}$  and  $u_{hi}$  to the standard error of  $u_{hi}$ , while  $\sigma_{hh}^{1/2}$  is the standard error on the hours equation.  $\lambda$  is the Mill's ratio, i.e. the ratio of the density to the cumulative frequency of a standard normal variable, and is included to take explicit account of any sample selection bias introduced into the estimation procedure as a result of using a non random sample<sup>3</sup>. Further elaboration of  $\lambda$  can be found in Heckman (1979).

The estimation procedure is to firstly estimate the coefficients of the likelihood function for labour force participation using probit analysis in order to derive estimates for the  $\lambda_i$ 's, then to run least squares regressions for the offered wage and hours functions, i.e. equations (5) and (6).

### 3. The Studies

Nine studies are included in this survey. They are the original Heckman work for the USA (as presented in Heckman, 1980), a second USA study (Dooley, 1982), and studies covering Canada (Yakamura, Yakamura and Cullen, 1981), France (Riboud, 1985), West Germany (Franz and Kawasaki, 1981), Sweden (Gustafsson and Jacobson, 1985), Spain (Hernandez Iglesias and Riboud, 1985), Holland (Hartog and Theeuwes,

1985) and Australia (Ross, 1986). Table 1 provides summary details of each study's data base and estimation procedure.

There is substantial variation in the participation rates across studies, as well as significant variation in the coverage and/or timing of the studies. The extent to which the variation in aggregate participation rates is influenced by country-specific institutional factors, as opposed to economic factors, is not known. Information on economic factors such as income taxation arrangements and the states of the national labour markets at the times of the surveys will be addressed in the following sections. There is also some variation in the definitions of key regressors used in the estimated functions; these definitions are itemised in Appendix A. Nevertheless, there is sufficient common ground in the studies to warrant a comparative study.

#### 4. Summary Empirical Results

These relate to the labour force participation index (discussed immediately after equation 6 above), the offered wage function (equation 5), and the hours of work function (equation 6). Each is discussed in turn.

##### 4.1 Participation Function

The participation function is estimated in order to estimate the  $\lambda_1$ 's, but the coefficients obtained also yield valuable insights into the participation decision itself. Although labour force participation covers both employment and unemployment, all nine studies measure participation to be actual employment. In all but two studies the unemployed are treated as being non-participants. The two exceptions are

Table 1: Countries in the Studies of Labour Supply  
of Married Women

Country (Author)	Year of Survey	Coverage (age)	Estimation Procedure <sup>a</sup>	Participation and Unemployment Rates at time of Survey (%) <sup>b</sup>
Australia (Ross)	1980	18-64	VII	48.0 6.0
USA (Heckman)	1967	30-44	VII	36.8 3.7
USA (Dooley)	1970	30-54	VII	40.8 4.8
West Germany (Franz/Kawasaki)	1976	20-64	VII	39.3 3.7
Canada (Yakamura/Yakamura /Cullen)	1971	20-59	VIII	43.8 6.1
Sweden (Gustafsson/Jacobson)	1981	20-59	VIII <sup>c</sup>	75.1 2.7
France (Riboud)	1978/79	18-67	IX	52.6 5.9
Spain (Hernandez Iglesias /Riboud)	1979	20-59	IX	19.2 8.5
Holland (Hartog/Theeuwes)	1979	23-60	X	25.3 5.4

Notes:

- a. Estimation procedures are summarised in Appendix B.
- b. Participation rates are derived from the studies. The unemployment rates presented are from OECD (1985) as unemployment rates are not available in the studies.
- c. No hours equation reported.

Australia and Holland; in these studies the unemployed were excluded from the estimation procedures completely. With the relatively high levels of sustained unemployment experienced in most economies in recent years, the issue of how to treat the unemployed in empirical models of labour supply will become more important; as the work of, for example, Flinn and Heckman (1981) and Ham (1982) has already indicated. Further, for those studies using annual hours worked as their basis for determining participation, the incidence of any unemployment spells during the year has been ignored by the authors.

The marginal impact on the participation decision of a variable is given by

$$d\rho_i/dX_j = (d\rho_i/dZ_i) \cdot (dZ_i/dX_j) \quad (7)$$

where  $\rho_i$ ,  $X_j$ , and  $Z_i$  denote the participation probability for the  $i^{\text{th}}$  woman, the  $j^{\text{th}}$  regressor, and the value of a standard normal variable for the  $i^{\text{th}}$  person respectively.  $Z_i$  is defined as  $[-(\delta/\sigma_{hh}^{1/2}) \cdot X_{hi}]$ , where  $(\delta/\sigma_{hh}^{1/2})$  is the vector of estimated coefficients in the likelihood function and  $X_{hi}$  is the vector of characteristics for the  $i^{\text{th}}$  person.

The precise form of  $(d\rho_i/dZ_i)$  depends on the stochastic specification. For probit analysis  $d\rho_i/dZ_i = \lambda_i \cdot \rho_i$ , while for logit analysis  $d\rho_i/dZ_i = (1-\rho_i)\rho_i$ . Finally, the  $dZ_i/dX_j$  term is just the coefficient for the  $j^{\text{th}}$  variable in the likelihood function.

For each  $X_j$  the value of (7) has the same sign as its coefficient although it will be non-linear and individual-specific.

Table 2 summarises the participation results. In all studies, the impact of schooling is positive, and in all studies bar one (Canada) the null hypothesis that the impact is not significantly different from

zero can be rejected at usual levels of confidence. Similarly, in each of the four studies reporting experience variables the marginal impact of a unit of previous market experience is positive, and statistically significant.

Further, all income variables indicate a negative and significant impact on participation of increases in access to sources of other income (i.e. other than own earnings). There are only two exceptions. In the Australian study the husband's income variable had a positive but statistically insignificant impact, while for Canada the non-earned income variable had a positive and significant impact.

Finally, the impact of young children on participation was as expected in all studies. No matter what formulation was used the impacts were negative, and where different age groupings were used the relative sizes of coefficients was in accord with expectations.

#### 4.2 The Market Wage Function

Table 3 summarises the market wage regressions. Given the variations in formulations, there is a remarkable degree of similarity in the results. All studies which used actual years of schooling indicate a (gross of income tax) rate of return to an extra year of schooling of between 6% and 11%. Of the studies that used dummy variables to capture the impact of education, all indicate that the return to extra schooling is positive since the coefficients increase in size with higher levels of educational attainment. The West Germany coefficients are somewhat difficult to interpret since the different educational levels reflect qualitatively dissimilar types of education as well as quantitative differences in years of schooling<sup>4</sup>. Of the four studies using previous market experience as a regressor, three report

rates of return to extra experience of 2%-5% (USA-Heckman, France, Spain), while the fourth (Australia) indicates a much higher return, of around 12%. This discrepancy in the estimated rates of return can be explained by the way in which the experience variable is derived. The Australian study had very detailed data on actual labour force experience over the sixty month period immediately prior to the survey date<sup>5</sup> permitting the calculation of full-time equivalent months of recent experience. However, each of the three studies with lower rates of return used proxies for labour force experience which implicitly assumed that all experience was in full-time employment. Such proxies overestimate the true extent of actual experience for married women whose work histories include spells of part-time and/or part-year employment.

The other variable of interest in the market wage function is  $\lambda$ , the variable included to capture the direct impact of sample selectivity bias. From equation (5), the coefficient on  $\lambda$  is proportional to the covariance of the errors in the wage equation and the hours equation. The results indicate that this covariance is positive for Canada, West Germany, Holland and Dooley's USA study. For the Swedish study the covariance across equations is negative, although not significantly different from zero above the 90% level of confidence, while for the French, Spanish, Australian and Heckman's USA studies the coefficient indicates that this covariance is not different from zero. For these countries, the null hypothesis of no sample selection bias in the market wage equation can not be rejected.

#### 4.3 The Hours of Supply Function

As is indicated in Table 4, not all studies presented hours regressions. It is assumed that data inadequacies are the reason for non

reporting of hours equations. Of the five studies reporting hours equations, three (Canada and the two USA studies) used annual hours as the hours measure while two (Australia, West Germany) used weekly hours. The comparison is therefore less precise for this equation.

All studies indicate that income elasticities - to be discussed further in section 5 - will be negative since the coefficients on the various income variables are always negative, although some are not statistically different from zero. Working women with children are more likely to be working part-time as the coefficients indicate that they work less hours than do their counterparts with no children, *ceteris paribus*.

The superficially poor performance of the schooling variables is not surprising. From equation (4) the coefficient on schooling in the hours equation reflects the relative size of two opposing effects. Given that the coefficient in the market wage equation is significant, an insignificant coefficient in the hours equation indicates that the impact of schooling on the reservation wage is of the same magnitude as its impact on the market wage. Evidently, for Australia and West Germany, the impact of schooling on women's internal evaluation of their time is just as great as it is on the market's value of their time.

The direct effect of sample selectivity bias in the hours equation is as follows. From equation (6), the coefficient on  $\lambda$  is the standard error on the hours equation, and should be positive. Curiously, while this result was found in the other four studies in which hours equations were reported, it was not found in Heckman's own study.

## 5. Structural Elasticities

In this section, structural elasticities of labour supply are derived for each study and these elasticities are compared with those reported in Killingsworth's excellent survey; see his Table 4.3 and associated discussion at pages 185-201.

For each study, compensated and uncompensated wage elasticities both of hours of supply and of overall labour force participation are presented in Table 5; these are discussed in sections 5.1 and 5.2. The formulae used to calculate these elasticities are detailed in Appendix C. Section 5.3 updates the Killingsworth survey of the hours elasticities, incorporating the estimates discussed in 5.1.

### 5.1 Hours Elasticities Estimates

The substitution effects, i.e. the compensated wage elasticities, are surprisingly consistent, as with the exception of Canada, all indicate that labour supply is elastic. Not surprisingly, the two US studies have the highest substitution effects. They use annual hours as the dependent variable in contrast to weekly hours and clearly there is more scope for varying annual hours of work. The Canadian results are difficult to explain. Killingsworth (pp 192 and 200) suggests that these results may reflect an omitted variables problem as no labour force experience variables are included although my own interpretation is that the results suggest a backward bending supply curve. Unlike the other studies, Yakamura et al used the log of the predicted hourly wage, rather than its determinants, in the hours equation. As the coefficient on the imputed log wage was negative, the method of calculating the uncompensated wage elasticity gives a negative elasticity, indicating a backward bending supply curve. However, mitigating against this

Table 5: Wage and Income Elasticities<sup>a</sup>

Country	Wage		Income
	Uncompensated	Compensated	
HOURS EQUATION			
Australia <sup>b</sup>	1.30	1.36	-.06
	1.29	1.35	-.06
USA (Heckman) <sup>b</sup>	1.45	1.48	-.03
	1.47	1.50	-.03
USA (Dooley)	4.50	5.64	-1.14
Canada <sup>c</sup>	-.08	-.02	-.06
West Germany <sup>d</sup>	1.08	1.28	-.20
	1.38	1.66	-.29
PARTICIPATION EQUATION			
Australia	.68	2.83	-2.15
USA (Heckman)	1.15	1.35	-.20
USA (Dooley)	3.40	4.21	-.81
Canada <sup>c</sup>	0.77	5.26	-4.49
West Germany	*10.77	*1.14	-.37
Holland	1.99	2.30	-.31
France	.89	1.02	-.13
Spain	1.53	2.96	-1.43
Sweden	0.29	0.32	-.03

Notes:

- a. all are evaluated at sample mean values of variables
- b. first row uses equation (C2) to calculate the uncompensated wage elasticity while the second row uses (C2').
- c. derived directly from Yakamura et al, Table 8.
- d. first row uses the vocational training (SV) coefficients, while the second row uses those for XXX.

explanation is that the income effect is not large enough in absolute size to imply a positive substitution effect. Probably, the true explanation is a combination of a backward bending supply curve and the lack of the experience variable problem. It is unfortunate that the other four studies - France, Spain, Sweden and Holland - were not able to report hours equations. These four studies used somewhat different estimation procedures and would have served as useful checks against the elasticities reported in Table 5.

Before concluding that labour supply is in fact elastic, it should be remembered that the woman's wage variables used are gross of income tax in all studies except the West German one. The coefficients used in these calculations are therefore systematically understated<sup>6</sup>, as are the wage elasticities<sup>7</sup>.

Of these five studies, three cover countries with income taxation systems which either require married couples to file joint income tax returns (West Germany) or provide incentives for couples to do so (USA) while in the other two countries - Australia and Canada - it is mandatory for individuals to file separately. With progressive income tax regimes, labour supply elasticity estimates based on gross wage variables will be lower with joint filing since joint filing is likely to lead to higher effective marginal tax rates for the female spouse than does separate filing<sup>8</sup>.

## 5.2 Participation 'Elasticities'

As can be seen from equations (13) to (16), the uncompensated own wage elasticities of participation are highly sensitive to the sample participation rate, either directly - equations (14) and (16) - or indirectly - equations (13) and (15). Given the range of participation

rates presented in Table 1, considerable variation is to be expected in the country-specific elasticity estimates presented in the second part of Table 5. Further, it is expected that the method of income tax filing will have a more pronounced effect here than it does in the hours decision. In those countries in which joint filing is mandatory or common<sup>9</sup>, the effective marginal tax rate faced by a married woman contemplating employment is likely to be higher, *ceteris paribus*, than if filing was separate; consequently the gross wage elasticity of participation is expected to be lower in countries with joint filing. Given the disparities in the participation rates and tax arrangements across countries, it is surprising that there is not much more variation in the figures presented in Table 5.

### 5.3 Comparison with Previous Estimates of the Hours Elasticities

Second generation static labour supply models is a generic term covering empirical developments designed to overcome the problems inherent in first generation static labour supply models; problems such as systematic missing data, data bunching and generally ad hoc approaches to econometric issues. Although arguably the dominant approach, Heckman's is not the only second generation model which could be applied in this scenario, i.e. cross-sectional data sets with neither longitudinal data nor expenditure data and with no specific direct utility function assumed. Appendix B, which is based on Killingsworth Table 4.1, details the various estimation procedures which have been applied to this specific scenario. A more comprehensive survey of all estimation techniques can be found in Wales and Woodland (1980).

Within the second generation procedures discussed in Appendix B there are two distinct subsets; those which restrict the supply function to be continuous and those which do not. Procedures VII to X allow for

discontinuities in the supply function, and so elasticities derived from these procedures are expected to be lower than those derived from procedures III to VI.

Table 6 presents procedure-specific average wage and income elasticities for the hours equation. Although the number of studies in each procedure is small, several points emerge. Firstly, the second generation procedures, i.e. procedures III - VIII<sup>10</sup>, indicate that labour supply is elastic<sup>11</sup>; by contrast the first generation estimates suggest that supply is inelastic; clearly, first generation studies lead to downward biased estimates.

The elasticities for procedures VII and VIII are lower than those from the other second generation procedures. Apparently, it is important to allow for discontinuities in supply, otherwise the responsiveness of female labour to changes in wages will be somewhat overestimated.

## 6. Conclusion

Sample selectivity bias is clearly an important issue when estimating disaggregate labour supply functions for married women. This cross-country comparison of estimates of female labour supply parameters demonstrates that sample selectivity bias is a common problem in the hours function, although it appears not to be such a problem in the market wage function. Heckman's procedure has led to fresh insights. Previous research using first generation models of labour supply have produced biased estimates of the structural parameters of interest and have resulted in underestimates of compensated and uncompensated wage elasticities of labour supply. Correcting for sample selectivity bias has typically resulted in supply elasticities which indicate that supply is in fact elastic, although usually close to unity; the only exception

Table 6: Hours Elasticities by Procedure<sup>a,b</sup>

Procedure <sup>c</sup>	Wage		Income
	Uncompensated	Compensated	
I (3)	.40 (.16, .60)	.35 (.21, .49)	.08 (-.06, +.26)
II (5)	.37 (.06, 1.14)	.38 (.06, 1.50)	-.02 (-.05, +.01)
III (4)	1.45 (-.44, 3.50)	1.45 (.56, 3.60)	0 (-.19, +.48)
IV (3)	6.17 (1.46, 14.79)	6.17 (1.48, 14.79)	0 (-.02, 0)
V (1)	4.47	4.47	0
VI (7)	3.19 (2.10, 4.50)	3.02 (2.18, 4.91)	-.14 (-.41, 0)
VIIK (7)	2.06 (.19, 7.73)	2.15 (.07, 7.73)	-.10 (-.20, 0)
VIIR (4)	1.80 (1.08, 4.50)	2.06 (1.28, 5.64)	-.26 (-1.14, -.03)
VIII (3)	.07 (-.24, +.64)	.18 (-.26, +.81)	-.11 (-.17, -.04)

Notes:

- All figures are simple averages from the number of studies using the procedure. All are derived from Killingsworth Table 4.1 except for VIIR, which was derived from the present study. The Canadian elasticities are included in VIII.
- Figures in parentheses in the body of the table indicate the minimum and maximum values reported.
- Figures in parentheses in this column indicate the number of studies reported.

being Canada, where negative wage elasticities were estimated but for which there are differing interpretations of the results obtained. By contrast researchers using first generation models typically concluded that supply was very inelastic.

Despite considerable inter-country variations both in labour force participation rates and the formulations of key variables, there is substantial consistency in the results reported. Rates of return to schooling are remarkably similar across all countries, as are rates of return to previous labour market experience, although not all studies were able to include a direct measure of this latter variable in their analyses. Young children have a significant impact on both participation and hours of supply, even in countries with relatively high participation rates such as Sweden and Australia.

Given the substantial variations in both labour force participation rates and the formulations of key variables, it is surprising that there is such a high degree of similarity in these results, especially given the lack of discussion of country-specific institutional factors and their impact on labour supply decisions.

The other function of interest, the reservation wage function, has received scant attention. Typically, its importance is acknowledged at the theoretical level but it is not examined in empirical work; of the studies discussed, Ross (1986) is the only one which attempts to estimate equation (2). Even if the reservation wage function is not identified (see footnote 2), some insights can be gleaned from inspection of the estimated coefficients of equations (1) and (3), provided that the latter is estimated. For example, equation (4) indicates that if a variable is expected to affect the reservation wage (equation 2) but not the offered wage (equation 1), then if that

variable (e.g. spouse's income, young children) is significant in the hours function (equation 3) it follows that the coefficient in the reservation wage function should be proportional to that in the hours function<sup>12</sup> and should also be significant. Further, for those variables expected to influence both wage functions, the combination of a significant coefficient in the offered wage function and an insignificant coefficient in the hours function indicates that the coefficient in the reservation wage function is of equal sign and magnitude to that in the offered wage.

There would appear to be three priority areas for attention in empirical research on labour supply in this scenario<sup>13</sup>; an inter-country study of the impact of institutional factors, unemployment modelling, and estimation of the reservation wage function. Further research on each of these areas would enable even further insights into the labour market behaviour of married women throughout the world.

## FOOTNOTES

1. In addition to the Heckman references above, see also Heckman, Killingsworth and MaCurdy 1981, pp 106-112, and Killingsworth 1982, chapter 4, as well as any of the studies referred to in this paper.
2. Provided there is one, but only one, variable in  $X_0$  not in  $X_r$ , successful estimation of all three equations in the system requires only that the hours equation and the offered wage equation can be estimated. This is so since once estimates of  $\alpha$  and  $\delta$  are obtained  $\beta$  can be uniquely derived. If there is more than one variable in  $X_0$  not in  $X_r$ , as is potentially the case, then multiple estimates for  $\beta$  would be obtained and the reservation wage  $W_r$  could not be identified. In this case, researchers tend to present estimates for (1) and (3) and pay scant attention to (2). Of the studies covered in this survey, none apart from my own explicitly discusses estimates of (2).
3. As has already been mentioned, although a random sample of working women is used it is not a random sample of all women.
4. I am grateful to Ernestine Gross for explanation of the West German education system.
5. Although the formulation reported here imputes all return on experience to the last five years, when a variable capturing all previous work experience was used the rate of return was even higher, at 15%; see Ross, 1986.
6. Denoting  $\delta_r$  as the true coefficient (i.e. that relating to the net wage), and  $\delta$  as the observed coefficient (i.e. that relating to the

gross wage), it can be shown that  $\delta = \delta_t(1-t_a)$ , where  $t_a$  is the average tax rate.

7. The true uncompensated own wage elasticity of hours is  $(dHr/Hr)/(dNW/NW)$ , where  $NW$  denotes the net wage. However, the estimate of this elasticity derived here is  $(dHr/Hr)/(dGW/GW)$ , where  $GW$  denotes the gross wage. Denoting the marginal tax rate as  $t_m$ , and noting that  $NW = GW(1-t_a)$  but that  $dNW = dNW(1-t_m)$ , it follows that the estimated elasticity differs from the true elasticity by a factor of  $(1-t_m)/(1-t_a)$ . With the progressive income tax systems used in each of the countries in this survey, the elasticity estimates must be underestimates since  $t_m > t_a$  will apply in each case.
8. This statement is certainly true for many part-time workers and, depending on the slope of the tax schedule, may well apply to most workers.
9. Joint filing is also mandatory in France and Spain.
10. Note that hours functions were not presented in the studies using IX and X.
11. Procedure VIII does not fit this claim. However apart from the Canadian study with its negative own wage elasticities, there is only one other study which used VIII; Cogan (1980) reports positive but inelastic elasticities for both white and black women.
12. From equation (4), the factor of proportionality is  $h$ .
13. i.e. when using a cross-sectional data base which contains neither longitudinal panel data nor expenditure data.

## APPENDIX A: Definitions of key

## DEPENDENT VARIABLES

WAGE (gross of income tax unless otherwise stated):

*Australia:*

Weekly earnings divided by HOURS (as defined below)

*USA (Dooley), Canada:*

Annual Earnings divided by HOURS (as defined below)

*USA (Heckman):*

Usual hourly wage

*West Germany:*

Net hourly wage (no more precise definition given)

*France:*

Annual earnings divided by annual hours worked

*Spain:*

Not defined, assumed to be annual earnings divided by annual hours worked

*Holland:*

Weekly earnings divided by mid-point of reported hours range

*Sweden:*

Hourly wage (no more precise definition given)

## HOURS:

*Australia, West Germany:*

Hours worked in survey week

*USA (Dooley), Canada:*

Hours worked in survey week\*weeks worked in previous twelve months

*USA (Heckman):*

Annual earnings divided by usual hourly wage

*France, Spain, Holland, Sweden:*  
no hours variable

## variables

## INDEPENDENT VARIABLES:

CHILDREN: (number of children in specified age group)

*Australia:*

C04 (aged 0-4),

C59 (5-9)

*USA (Heckman):*

C05 (0-5)

*USA (Dooley):*

none used

*France:*

C25 (0-24)

*Spain:*

CT, total number of children

*Canada:*

C05 (see USA)

C11 (6-11)

C15 (12-15)

C20 (19-24 in education)

CT (see Spain)

*West Germany:*

C02 (0-2)

C35 (3-5)

C69 (6-9)

C10 (10-14)

C15 (15-18)

C19 (19+)

*Holland:*

C05 (see USA)

C11 (6-11)

C15 (12-15)

*Sweden:*

C05 (see USA)

C65 (6-15)

## EDUCATION:

*Australia, USA (Heckman), France,  
Spain, Canada:*

S, Years of completed  
schooling

*USA (Dooley)*

S, as above  
SV (=1 if any vocational  
training)

*West Germany:*

S1 (=1 if Hauptschule)  
S2 (=1 if Realschule)  
SF (=1 if Fachhochschule)  
S3 (=1 if Abitur)  
SV (as above)

*Holland:*

SB (=1 if completed basic  
primary school only)  
SP (=1 if completed extended  
primary school)  
SS (=1 if completed high  
school)  
SH (=1 if vocational training  
or university degree)

*Sweden:*

S6 (=1 if no more than 6  
years of schooling)  
S6V (=1 if 6 years of  
schooling and vocational  
training)  
S9 (=1 if 9 years of  
schooling)  
S9V (=1 if 9 years plus  
some vocational training)  
SU (=1 if completed high  
school or university)

## EXPERIENCE:

*Australia:*

EX5, full-time equivalent  
months of experience in  
the last five years

*USA (Heckman):*

EXH, number of years in  
which woman has worked  
six months or more

*France:*

EXF = age - age at first  
job - estimate of length  
of time out of the labour  
force

*Spain:*

EXS, not clearly defined,  
described as 'years of  
experience'

*USA (Dooley):*

not available, age dummies  
used

*Canada:*

not available, age at first  
marriage used as proxy

*West Germany:*

not available, no proxy  
used

*Sweden, Holland:*

not available, own age and  
number of children  
variables used as proxies

OTHER INCOME (gross of tax unless indicated): AGE

Australia:

HW, husband's hourly wage,  
OY, other family income per annum

Australia

AG1 (=1 if age < 25)  
AG2 (=1 if 25-34)  
AG3 (=1 if 35-44)  
AG4 (=1 if 45-54)  
AGR (=1 if > 54)

USA (Heckman):

HW, as above

Holland

AG5 (=1 if 22-24)  
AG6 (=1 if 25-29)  
AG7 (=1 if 30-34)  
AG8 (=1 if 35-39)  
AG9 (=1 if 40-44)  
AG10 (=1 if 45-49)  
AG11 (=1 if 50-54)  
AGR (=1 if > 54)

USA (Dooley):

PH, husband's predicted earnings  
TH, husband's actual earnings - PH

France, Spain:

HA, husband's annual earnings  
OY, (as above)

Canada:

HA, as above  
AI, family asset income  
PPFI, = (HA + AI)/persons in family

West Germany:

HNE, husband's net monthly income

Holland:

PHW, husband's predicted hourly wage  
OY, (as above)

Sweden:

NI, = HA + OY (some tax adjustment on OY)

APPENDIX B: Alternative Procedures Used for Estimating  
Static Disaggregate Labour Supply Models

There have been at least ten different estimation procedures applied to data fitting the scenario outlined in section 2 above. Killingsworth (1983, Table 4.1) surveys eight procedures, and two more have been introduced in the research discussed in the present paper. Adopting the terminology used by Killingsworth, the ten procedures are denoted here sequentially as Procedure I to Procedure X. Readers are referred to Killingsworth - see especially his discussion of Table 4.1 at pages 149-161 - for further information on procedures I to VIII.

As Killingsworth notes, procedures I and II are the first generation methods, procedure III is the Tobit approach, while procedure IV uses a linear participation likelihood function. Procedure V is a modified tobit likelihood function approach, while procedure VI is Heckman's tobit (or Heckit; Killingsworth p 156). Procedure VII is the standard Heckman method, and procedure VIII is a variation on the Heckman method in which an imputed wage is used in place of the determinants of the wage in the hours function.

Procedures IX and X have been introduced since the Killingsworth survey. Procedure IX uses the Heckman procedure to correct for sample selectivity bias in the wage equation but then re-estimates the participation function using the imputed wage as a regressor in place of its determinants. Procedure X differs from procedure IX in two respects; logit analysis is used in place of probit analysis and the natural log of the imputed wage is used in the re-estimation of the likelihood function. No author using either of these two procedures presents an hours function.

## APPENDIX C: Estimation Formulae for the Wage and Income Elasticities

Six different elasticities are reported in the text; the uncompensated own wage elasticity of hours, the compensated own wage elasticity of hours, the income elasticity of hours, the uncompensated own wage elasticity of participation, the compensated own wage elasticity of participation, and the income elasticity of participation. In the text, point elasticities are presented and have been calculated using sample mean values of all relevant variables. The formulae used are set out below.

## I Hours Equation

(i) Uncompensated Own Wage Elasticity of Hours (denoted  $\Sigma_{HUV}$ )

$$\begin{aligned}\Sigma_{HUV} &= \frac{\% \text{ change in hours}}{\% \text{ change in wage}} \\ &= \frac{d(\text{Hours})/\text{Hours}}{d(\text{Wage})/\text{Wage}} \\ &= \frac{d(\text{Hour}) \cdot \text{Wage}}{d(\text{Wage}) \cdot \text{Hour}} \quad \text{(C1)}\end{aligned}$$

Denoting hourly wages by  $W$ , hours of work by  $H$ , years of schooling by  $S$ , the natural log of  $W$  by  $W_0$ , then by applying the product rule of differentiation and noting that  $d \ln(x) = (dx)/x$ , the uncompensated own wage elasticity  $\Sigma_{HUV}$  can be rewritten as

$$\begin{aligned}\Sigma_{HUV} &= \frac{dH}{dS} \cdot \frac{dS}{dW} \cdot \frac{W}{H} \\ &= \frac{dH}{dS} \cdot \frac{dS}{dW_0} \cdot \frac{1}{H} \\ &= \delta_S \cdot \frac{1}{\alpha_S} \cdot \frac{1}{H} \quad \text{(C2)}\end{aligned}$$

For those studies which reported an experience variable, the elasticity was also calculated replacing  $\alpha_S$  and  $\delta_S$  by  $\alpha_E$  and  $\delta_E$  respectively, i.e.

$$\Sigma_{HUV} = \delta_E \cdot \frac{1}{\alpha_E} \cdot \frac{1}{H} \quad (C2')$$

(ii) Income Elasticity of Hours ( $\Sigma_{HY}$ )

Following Killingsworth, (note to Table 4.3, p 199)

$$\begin{aligned} \Sigma_{HY} &= W_0 \cdot \frac{dH}{DHI} \\ &= W_0 \cdot \delta_{HI} \end{aligned} \quad (C3)$$

(iii) Compensated Own Wage Elasticity of Hours

This is just the uncompensated wage elasticity less the income elasticity, i.e.

$$= (C2) - (C3)$$

## II. Participation Function

(i) Uncompensated Own Wage Elasticity of Participation ( $\Sigma_{PUW}$ )

$$\begin{aligned} \Sigma_{PUW} &= \frac{\% \text{ change in participation probability}}{\% \text{ change in hourly wage}} \\ &= \frac{d(\text{probability})/\text{probability}}{d(\text{wage})/\text{wage}} \\ &= \frac{d(\text{probability})}{d(\text{wage})} \cdot \frac{\text{wage}}{\text{probability}} \end{aligned} \quad (C4)$$

As indicated in the text four variations on this formula are needed; one for the probit function, one for the logit function, and country-specific ones for both Sweden and Holland. Each is discussed in turn.

(i.a). the probit function

Using the chain rule, and denoting the participation probability by  $p$ ,  $\Sigma_{PUW}$  becomes

$$\Sigma_{PUW} = \frac{dp}{dS} \cdot \frac{dS}{dW} \cdot \frac{W}{p}$$

$$= \frac{d\rho}{dS} \cdot \frac{dS}{dW_0} \cdot \frac{1}{\rho} \quad (C5)$$

As noted in the text the marginal impact of a variable on the participation probability, i.e.  $d\rho_i/dX_j$ , is non-linear and individual-specific. For the  $X_j$ <sup>th</sup> regressor and the  $i$ <sup>th</sup> individual,

$$\begin{aligned} d\rho_i/dX_j &= (d\rho_i/dZ_i) \cdot (dZ_i/dX_j) \\ &= f(Z_i) \cdot (\delta_j/\sigma_{hh}^{1/2}) \end{aligned} \quad (C6)$$

where  $f(Z_i)$  is the density of a standard normal variable  $Z_i$  [ $= -(\delta/\sigma_{hh}^{1/2}) \cdot X_{hi}$ ], and  $(\delta_j/\sigma_{hh}^{1/2})$  is the probit coefficient for  $X_j$ . But  $f(Z_i)$  is equal to  $(\lambda_i \cdot \rho_i)$ . Substituting (C6) into (C4), the elasticity becomes

$$\begin{aligned} \Sigma_{PUW} &= \lambda_i \cdot \rho_i \cdot \frac{dS}{dW_0} \cdot \frac{1}{\rho_i} \\ &= \lambda_i \cdot (\delta_S/\sigma_{hh}^{1/2}) / \alpha_S \end{aligned} \quad (C7)$$

(i.b). logit function

Here  $d\rho/dX_j = (1-\rho) \cdot \rho$ , and so the elasticity becomes

$$\begin{aligned} \Sigma_{PUW} &= (1-\rho) \cdot \rho \cdot (\delta_S/\sigma_{hh}^{1/2}) \cdot \frac{1 \cdot 1}{\alpha_S \rho} \\ &= (1-\rho) \cdot (\delta_S/\sigma_{hh}^{1/2}) / \alpha_S \end{aligned} \quad (C8)$$

(i.c). Sweden

The Swedish study used the imputed hourly wage, denoted PW, as a regressor in the probit function. Substituting (C6) directly into (C4), and after re-arrangement, the elasticity becomes

$$\Sigma_{PUW} = \lambda \cdot PW \cdot (\delta_{PW}/\sigma_{hh}^{1/2}) \quad (C9)$$

(i.d). Holland

The dutch study used the natural log of the imputed wage, denoted LW here, as a regressor in the logit function. The elasticity now becomes

$$\Sigma_{PUW} = (1-\rho) \cdot (\delta_{LW} / \sigma_{hh}^{1/2}) \quad (C10)$$

(ii) Income elasticity of participation ( $\Sigma_{PI}$ )

To maintain comparability with the income elasticity of hours, this formula is

$$\begin{aligned} \Sigma_{PHI} &= W_0 \cdot d\rho / dHI \\ \Sigma_{PHI} &= W_0 \cdot \lambda \cdot \rho \cdot (\delta_{HI} / \sigma_{hh}^{1/2}) \end{aligned} \quad (C11)$$

(iii) Compensated Own Wage Elasticity of Participation ( $\Sigma_{PCW}$ )

This is the uncompensated elasticity adjusted for the income elasticity, i.e.

$$\Sigma_{PCW} = \Sigma_{PUW} - \Sigma_{PHI} \quad (C12)$$

$\Sigma_{PCW}$  will therefore have four variations, one for each variation of  $\Sigma_{PUW}$ .

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