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ABSTRACT

How Responsive is Female Labour Supply to Child Care Costs: New Australian Estimates*

The degree of responsiveness of Australian women's labour supply to child care cost has been a matter of some debate. There is a view that the level of responsiveness is very low or negligible, running counter to international and anecdotal evidence. In this paper we review the Australian and international literature on labour supply and child care, and provide improved Australian estimates of labour supply elasticities and child care demand elasticities with respect to gross child care price. We find that the limited literature in Australia has suffered from measurement error problems stemming in large part from shortcomings with data on child care price and child care usage. We use detailed child care data from three recent waves of the Household, Income and Labour Dynamics in Australia (HILDA) Survey (covering the period 2005 to 2007) to address these problems. We extend the standard labour supply and child care model to allow for separate effects of different child care prices for children in different age ranges and we calculate regional child care prices based upon child-level information. The salient finding is that child care prices do have statistically significant effects on mothers' labour supply and child care demand. The new estimates are in line with international findings, and their robustness is supported by a validation exercise involving an alternative technique and an earlier time period.

JEL Classification: J22, J13

Keywords: labour supply, child care price, child care demand, elasticity

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1. INTRODUCTION

A core principle behind child care policy in many countries including Australia is to assist women who wish to work to be able to fully participate in the labour market. This principle is based upon a belief that the labour supply of women is responsive to child care costs. The policy relevance of this issue has generated a considerable international and a small national literature on the responsiveness of female labour supply to the cost of child care.

Anecdotal evidence suggests that women do weigh up child care costs when making decisions about whether and how much to work. The international literature generally confirms the link between women's labour supply and child care prices, although the estimates are spread across a rather wide range. In Australia, on the other hand, the econometric literature finds that female labour supply response to child care cost is zero or at most very small.

The question is whether the labour supply of Australian women is truly non-responsive to child care costs or whether methodological shortcomings and data limitations have led to findings of such small responses. The primary aim of this paper is to answer this question. We begin by reviewing the existing Australian and international literature on labour supply and child care costs to identify modelling and data issues that may explain the existing findings. We then apply new techniques and data to model and analyse the labour supply

and childcare demand of married women with young children[1] focusing on key issues identified in our literature review.

We estimate the labour supply of married women with young children and the child care demand for each child in the household using data drawn from the fifth to seventh waves of the 'in-confidence' version of the Household, Income, and Living Dynamics in Australia (HILDA) Survey (covering the period from 2005 to 2007), and provide estimates of the responsiveness of married women's labour supply to child care prices. Our main objective is to estimate the labour supply elasticity with respect to child care price, which we will also refer to as the child care price elasticity of labour supply. This is defined as the relative (percentage) change in labour supply for a 1 per cent increase in the child care price.

The rest of the paper is organised as follows. The next section (Section 2) presents findings from the literature review, with discussion of modelling approaches, elasticity estimates, and modelling issues. Section 3 covers the new estimates of elasticities, undertaken in a manner which attempts to overcome a number of the shortcomings identified with previous estimates. Section 4 concludes.

1 In this paper, married women with young children include both legally married women and women in de facto relationships with children who are 12 years old or younger. They are also referred to as 'the mothers', and their partners are referred to as 'the fathers'.

2. FROM THE LITERATURE REVIEW

There are existing Australian and international review papers on women's labour supply and child care: see, for example, Brewer and Paull (2004) and Kalb (2009). This review takes a different angle; investigating whether modelling and data issues may explain the difference between Australian and international estimates. The findings from the review are presented below in terms of: economic models of parents' labour supply and child care demand, elasticity estimates, and modelling issues.

The international studies included in the review are generally for other OECD countries, including: the United States, Canada, the United Kingdom and other countries in Western and Northern Europe. The Australian and international studies covered in the review are summarised in Table A.1.1 of Appendix A.1.[2]

2.1 Common economic models of parents' labour supply and child care demand in the literature

The studies can be broadly classified into two categories based upon the assumptions they make about the household's demand for child care. We identify two key assumptions:

2 We exclude descriptive studies, including Australian studies such as Teal (1992), Van den Heuvel (1996), and Cobb-Clark et al. (2000). For example, Cobb-Clark et al. (2000) describe the pattern of labour supply of married women and child care demand and suggest that married women's labour supply is not affected by child care costs. However, they do not model the behavioural relationship between child care costs and labour supply.

- child care is used by the household to free up time for parents, especially for paid work, and thus forms part of the costs of working; and
- child care is an input for children's development and, as such, directly affects the welfare of the family.

Very few papers are based upon the first assumption alone, because it provides only a partial explanation of why families use child care. It effectively assumes that child care only forms a part of the costs of working and is determined by labour supply. While not common, this approach is separately identified here because two of the oft-cited Australian studies (Doiron and Kalb, 2005,[3] and Kalb and Lee, 2008) took this approach. We label this approach the 'costs of working model'.

The majority of the literature is based on models that take account of both assumptions: child care increases the cost of work, and child care is also important as a direct contributor to household utility through its impact on children's development. More and more evidence support the second assumption (see Jacob, 2009, for a review). In these models, labour supply and child care demand are chosen simultaneously; and we thus label this approach the 'simultaneous model'.

Studies can be classified further into one of two sub-groups depending upon whether household preferences are specified and estimated directly or not. This

3 An earlier paper, Doiron and Kalb (2002), covers the same material as Doiron and Kalb (2005).

distinction has been applied in this review to studies based on 'simultaneous' models, but not to the very few studies based on 'costs of working' models.

2.1.1 Costs of working models

By not capturing the role of child care as an input into children's development, the 'costs of working' models assume that child care enters the household decision-making process only as a cost of working. As mentioned earlier, this provides only a partial explanation of parental use of child care. The approach is, however, sometimes used as a 'useful vehicle for beginning the analysis of work incentive effects of child care subsidies' (Blau, 2003), especially in studies focusing on the impacts of complicated tax systems/reforms on labour supply (see, for example, Averett, 1997, and Blundell et al, 2000). This type of consideration was a factor in adoption of the 'cost of working' approach in the Australian studies by Doiron and Kalb (2005) and Kalb and Lee (2008).

The merit of the 'cost of working' approach is that it simplifies an otherwise complicated model in the case where the main focus is not on child care but there is a need to take child care into account in some minimal way. However, if households also use child care as an input into child development, ignoring this part of behaviour is likely to lead to biased estimates of labour supply responses to a change in child care costs. It is not possible to make any general statement about the direction of the bias generated in this situation. It will depend, in a complicated fashion, upon how households value the trade-off between general consumption and child development and between pure leisure and child development. More specifically, it depends upon the shape of the marginal utility functions with respect to labour supply, child care demand, and consumption (for more details, see the discussion in Appendix A. 2).

2.1.2 The simultaneous model

The conceptual framework in the 'simultaneous' approach assumes that households maximise their utility by choosing optimal consumption, leisure of the mother (or its complement, labour supply), and child care (for children's development), subject to a household budget constraint which is determined by wage rates, child care prices, and non-labour private income, together with the tax and welfare system (see, for example, Heckman, 1974; Ribar, 1992; Connelly, 1992). Both labour supply and child care demand are thus functions of wage rates and child care prices, and are simultaneously determined as a result of the optimisation process. The details of such a model are presented and discussed in Appendix A.2.

2.1.3 Direct and indirect approaches

Depending upon whether the utility function is specified and estimated, the empirical studies can be grouped further into two categories which are defined below.

In some studies, the preference (utility function) of the household is explicitly specified (together with the budget constraint) and estimated. We call this the 'direct approach'. Estimates of preference parameters are then used to obtain the optimal labour supply and child care demand, and the elasticities can either be derived as functions of the parameters or, more commonly, by simulation. The main advantage of this approach is that it allows for simpler analysis in environments of complicated tax and welfare settings, such as progressive tax and/or means-tested welfare systems. In addition, it is possible to calculate both gross price and net cost elasticities (see Section 2.2); the latter being probably more useful for policy makers. Where there is some form of assistance with

meeting the costs of child care, gross and net elasticities will generally differ from each other on average and for each household.

A disadvantage of this 'direct' approach is the un-testable assumptions regarding the functional form of the utility function. The function is simply asserted and estimated, and it is hard to make general statements about the consequences of any mis-specification of the utility function. Mis-specification is probably innocuous in some cases, but may produce misleading results in other cases. Another drawback with this approach is that the models are difficult to estimate, but with ever-increasing computer speed and power this disadvantage is rapidly diminishing.

In the 'indirect approach', labour supply and child care demand equations are specified and estimated.[4] These equations are consistent with the maximisation process, but normally cannot be associated with a particular utility function. In most cases, the equations are assumed to be linear so that they can be estimated using commonly available techniques such as ordinary least squares (OLS). A drawback of this approach is that it only provides average or approximated measures for the price effects on labour supply or child care demand. In most cases, the model assumes that the tax and welfare systems are linear or that each household faces the same simple tax and welfare system (for example, the same tax rate). The approach is thus clearly an approximate one in the case of complicated systems, such as the progressive tax and welfare structures that exist in most developed countries. Also, because it assumes away the complexity

4 This is the approach used in this paper. It is sometimes called the 'reduced-form' approach, for example, in Brewer and Paull (2004), but it is 'structural', as the equations are derived from the utility maximisation process and include 'structural' variables such as wage and child care prices.

of the tax and welfare system, this indirect approach does not allow the recovery of net price elasticities unless additional information or assumptions are imposed upon the correspondence between gross and net prices.

2.2 International and Australian elasticity estimates

2.2.1 Some definitions

The elasticity is the percentage change of a variable for a 1 per cent change in another variable. It provides a standardised measure of the responsiveness of one variable to another variable. In the context of this paper:

- the child care price (or wage, or income) elasticity of labour supply means the relative (percentage) change in labour supply which results from a 1 per cent change in child care price (or wage, or income); and
- the child care price (or wage, or income) elasticity of child care demand means the relative (percentage) change in child care demand which results from a 1 per cent change in child care price (or wage, or income).

Although a clearly defined concept theoretically, the exact definition of child care price elasticities reported by researchers does sometimes differ, making comparison difficult. For example, the child care price elasticity of labour supply in its narrow sense describes the change in hours worked by those working; in its broad sense it also includes the change in participation. In this paper, unless otherwise stated, the term 'child care price elasticity of labour supply' is used in its broad sense, which refers to both hours of work and participation. As in most of the empirical studies in this field, the terms 'participation' and 'employment'

are used interchangeably in this paper.[5] Another important distinction between reported elasticities comes from the measure of child care price itself. In most papers, elasticity is reported with respect to gross hourly child care costs. But in others, elasticities with respect to the 'net price' (the hourly child care cost after any tax and/or subsidy) are also reported. Still, in some studies, such as Connelly (1992), the reported elasticities are with respect to child care costs per hour worked.

2.2.2 Elasticity estimates

The 20 studies summarised in Table A.1.1 cover the United States, Canada, European countries and Australia. Most of them (18 studies) covered married women, seven of these studies also covered single parents, and two of the studies focused exclusively on single mothers. The estimated elasticities of labour supply from those studies are summarised in Table 1.

The most commonly reported elasticity is the gross child care price elasticity of participation. Estimates vary across a wide range (for example, from -0.92 to 0 for married mothers) but they indicate that, in general, the labour supply of mothers does respond negatively to increases in child care costs. This variation will partly reflect the fact that child care and other welfare institutions vary across countries, but differences in methodology and data sources may also play an important role which often make direct comparison difficult. Nevertheless, estimates from most of the international studies are negative and statistically significant, with an average of -0.34 for the married mothers. This provides evidence of an economically significant negative relationship between labour

5 In other contexts, labour force participation often means being active in the labour market; either employed or unemployed. In this paper, participation means employment, and does not include unemployment.

supply and child care costs. In contrast, the corresponding average of the three Australian estimates is almost zero.

Table 1. Estimates of labour supply elasticities[a] with respect to gross[b] child care price from the Australian and international literature

	Elasticity of employment					Elasticity of hours worked				
	No. of studies	No. of estimates around zero	Estimated elasticity			No. of studies	No. of estimates around zero	Estimated elasticity		
			Mean	Min	Max			Mean	Min	Max
Married mothers										
International	10*	0	-0.34	-0.92	-0.04	4	0	-0.34	-0.74	-0.12
Australian	3	2	-0.01	-0.02	0	3	2	-0.01	-0.02	0
All	13	2	-0.27	-0.92	0	7	1	-0.20	-0.74	0
Sole parents										
International	4*	1	-0.29	-0.58	0	1	0	-0.16	-0.16	-0.16
Australian	2	0	-0.12	-0.19	-0.05	2	0	-0.11	-0.16	-0.05
All	6	1	-0.23	-0.58	0	3	0	-0.12	-0.16	-0.05

* In one study, elasticities for two subgroups are reported.

(a) The elasticity of employment refers to the percentage change in the rate of employment. The elasticity of hours worked refers to the percentage change in hours worked, including the employment changes covered by the elasticity of employment.

(b) In one Australian study, Rammohan and Whelan (2005), the estimates are not strictly gross price elasticity, rather, they are somewhere between a net and gross price elasticity. See Section 2.3.

The notably low average elasticity for married mothers from the Australian studies is the result of consistently low estimates from the limited Australian literature: altogether, four papers which consist of two sets of related studies. For example, Rammohan and Whelan (2005) found that the elasticity of employment for married mothers was statistically insignificant. Doiron and Kalb (2005) and Kalb and Lee (2008), in two related papers, estimated the elasticity to be -0.02 and -0.00. Why is Australia so different from other countries? It would be folly to use the estimates from other countries for Australia without considering Australian institutions, but it is difficult to believe that Australian institutions are such that they remove all relationship between the price of child care and women's labour supply. Differences in samples, methodologies, and the exact definitions of elasticity may also be factors but are unlikely to explain the whole difference.

Seven of the studies that covered married mothers also reported an elasticity of hours worked. The four international studies had an average elasticity of -0.34 and a range between 0.12 and -0.74. The three Australian studies among the seven all provided estimates around zero. Where studies have provided elasticities of both hours worked and participation, the elasticities of participation are generally smaller than the elasticities of hours worked.

Turning to estimated elasticities for single mothers, the average gross child care price elasticity of participation across three international studies is -0.29, but just -0.12 for the two relevant Australian studies. For the elasticity of hours worked for single mothers, there are just three applicable studies, and an average child care price elasticity of hours worked of -0.12. Two of these three studies are related Australian studies which use the same 'costs of working' methods but data for different years.

2.3 Modelling issues

Our literature survey reveals that methodological issues may provide some explanation for the variation in estimated elasticities across studies and for the difference between Australian and international findings. These issues are mostly related to measurement error in the key variable, child care price, due to its construction.

In the literature, it is common to assume that households face a single 'price' for each type of child care (by type, we mean long day care, family day care, before school care, after school care, etc.). In many studies this price is constructed by dividing total child care costs by total child care hours, aggregating over children from very different age groups. The assumption being made in this construction is that child care of the same type for different children in the

household is a homogeneous good and can be represented using a single price. If true prices are different for each child, each price would have its own (albeit possibly the same) effect on the mother's labour supply and should enter the labour supply equation separately (see the discussion in Appendix A.3). It is also important to note that the 'price' constructed as the average *cost* of all child care to the household per hour is different from the average of hourly *prices*. The average cost of all child care per hour varies with the relative hours used by children of different age groups when the actual prices are different for each age group. It is the actual prices for each age group which should enter into the household's decision-making process. Treating the average cost of all child care per hour as a 'price' will cause biased estimates when households have more than one child. The consequences may be less pronounced for more homogenous samples: for example, if considering a sub-sample of only pre-school children, as in Blau and Hagy (1998).

A second issue which plagued the early literature was the lack of information about child care, especially child care prices, in survey data. Lack of good child care information forced researchers to construct various approximate measures of 'child care price'. Without observing any child care price directly, Heckman (1974) normalised the price of formal child care to '1' and 'estimated' the price of informal child care (relative to formal care) using demographic variables and an interesting number and array of assumptions. Connelly (1992) only had total child care costs in households where the mothers are working and no information on child care hours. She constructed the 'child care price' by dividing child care costs by hours worked of the mothers who work. This approach has been followed by several studies including Powell (1997) for Canada and Rammohan and Whelan (2005, 2007) for Australia. However, this

provides a problematic measure of the 'child care price' because it varies with hours worked even if the true child care price is constant. By construction, it is correlated with the variable it is intended to explain (hours worked), which means that it is endogenous and regression results will be unreliable.[6] Powell (2002) only had access to data about work-related child care. Moreover, with the exception of Blau and Hagy (1998), Doiron and Kalb (2005) and Kalb and Lee (2008), who used additional data sources for prices, all of the studies had to predict the 'price' for non child care users using information from the users of child care.

A third issue, and undoubtedly an important one from the families' point of view, is that of the heterogeneous quality of child care. Arguably, the household chooses not only hours of child care but also quality of child care. Ignoring child care quality in the model makes the 'observed' child care price endogenous and will lead to biased results. However, taking quality into account, and having adequate data on quality, are demanding tasks and Blau and Robins (1988) and Blau and Hagy (1998) seem to be the only studies that have modelled it to some satisfactory degree. They used a 'quality adjusted' price at the local market level predicted from additional data on child care providers. In an Australian study, Breunig and Gong (2010), studying the relationship between the average subjective assessments on child care availability, quality, and affordability in a region, found that these non-price factors have significant impacts on the labour supply of married mothers with young children.

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6 Connelly (1992) claimed that 'The measure of child care costs relevant to the labour supply decision of the mother is the total expenditure on child care per hour the mother is employed'. However, the number of hours worked and that of child care could correspond to each other in such a simple way if child care is only work-related.

Fourthly, an important feature of the child care market is the existence of informal child care which provides an (imperfect) substitute for formal care. Although the focus in most studies is on formal child care, the treatment of informal child care in modelling may also be expected to have an impact on the estimates. In some studies, such as Connelly (1992), informal care was not modelled explicitly, while in other studies it was; such as Heckman (1974), Blau and Robins (1988), and Blau and Hagy (1998).

The Australian literature suffers from additional data and modelling problems. Rammohan and Whelan (2006, 2007) used a sample of 1,138 married women drawn from the second wave of HILDA, where only about 190 cases in the sample paid for child care. In addition, the child care costs used in the analysis are the costs 'net' of government subsidies, which are partly determined by the labour supply of the parents.[7] Doiron and Kalb (2005) (and Kalb and Lee, 2008) use information on the average child care price by age group at the state level, though the measure may be too aggregated and quite noisy. Since prices within a state, particularly between metropolitan and other areas, are likely to vary considerably, this has the effect of adding a large amount of measurement error into the data. State-level prices are unlikely to capture the local market price to which households react when making child care and labour supply decisions.

7 Thus, unlike in Connelly (1992) and other studies using the same approach where gross costs are used to calculate the price measures, the Rammohan and Whelan estimates are not strictly gross elasticities. Nevertheless, these estimates cannot be called net elasticities either because the underlying assumption in the model used is that child care costs are linear with respect to the gross price (as one of the regressors) so that the calculated elasticity should be interpreted as being with respect to gross price. They calculate child care price based upon hours worked by the mother, which introduces additional endogeneity—see the discussion below in Section 3.1. This is probably one of the reasons why Rammohan and Whelan (2005, 2007) obtained different results from the other similar studies.

Hence it is not surprising that the reported estimates are very small, although it is hard to tell their statistical significance without standard errors. Another issue with the approach taken by Doiron and Kalb (2005) and Kalb and Lee (2008) is the way in which child care usage is determined. Child care usage is first predicted conditional on the level of labour supply. Household labour supply is then simulated from a model where households maximise their utility subject to a budget constraint from which these predicted child care costs (including account of their distribution) at each possible hours of work are subtracted. This procedure could be justified where there is a need to take child care costs into account in general labour supply modelling, but is arguably an over-simplification when the main focus is on child care. This is because there is an element of circularity with labour supply predicted by child care costs which have already been predicted by labour supply.

3. NEW ESTIMATES OF CHILD CARE ELASTICITIES USING AN EXTENDED STRUCTURAL MODEL

In this section, we provide estimates from an extended structural labour supply and child care demand model using data from three waves of the 'in-confidence' version of HILDA. The approach addresses a number of the modelling and data issues mentioned above. However, due to sample size issues, the estimates are only provided for married mothers: sole parents are not covered.

3.1 The extended structural labour supply and child care demand model

An implicit assumption in the standard simultaneous model is that there is only one (aggregated) child in the family. Generalisation to multiple-child households is not straightforward. It is difficult to argue that child care for

children of different age groups (for example, long day care for a pre-school child compared to after-school care for a 10-year old) are the same product and that families face a single child care price. It is also difficult to argue that the total or average parental care (or non-parental care) can be linked directly to children's development for those households with multiple children because this approach assumes that the family gives the same weight to child care hours irrespective of each child's characteristics. In other words, the assumption is that the family values child care the same for each child regardless, for example, of their age.

Our model extends the standard simultaneous model by recognising that households with multiple children may face more than one child care price and that households are simultaneously choosing mother's labour supply and multiple child care products. Within this simultaneous framework, we take the 'indirect' approach and estimate labour supply and child care demand equations separately.[8] Details of the model are presented in Appendix A.3.

Relaxing the restriction that the household chooses child care aggregately for all children, we allow child care prices to be different for children in three different age groups: 0-2 year olds, 3-4 year olds and school-aged children (ages 5-12 inclusive). This extension is important because it implies that labour supply depends upon all three child care prices.

8 An alternative approach could be to estimate labour supply and child care demand jointly. This would allow the error terms to be correlated with each other. Given our model specification, this choice matters more for efficiency than for consistency of the estimators.

It also implies that there is a separate child care demand for each child which depends upon own price and price for children in the other age groups. To simplify the empirical estimation, we restrict the effect of child care price in the labour supply function to be the same, so the estimated effect is effectively the average effect of the three child care prices. The restriction does not change the fact that labour supply is determined by three price variables. This is conceptually fundamentally different from what is in the standard model, where the only 'price' variable is actually the average child care costs of all children divided by the total hours (of child care or of mother's labour supply) and the coefficient is *the effect of average cost*. We added the restriction because we believe that the three child care markets are closely related so the individual price effects are hard to identify separately and it is easier to interpret a single average price effect instead of three.[9] Following similar reasoning as for the labour supply equation, we also restrict the cross-price effect in the child care demand function to be zero so that child care demand of a particular age group depends only upon the price in its own market.

We do not model informal child care and its price explicitly, as in most cases there is no payment made for informal care. However, we include in both the labour supply and child care demand equations variables such as the presence

9 It would be interesting in further work to relax this restriction to allow the differentiated price effects across age groups. The aim of this paper, however, is to determine whether on average, there is an price effect on labour supply, and we use this restriction to get a simpler interpretation of the parameters. We also estimated the model without this restriction, and found the effect of child care price of the youngest age group on mothers' labour supply is always negatively significant and its magnitude corresponds to that in the restricted model. The other prices are not always significant. This may be partly because the three prices are correlated and the effects of the other two are picked up by the first price, and partly because fewer school aged children use child care. The results of the unrestricted model are not presented but are available upon request.

of other female adults, migration status of the parents, and siblings in the family, which are likely to provide some information about the availability and shadow price of informal child care.

We calculate hourly child care prices by dividing the child care expenditure per child by the hours of child care used by that child, rather than the hours worked by the mother. This departs from previous studies, such as Rammohan and Whelan (2005) in two main ways: first, our price is a per child care hour price rather than a per hour worked price, and; secondly we calculate a price per child instead of a household average over all children.

The observed individual child care price may also be the result of idiosyncratic choices which depend upon factors unobservable by the researchers but which are also correlated with the labour supply and child care decisions. This is the so-called endogeneity problem. To overcome the endogeneity of child care price and to control for quality variation, we calculate and use in the regression the median price[10] for each age group at the level of the Labour Force Survey Region (LFSR) using all children from households in that LFSR.[11] [12] See more information on the construction of child care prices in Appendix 4. We believe the ex ante information that the households use for determining their child care demand is the price representing the local market where the households live and/or work and where they are most likely to send their children for care. Such a measure is in some respect a 'quality-adjusted' price as in Blau and

10 The medians are used on the grounds that they are less vulnerable to outliers than are means.

11 Australia was divided into 77 LFSRs according to the 2004 classification.

Hagy (1998), except that we do not have information on specific attributes of the providers at the local level and are thus not able to control for specific attributes as they did.[13] We do, however, include in the model variables such as the state average of proportions of staff with qualifications to provide some control for the quality of providers. Nevertheless, the extent to which households are able to use detailed information on various quality attributes of each individual provider in determining their demand for child care is questionable. Mocan (2007) shows that, in the US, information asymmetry often prevents parents from getting the right perception of child care quality even though they say that they care a lot about quality: in particular, parents have difficulty in distinguishing between quality levels of alternative providers.

3.2 Data

3.2.1 Data source and sample

Data used for the main analysis are drawn from waves 5, 6 and 7 of the `in-confidence' version of HILDA (hereafter referred to as 'the 2005-2007 Sample') Each wave of the survey is conducted in the second half of the corresponding calendar year, and the financial information is for the previous financial year. This choice of data is based upon the following three considerations. First, the data are pooled to give a sufficiently large sample to get good estimates of child care price in each LFSR (see Appendix 4). Second,

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12 We do not distinguish between types of child care, for example, between Long Day Care and Family Day Care, due to the small sample size. According to Child Care Census (2006), the average hourly prices are not very different between the two.

13 Blau and Hagy regressed price on a number of variables relating to quality. The simplest such regression is the average or median, thus, we argue that using the median of LSFR average out the idiosyncratic quality difference in a similar (but rougher) manner than in Blau and Hagy.

over the period from 2005 to 2007 child care policy was relatively stable, making pooling reasonable. For example, there had been no major change in Child Care Benefit over the period, and the Child Care Tax Rebate (now Child Care Rebate) had been announced at the beginning of the sample period but was not paid out to families until they filed their tax return for the 2006-07 financial year.[14] Third, only the data from wave 5 onwards have enough detailed child care information in the 'in-confidence' version of HILDA. In particular, it is only since then that data on both employment-related and non-employment-related child care usage has been collected for each child separately. In addition, the ABS Gross Child Care Price Index, which is used to make the child care price comparable across waves, is also only available from 2005.

We focus on the labour supply of married mothers and on the demand for formal child care of children under age 13 with fathers' labour supply assumed to be exogenous. After discarding observations with missing values for key variables, we use a sample of 4,184 married mothers and their 7,682 children in the 2005-2007 sample for estimating the models.

In the remainder of this section, we discuss the key variables used in the analysis such as labour supply, wages, and child care usage and costs. A number of demographic variables describing family and children's characteristics are included in the model; including variables such as immigration status and the presence of additional female adults in the household that are included to proxy

14 There are some minor adjustments, for example, in 2007 CCTR was shifted from a 'rebate' in the tax system to a 'payment' in the benefit system and would be paid in the financial year after the expenses were incurred.

the availability and the shadow price of informal child care. The sample statistics for the mothers are presented in Table A 5.1 of the Appendix.

3.2.2 Labour supply, wage, and non-labour income

For the period from 2005 to 2007, the average hours worked by the married mothers in the sample was about 18 hours per week with 67 per cent of the 4,184 mothers working at the time of interview. The average hourly wage was $22.5 for the mothers and $25.9 for the fathers for the 2005-2007 sample (in June 2005 terms). The wages of non-working parents and some of the working parents are not observed and are predicted by a standard Mincer wage equation using the Heckman (1979) procedure. The explanatory variables include age and its square, a set of education dummy variables, country of birth and family characteristics at the age of 14. Estimates of the wage equations correspond to typical estimates from the literature (see for example Breunig et al., 2008 and Breunig and Mercante, 2010) and are available from the authors on request.

Non-labour income is another variable which is predicted by theory to be a determinant of families' labour supply and child care preferences. The term 'non-labour income' includes the partner's earnings and the couples' unearned income, but excludes transfer income. As with the standard models in the child care literature, the father's labour supply is taken as given. Thus, the father's earnings form part of the 'non-labour income' of the mother. The average non-labour income, including fathers' earnings, was about $1,042 per week for the 2005-2007 Sample (in June 2005 terms).

3.2.3 Child care usage for the 2005-2007 sample

Of the 7,682 children in the 2005-2007 Sample, 4,640 of the children were school-aged children (defined as children aged 5-12 years) and the other

3,042 children were not yet in school (defined as aged between 0-4 years) at the time of the survey. A summary of formal child care usage by these children is given in Table 2.[15]

Table 2. Formal child care usage in couple households

Age group	% of children using formal care in each hour category per week					Children in formal care (%)	Avg. hours attended for those using formal care	Obs.
	1-9	10-19	20-29	30-39	40+			
Not-yet-in-school	22.0	37.2	21.4	9.5	9.8	38.8	19.7 (12.3)	3,042
School-aged	75.3	20.8	3.3	0.5	0.0	12.4	6.9 (5.7)	4,640
All	39.5	31.9	15.5	6.6	6.6	22.9	15.5 (12.2)	7,682

Standard deviations are in the parentheses. Source: calculated from HILDA

As would be expected, not-yet-in-school children use much more formal child care than school-aged children. About 40 per cent of not-yet-in-school children used formal care and the average hours attended by those using formal care was approximately 20 hours per week. This is a little bit more than the 18 average hours worked by the mothers in the sample. Only about 12 per cent of school-aged children used formal child care and, on average, these users spent about seven hours per week in care. Together with thirty hours at school, this equates to approximately the hours of a full-time worker.

15 For school-aged children, only care during the non-vacation period is considered.

To get an idea of how child care information from HILDA compares with that from administrative data, Table 3 presents information on child care usage from the 2006 Child Care Census (DEEWR, 2008).[16] Because the Child Care Census data does not distinguish between married couples and single parent families, the comparable HILDA data are for these two groups combined (not just for married couples). The pattern for not-yet-in-school children matches the Child Care Census data better than that for school-aged children, with the Child Care Census data showing fewer school-aged children using lower hours of care than in the HILDA data. This may be due to our weighting assumption in the Child Care Census calculation (as described in Footnote 16), which may somewhat overestimate the usage by school-aged children.

16 The child care census publication does not give a breakdown of hours of childcare by age. It presents the data by type of care (long-day care, family day care, before and after school care, and so on). It does give a summary of hours attended by all children and a proportion of children that are school-aged in each type of care. Using this proportion, children in each type of care were weighted into the school-aged and not-yet-in-school groups, under the working assumption that the number of hours in care is independent of age. This might look like an unrealistic assumption but, given that family day care is the only main type of care affected because of the wide usage by both school and not-yet-in-school children, we do not expect a significant impact.

Table 3. Comparison of formal child care usages between 2006 Child Care Census and HILDA

Age group	% of children using formal care in each hour category per week					Children in formal care (%)	Avg. hours attended for those using formal care	Obs.
	1-9	10-19	20-29	30-39	40+			
Not-yet-in-school								
HILDA all hh. (per child)	21.0	36.6	21.0	10.8	10.6	39.6	20.2 (12.1)	3,538
CC Census	25.7	33.4	20.9	10.3	9.6	-	-	-
School-aged								
Hilda all hh. (per child)	72.1	23.1	4.1	0.7	0	12.9	7.2 (5.7)	5,841
CC Census	56.5	35.5	3.9	2.0	2.1	-	-	-
All								
Hilda all hh. (per child)	38.9	31.9	15.1	7.3	6.8	23.0	15.6 (12.4)	9,379
CC Census	35.1	34.0	15.7	7.8	6.3	-	15.5	-

Standard deviations are in the parentheses.
Sources: calculated from HILDA and 2006 Child Care Census

3.2.4 Child care prices

One of the crucial steps in this analysis is the method used to obtain improved estimates of the hourly child care price. In HILDA, only child care costs net of 'regular child care benefits' are available. However, with information on child care usage by each child, gross family income, child and family characteristics, and eligibility rules for Child Care Benefits, we are able to construct the gross hourly child care price. See Appendix A.4 for details.

We also compare our calculated prices for the 2005-2007 Sample with the 2006 Child Care Census in Table A.4.1. In that table, both mean and median prices (converted to a June 2005 price using the ABS Child Care Price Index) for each state and territory and the two age groups are presented. The calculated medians largely resemble the means from the administrative data, especially for the younger age group. The constructed prices are somewhat higher than the administrative data for the school-aged children. Importantly, the relative rankings of the constructed prices are consistent with the data from the Child Care Census.

3.3 Results

Parameter estimates of the labour supply and child care demand equations (Equations 4'' and 5'' in Appendix A.3) for the 2005-2007 Sample are presented in Tables A.5.2 and A.5.3 in Appendix A.5. Model II differs from Model I in that interaction terms between the child care prices and non-labour income are included to capture the potential differentiated child care price effects across income groups. The inclusion of this interaction term also adds some flexibility in this kind of model with a restrictive linear functional form. The estimated parameters for the key variables — child care price, wage rates, and non-labour income are all significant, by themselves or jointly, with the expected sign. In particular, the interaction terms between child care price and other private income are jointly significant, indicating that the effects of child care price and other private income on labour supply and child care demand are different for different income groups. The coefficients of other private income are significantly negative in the child care demand equation, but are not statistically significant in the labour supply equation.

3.3.1 Elasticity estimates

Based upon the estimated models, elasticities of labour supply and child care demand for an 'average'[17] married mother with a child under 13 are calculated and presented in Table 4.

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17 By 'average' we mean a woman with the mean participation propensity (for the employment elasticity) or with the mean hours worked (for the hours elasticity) in the sample. These elasticity estimates are for a reference person, which vary (in this model, decreases) with her number of hours worked or employment propensity. In this case, the reference person is 'the average woman' so that the elasticity estimates are 'the elasticity of the average'. Alternatively, 'the average elasticity', which is defined as the average of the elasticities for everybody in the sample, could also be calculated. Both measures are commonly estimated and can be quite different.

Table 4. Estimated elasticities for the 2005-2007 Sample

	Labour supply elasticities		Child care demand elasticities	
With respect to	**Model I**	**Model II**	**Model I**	**Model II**
Child care price (at mean income)				
Hours	-0.654** [0.17]	-0.653** [0.17]	-0.644** [0.11]	-0.655** [0.10]
Employment	-0.287** [0.08]	-0.287** [0.07]		
Wage	0.350** [0.04]	0.349** [0.05]	0.223** [0.06]	0.227** [0.05]
Non-labour income (at mean price)^	-0.001 [0.01]	-0.005 [0.01]	-0.010 [0.01]	-0.014* [0.01]

Labour supply elasticities are calculated at 18 (the average) hours worked, and the child care demand elasticities are calculated at 15.6 hours, the average of child care usage. Standard errors are in the brackets,

** significant at 5 per cent level;

* significant at 10 per cent level.

^ Labour supply income elasticity is significant at higher price levels for Model II.

The first and most important finding shown in Table 4 is that the estimates of the child care price elasticities of labour supply are all significantly negative; in line with the international literature. For example, according to Model II, the point estimates of labour supply elasticities indicate that, for a typical married mother, for every per cent increase in the average child care price, her rate of employment would decrease by about 0.29 per cent, and her hours worked would decrease by 0.65 per cent. The 95 per cent confidence intervals are between -0.12 and -0.44 for the employment elasticity and between -0.32 and -0.98 for the hours worked elasticity.

Secondly, the estimates of the other elasticities shown in Table 4 are also consistent with theory and with the international literature. For example, the child care price elasticity of child care demand is estimated to be about -0.66, and the estimated wage and income elasticities of labour supply are approximately 0.35 and -0.01.

Thirdly, it is worth noting that the wage elasticity of child care demand is positive, which means that if the mother's wage is increased by 1 per cent, the family would increase the demand for child care demand for each of her

children (by 0.23 per cent according to these estimates). This implies the expected point that mother's labour supply and child care demand are strong complements.

Fourthly, we find indications that child care price elasticities vary across income groups. In Charts A.5.1 and A.5.2 (in Appendix A.5), we plot child care price elasticities of employment and child care demand against other private income. The magnitude of the child care price elasticity of child care demand decreases with income but the magnitude of the child care price elasticity of labour supply increases slightly with income. This can be translated as suggesting that, compared to lower-income families, in higher-income families the mothers' labour supply is more responsive to child care price changes but the demand for child care is less responsive. The confidence intervals are wide, but one interpretation may be that, when the child care price changes, females in low-income families are more likely to adjust their formal child care demand than their labour supply.

The variations in responsiveness with income are, however, quite small; especially when the width of the confidence intervals is considered. However, one has to bear in mind that the elasticities are with respect to gross child care price. Because of the nature of the tax and transfer system, in particular the means-testing of Child Care Benefit, the same change in gross price would mean different changes in net costs for women in high and low income families. Hence, the gross price elasticity may only approximate the variation in underlying responsiveness, and a net price elasticity would be a more useful measure for understanding the variation in responsiveness with income. To recover the net price effects, the direct approach should be used where the tax and transfer systems are modelled fully. The different pictures that could be

expected from gross and net price elasticities underline the need for care when comparing estimates from different studies.

3.3.2 Validation of the findings with alternative approach and data

Besides the standard testing of the econometric equations used to generate the elasticity estimates described above, further validation has been undertaken to help us understand the difference between these estimates and the earlier Australian estimates. Specifically, can the difference be attributed to the different estimation techniques (in particular, the treatment of child care price) or could it simply relate to the fact that the estimates refer to different time periods and use different data samples? As noted above, a gross price elasticity is specific to policy settings, and these have changed between the two periods in question.

For this validation, two techniques and two time periods are distinguished. The first technique is that used in this paper; the second is the technique previously used by Rammohan and Whelan (2005, 2008), which was in turn based on the Connelly (1992) model. The key difference between the two techniques is the way in which the child care price is calculated: in the Connelly (1992) approach, it is the average household child care costs per hour worked by the mother; in the approach used in this paper it is a per child cost per hour of child care used. The first time period is 2002-04 (the period in which the earlier estimates were made by Rammohan and Whelan); the second is 2005-07 (the period to which the main estimates in this paper relate).

A strength of the new estimates reported in this paper is their ability to exploit the more detailed child care data that have been collected in more recent waves of the HILDA survey. Such detailed child care data are not available for the earlier period, which means that our technique can not be fully applied to the

2002-04 period. But it can be applied to a subset of the population; couples with at most one child under school-age and at most one school-aged child. This subset, termed the 'restricted sample' is about half the size of the full sample.

The comparison uses the restricted sample for both 2002-04 and 2005-07, and also uses the full sample for 2005-07. The results are shown in Table 5. Selected parameter estimates of the model (using our approach with the 2002-04 sample and the Connelly approach using the full 2005-07 sample) are in Tables A.6.2 and A.6.3 in Appendix 6.[18]

The second column of Table 5 contains the elasticity estimates from the Connelly approach. This approach does not reveal any statistically significant relationship between the price of child care and mothers' employment for either period or sample. None of the estimates are significant at the 10 per cent level, which means that the estimate of a child care price elasticity from that approach is very imprecise. For example, the point estimate for the full 2005-07 Sample is -0.009 with a standard error of 0.35. This is consistent with the notion that larger measurement errors are likely to water down the estimates and illustrates that the particular way in which the child care price was measured is probably one of the main reasons why a statistically significant relationship with labour supply had not been found previously.

The elasticity estimates of employment using our approach are presented in the first column of Table 5. Our approach results in estimates of statistically

18 Parameter estimates for the other combinations of approach and sample covered by Table 5 are qualitatively similar to the corresponding estimates among those presented (parameter estimates for our approach applied to the 2005-07 sample are provided in Table A5.2).

significant negative elasticities for both of the two periods. For the earlier 2002-04 period, the point estimate of child care elasticity of labour supply is about -0.09 at the average income, which is smaller in magnitude than that for the later period. It is also less precise in that it is only significant at the 10 per cent level. In fact, the difference between the estimates using our approach with the restricted sample for 2002-04 and 2005-07 is not statistically significant.

Table 5. Validation: estimates of Australian employment elasticities[a] with respect to gross child care price using alternative techniques and for two time periods (married women with children)

	Estimation approach	
	Our approach	**Connelly approach**
Restricted sample[b]		
2002-04[c]	-0.1*	0.06
2005-07	-0.2**	0.02
Full sample		
2005-07	-0.3**	-0.01

** significant at 5% level;

* significant at 10% level.

(a) Elasticities are calculated for a married woman with the average probability of being employed (or the average hours worked) and average level of family private income (excluding her own earnings).

(b) The 'restricted sample' includes only those couples with at most one child under school-age and at most one school-aged child.

(c) The child care price index used is the ABS Gross Child Care Price Index for 2005-2007, but the CPI for 2002-04 (as the specific ABS child care price index is not available for this earlier period). Coefficients of other demographic variables.

Source: Own calculation using HILDA data.

In contrast to the findings from using the full 2005-2007 Sample, the child care price effect on labour supply is found to be slightly decreasing with income level

on the basis of the restricted 2002-2004 Sample.[19] The different findings may reflect the difference in the samples (one full, one restricted) or be due to the different time periods. Different policy environments for the two periods raises the possibility of a changing pattern across income in the relationship between gross price changes and the underlying net child care price changes. This again highlights how the gross price elasticities are specific to a particular policy environment.

4. CONCLUSIONS

In this paper we attempt to answer the question of whether the labour supply of Australian women is truly unresponsive to child care cost. We review the existing Australian and international literature on labour supply and child care price, and investigate the reasons why previous Australian econometric studies have not found convincing evidence for a relationship between the two. Our review found that the approach taken in the previous Australian literature, in particular the way in which the price of child care has been measured, has contributed to the view that women's labour supply is not responsive to the price of child care. In particular, measurement error problems, due to lack of data or the way in which variables are constructed, are common in the literature.

Having identified key methodological and data issues, we provide new estimates of labour supply and child care demand elasticities with respect to

19 As could be seen in Table A.5.1, the coefficient for the interaction between other private income and child care price is positive, implying that the child care price elasticity of employment decreases with income level in the earlier period. This is different from the later period. However, for both periods, the differences across income levels are not very large.

gross child care prices using new techniques and drawing on data from three waves of the 'in-confidence' version of HILDA.

The new estimates suggest that the cost of child care does have a statistically significant negative effect on the labour supply of married mothers with young children. This is in stark contrast with previous Australian estimates but well in line with the international evidence from comparable countries. The estimated elasticity of employment with respect to the gross child care price for an average married mother with young children is -0.3, and the corresponding elasticity of hours worked is -0.7. These results correspond to our intuition that child care price must matter for a woman's decision of whether or not to work and of how much to work. The estimated elasticity of employment is in the middle of the range of those found in the international literature, while the elasticity of hours worked is at the high end of the range of international estimates. The findings are supported by a validation exercise involving comparison with an alternative technique, and application of our technique to an earlier period.

There is scope for further improvement of the estimates with the availability of better data. There are also unanswered questions concerning, for example, the behaviour of sole parents, how the responsiveness of labour supply to child care costs varies with income, the role of informal child care, and changes in the relationship between child care price and labour supply over time. The availability of better data has been an important element in the new research reported here, and further steps in this area of research will similarly benefit from continuing improvement and availability of child care data. In addition, alternative approaches that take explicit account of the tax and transfer system and allow the calculation of the net price elasticity may provide more insights into the relationship between labour supply and child care.

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APPENDICES

A.1 SUMMARY OF THE LITERATURE

Table A.1.1 Empirical studies of female labour supply and child care demand

Approach category	Study	Country	Demographic group and data sources	Methodology	Estimates of gross child care price elasticities of	Measure of child care prices
Indirect simultaneous model	Connelly (1992)	US	Married mothers from SIPP (1984-85)	Probit labour force participation model	Participation: -0.2	Household child care costs per hour worked by the mother; child care data available for working mothers only.
	Ribar (1992)	US	Married women from wave 5 of SIPP	Probit labour force participation model	Hours worked: -0.74	Predicted weekly child care expenditure as a function of hours worked; child care data available for working mothers only.
	Powell (1997)	Canada	Married Women from CNCCS	Similar to Connelly (1992)	Participation: -0.38 Hours worked: -0.32	Predicted work related child care expenditure per hour worked by the mother.
	Kimmel (1998)	US	Married and single mothers from SIPP (1987)	Probit for participation	Participation: Married: -0.92 Single: -0.22	Predicted cost of child care per hour worked
	Anderson and Levine (1999)	US	Married and single mothers from SIPP (1990-1993)	Probit for participation	Participation: Married: -0.30 (mothers of<13), -0.46 (mothers <6); Single: -0.47 (mothers of<13), -0.58 (mothers <6);	Predicted cost of child care per hour worked
	Rammohan and Whelan (2005)	Australia	Married Women from wave 2 of 'general-release' HILDA	Linear labour supply model (similar to Connelly 1992)	Hours worked: -0.12 (insig.)	Net child care 'price' per hour worked by the mother.
	Rammohan and Whelan (2006)	Australia	Married Women from wave 2 of 'general-release' HILDA	Ordered porbit model of non-participation, partime, and full time work	Participation: 0.0 Working part-time: -0.06 Working full-time: -0.21	Net child care 'price' per hour worked by the mother. (as in Rammohan and Whelan, 2005)

Table A.1.1 (continued) Empirical studies of female labour supply and child care demand

Approach category	Study	Country	Demographic group and data sources	Methodology	Estimates of gross child care price elasticities of	Measure of child care prices
Direct simultaneous model	Heckman (1974)	US	Married Women from 1966 NLS	Estimable indifferences by maximum likelihood.	no direct estimate, but price effect of child care on marginal substitution rate of leisure is significantly positive	Child care prices are not observed. Prices of formal cares are normalised to 1 and those of the informal cares are estimated and assumed to be less one.
	Blau and Robins (1988)	US	Married Women from the 1980 Household Survey of the Employment Opportunity Pilot Projects	Indirect utility function	Participation: -0.38	Geographic site-average of non-zero child-care costs per child.
	Micgalopolous et al (1992)	US	Working women who purchased child care from wave 5 of SIPP (1984-85)	Utility specified and estimated	No estimates but suggested the child care price effect on hours of worked of the working women is close to zero but significant.	Weekly childcare expenditure.
	Ribar (1995)	US	Married women from wave 5 of SIPP	Structural labour supply model with utility estimated directly subject to a discrete budget constraint.	Participation: -0.09	Predicted weekly child care expenditure as a function of hours worked; child care data available for working mothers only.
	Blau and Hagy (1998)	US	Married women of children under 7 from National Child Care Survey and the Profile of Child Care Settings (1989-90)	Indirect utility function jointly estimated with labour supply, demand for quality and hours of child care	Participation: -0.20	Predicted 'quality-adjusted' hourly cost of child care
	Powell (2002)	Canada	Married Women from 1988 Canadaian National Childcare Survey (CNCCS)	Utility over labour supply and child care specified and estimated using multinomial logit models	Participation: -0.12 (derived from the results)	Predicted work related child care expenditure per hour worked by the mother.

Table A.1.1 (continued) Empirical studies of female labour supply and child care demand

Approach category	Study	Country	Demographic group and data sources	Methodology	Estimates of gross child care price elasticities of	Measure of child care prices
Direct simultaneous model	Andren (2003)	Sweden	Single mothers from Swedish Household Income survey (1997, 1998 pooled)	Structural labour supply model with utility estimated directly subject to a discrete budget constraint.	Participation: 0; Hours worked: -0.163	Predicted cost per hour of child care.
	Kornstad and Thoresen (2007)	Norway	Married Mothers from Home Care Allowance 1998	Structural labour supply model with utility estimated directly subject to a discrete budget constraint.	Participation: -0.12; Hours worked: -0.17	Predicted weekly expenditure.
	Wrohlich (2009)	Germany	Married mothers from three waves (2001-2003) of GSEOP	Similar as in Kornstad and Thoresen (2007)	Participation: -0.04 Hours worked: -0.13	
Cost of working	Averett et al (1997)	US	Married mothers from 1986 NLSY	Labour supply function with piece-wise linear budget set	Participation: -0.78	Child care cost per hour of work
	Blundell et al. (2000)	UK	Single and partnered mothers from Family Resources Survey (1994-1996)	Simulation based upon a labour supply model	Elasticities are not reported.	Weekly child care costs
	Doiron and Kalb (2005)	Australia	Lone parents and couples from CCS (1996) SIHC	Predicted child care costs using a reduced form bi-variate tobit model conditional on labour supply are included in the labour supply model. The elasticity is obtained from simulation	Lone parents: Hours worked: -0.05 Participation: -0.05 Married parents: Hours worked:-0.02 Participation: -0.02	Hourly child care prices are state averages or each age group weighted by number of children in each age of the family.
	Kalb and Lee (2008)	Australia	Lone parents and couples from SIHC and HILDA (2002)	Same as Doiron and Kalb (2005)	Lone parents: Hours worked: -0.16 Participation: -0.19 Married: Hours worked: -0.00 Participation: -0.00	Hourly child care prices are state averages or each age group weighted by number of children in each age of the family.

A.2 ECONOMIC MODEL BEHIND THE SIMULTANEOUS MODEL

In this approach, the household with characteristics X is assumed to maximize its utility, $U(y,l,c_m,X)$ by choosing general consumption y, maternal child care $c_m (=T-c$, an indicator for child development and the residual of the non-maternal child care c), and leisure of the mother l $(=T-h-c_m$, the residual of labour supply h and maternal child care c_m), subject to a budget constraint including child care costs, $y \le \tau(y_0 + w(T-l-c_m),X) - \nu(p(T-c_m),X)$, where y_0 is the non-labour income, w is the wage rate, T is the total time endowment of the mother and the child, and p is the hourly child care price.[20] In addition, τ is the tax and welfare system, and ν is the child care subsidy system, both of which may be determined by families' characteristics. To be specific, the household is assumed to be solving the following problem:

$$\underset{y,l,c_m}{Max}\ U(y,l,c_m,X) \tag{1}$$

$$\text{s.t. } y \le \tau(y_0 + w(T-l-c_m),X) - \nu(p(T-c_m),X) \tag{2}$$

The labour supply and child care demand of the household are thus governed by the first-order conditions:

$$\frac{U_l}{U_y} = \frac{U_c}{U_y} - \nu' p = \tau' w \tag{3}$$

20 In this literature of child care and maternal labour supply, it is often assumed that the father's labour supply is fixed and the mother is the one who takes the care responsibility.

where $U_s, s = y,\ l,\ c_m$ are marginal utilities with respect to its arguments, and τ' and ν' are the marginal change in after tax income and in child care costs. The optimal labour supply and child care demand can be derived from these conditions and can be written as

$$h^* = h(y_0, w, p, X) \tag{4}$$

$$c^* = c(y_0, w, p, Q) \tag{5}$$

where Q is the characteristics specific to the child.

If child care is ignored as an argument of the utility function when it should not be, the first part of condition (3) would be evaluated incorrectly and the resulting labour supply equation would be wrongly specified as well. This is why the costs of working approach may provide biased estimates of child care price elasticity of labour supply.

In the *Direct Approach*, the utility function (1) is explicitly specified (together with the budget constraint (2) and estimated. The estimates of the preference are then used to obtain the optimal labour supply and child care demand either by tangency rules or more commonly by simulations. The advantage of this approach is that it makes possible policy evaluations in environments of complicated policy settings, such as highly non-linear τ and/or ν. However, the disadvantages are that un-testable assumptions such as the functional form of the utility function have to be made and such models are often more difficult to estimate.

In the *Indirect Approach*, labour supply (or its transformation, for example, participation equations) and child care demand functions consistent with

first-order conditions of this maximization process (Equations 4, and 5) are specified and estimated. In most cases, they are assumed to be linear so that they can be estimated using commonly available techniques such as OLS. The drawback of this approach, however, is that its estimates are valid only in relatively simple tax and welfare systems such as linear or from relatively homogeneous samples such as each household facing the same tax and welfare system (for example, the same tax rate) and are at best approximate measures in the presence of complicated systems such as progressive tax and welfare institutions in most developed countries.

A.3 AN EXTENDED SIMULTANEOUS MODEL

Suppose the household has K children, the utility function (1) and budget constraint (2) of the household become

$$\underset{y,l,c^1_m,\ldots c^K_m}{Max}\ U(y,l,c^1{}_m,\ldots c^K_m,X) \tag{1′}$$

and

$$\text{s.t. } y \le \tau(y_0 + w(T-l-c^q_m),X) - \nu(\sum_{k=1}^{K} p^k(T-c^k{}_m),X) \tag{2′}$$

where $c^q_m(\equiv \max(c^1_m,\ldots c^K_m))$ is the length of time that the mother spends on parental child care which is assumed to be the same as the longest of the hours spent on each child.

Consequently, the optimal labour supply and child care demand are regulated by more first-order conditions so that Equations (3), (4), and (5) become

$$\frac{U_l}{U_y} = \frac{U_{c^k}}{U_y} - \nu' p^k = \tau' w,\ k=1,\ldots K, \tag{3′}$$

$$h^* = h(y_0, w, p^1,\ldots p^K, X), \tag{4′}$$

and

$$c^{k*} = c^k(y_0, w, p^1,\ldots p^K, Q),\ k=1,\ldots K. \tag{5′}$$

These equations are effectively functions of all instead of a single child care price. And, (5′) are K child care demand functions instead of one.

The specification assumes one type of care for each child, but it can be readily extended without further implications to multiple types including informal care as long as their prices are observed.

Empirical specification and estimation

To simplify the model we made some additional assumptions. In particular, in the labour supply equation, we restrict the effects of the three child care prices to be the same, and in the child care demand equations, we restrict the cross price effect (for the prices other than the price which the family faces for that child) to be zero and the effect of other explanatory variables to be the same for each child. Another simplification is that we assume the child care equations for each child are identical in parameters so that we can pool these equations for different age groups together for estimation.

Our empirical counterparts of Equations (4′) and (5′) are thus specified as follows,

$$h^* = \alpha + \eta^w \ln w + \eta^p \overline{\ln p} + \eta^I y_0 + \eta^{pI} (y_0 \cdot \overline{\ln p}) + \beta X + \varepsilon, \qquad (4'')$$

where the effects of various child care prices are restricted to be the same and

$$c^{k*} = \gamma + \theta^w \ln w + \theta \ln p^k + \theta^I y_0 + \theta^{pI} (y_0 \cdot \ln p^k) + \omega Q_k + \mu_k, \qquad (5'')$$

where α, η's, β, γ, θ's, and ω are parameters to be estimated. The interaction terms in all the equations capture potential differentiated price effects for various income groups.

We do not model informal child care and its price explicitly due to the fact that most of informal child care is not paid for. Instead, we include in X and Q variables, such as: presence of female adults, migration status of the parents, and

older siblings in the family. These are likely to affect the availability and shadow prices of informal child care.

We use the median hourly child care prices at the local LFSR where the household resides to overcome the potential endogeneity issue related to the individual price measures. (Higher prices paid by individuals may be correlated with higher quality care and this in turn may be correlated with other unobserved preferences which are related to labour supply.) It can also be seen as a measure of 'quality-adjusted' price. In addition, we include the state average percentages of qualified and experienced staff of child care providers in X to partly take account of variations in child care quality.

The labour supply equation (4'') and child care equations (5'') are specified as Tobit models and estimated separately using maximum likelihood methods. The correlation between the error terms in the two equations is ignored because otherwise we would need to estimate a multiple equation system with the number of equations varying from household to household. And in this case, the gain would only be to increase the efficiency of the estimates without affecting the consistency. The estimates and their standard errors are obtained by bootstrapping to take into account correlations between multiple observations from the same households.

A.4 CONSTRUCTION OF CHILD CARE PRICES

In the data, the number of child care hours is observed for each child and type of child care. It is believed that families only report child care hours used instead of hours paid for. We round up the reported hours in multiples of five hours and three hours (for not-yet-in-school children and for school-aged children, respectively) to reflect lengths of paid sessions.[21] Together with information on family taxable income and family structure, this information is used to calculate the Child Care Benefit (CCB) entitlement for each child.

Net child care costs are observed for each type of care but for all children in the same age group. The net costs are allocated to each individual child proportional to the child care hours of that type of care. The gross hourly price of each type of child care is calculated by dividing the sum of the net cost and CCB by child care hours of that type.[22]

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21 For not-yet-in-school children, long day care centres and family day care centres typically operate 50 hours per week, and typical part-time arrangements are at least in units of half-days. For school-aged children, typical after-school care sessions are 3 hours.

22 Gross hourly child care prices are calculated under the assumption that the child care costs reported by the household are not net of Child Care Tax Benefit (CCTR) on the grounds that CCTR payment was only paid after the sample period and that the prices calculated under the alternative assumption would be too high compared with the administrative data.

Table A.4.1 Comparison between hourly gross child care prices constructed from HILDA (the 2005-2007 Sample, at June 2005 price level) and from 2006 Child Care Census ($/hour of care)

* CC Census hourly prices for not-yet-in-school children are the averages of the long day care centres and family day cares weighted by the number of children in each type of care.

CC Census hourly prices for school-aged children are the averages of before and after school care per session fee divided by their typical session lengths (3 hours for after school care and 1.5 or 2 for before school cares).

Prices from Hilda are calculated from children from both couple and sole parent families.

	Not-yet-in-school Children			School-aged children		
	HILDA		Child Care Census*	HILDA		Child Care Census#
	Median	Mean		Median	Mean	
NSW	4.31	4.54	4.56	5.10	5.40	4.16
VIC	4.44	4.55	4.39	4.00	4.78	3.40
QLD	4.31	4.43	3.98	4.59	5.51	3.52
SA	4.17	4.19	4.14	4.48	5.12	3.52
WA	4.15	4.28	4.14	5.55	5.66	4.57
TAS	4.86	4.86	4.18	5.39	5.80	4.77
NT	5.00	4.59	4.04	4.87	4.88	5.36
ACT	5.72	5.16	4.88	5.41	6.78	4.93
All	4.33	4.49	4.31	4.62	5.26	3.68

The median price for each age group of children of each LFSR is calculated using the observed prices for each child. Thus, multiple observations from the same household are treated as different observations, but very few families have more than one child in the same age group. This requires sufficient number of observations in the LFSRs. Table A.4.2 shows that, most of the LFSRs are covered by the sample. And on average, the numbers of observations are reasonably large for this operation. For example, there are just under 10 observations in each LFSR for the youngest group.

Table A.4.2 Number of observed prices in LFSRs

Children in couple families	No. of LFSRs*	Average number of observations in each LFSR	Standard Deviations
0-2 year olds	65	9.7	6.6
3-4 year olds	65	11.1	8.1
School aged	61	13.9	12.2

* This is the number of LFSRs with at least one observed price for that age group out of the total 77 LFSRs in Australia.

A.5 SAMPLE STATISTICS AND PARAMETER ESTIMATES FOR THE 2005-2007 FULL SAMPLE

Table A.5.1 Sample statistics

Variables	The mothers Mean (Std. dev.)	The children Mean (Std. dev.)
Hours worked per week by the mother	18.20 (17.0)	
Hours of child care of children using care		15.47 (12.2)
Proportion of children using care		22.9%
Wage rate of the mother (at June 2005 price)	22.53 (26.0)	
Unearned private income of the mother	1041.93 (1192.6)	
Mean median child care prices (at June 2005 price)	4.73 (0.8)	
Age of the mother	36.63 (6.9)	
Dummy, mother received higher edu.		0.28
Dummy, mother received vocational edu.		0.25
Dummy, mother finished Year 12 only		0.20
Dummy, mother did not finish Year 12		0.27
Dummy, father received higher edu.		0.23
Dummy, father received vocational edu.		0.41
Dummy, father finished Year 12 only		0.17
Dummy, father did not finish Year 12		0.19
Age of the child		5.98 (3.8)
Dummy, presence of a younger sibling		0.43
Dummy, presence of an elder sibling		0.60
Dummy, sex of the child, 1 if boy		0.50
Indicator that the child is in school		0.60
No. of children aged 0 to 5	0.83 (0.8)	
No. of children aged 6 to 12	0.98 (0.9)	
No. of children aged 13 to 15	0.25 (0.5)	
Age of the youngest child	4.83(3.9)	
Dummy, presence of extra female adult	0.08	
At least one of the couples not Aus-born	0.23	
None of the couples Aus-born	0.12	
NSW	0.29	
VIC	0 .25	
QLD	0.21	
SA	0.08	
WA	0.09	
TAS	0.03	
NT	0.01	
ACT	.02	
% of child care staff w/t exp. (state avg.)		16% (8.0%)
% of child care staff w/t qual. (state avg.)		65% (48.0%)
Obs. (number of married mothers)	4,184	7,862

Table A.5.2 Tobit estimates of the labour supply equation

Variables	Model I	Model II	
(*ln*) wage of the mother	6.293**[7.03]	6.274*8[6.87]	The coefficient of child care price is jointly significant with its interaction with income at 5% level. ($\chi^2(2) = 20.12$) The coefficient of income is jointly insignificant with its interaction with price ($\chi^2(2) = 2.92$)
(The average of *ln*) child care prices	-11.775**[-4.27]	-3.438[-0.60]	
(*ln*) income excl. the mother's earnings	0.015[0.11]	2.428**[1.70]	
child care price × income		-1.555*[-1.71]	
Age	0.068[0.88]	0.069[0.92]	
No. of children aged 0 to 5	-4.986**[-5.84]	-4.979*8[-6.42]	
No. of children aged 6 to 12	-2.993**[-6.37]	-2.986**[-6.22]	
No. of children aged 13 to 15	-4.871**[-6.19]	-4.870**[-5.59]	
Age of the youngest child	1.478**[7.95]	1.473**[8.03]	
Dummy, presence of extra female adult	-2.826*[-1.88]	-2.884**[-2.15]	
At least one of the couples not Aus-born	-0.182[-0.21]	-0.203[-0.22]	
None of the couples Aus-born	-1.165[-0.93]	-1.272[-1.10]	
Constant	9.648*[1.85]	-3.283[-0.35]	
State dummies	Yes		
Year dummies	Yes		
Std. error of the model ($\hat{\sigma}$)	22.180(0.33)	22.171(0.30)	
Likelihood	-13,849.2	-13,847.2	
Obs. (number of married mothers)	4,184		

Bootstrapping methods are used for calculating the standard errors. The number of repetitions is 200. *t*-values (standard errors) are in the brackets (parentheses), * significant at 10%; ** significant at 5%. The reference groups for dummies are women in families with no-extra female adult, both couples born in Australia, from NSW in Year 2005.

Table A.5.3 Tobit estimates of the child care demand equation

Variables	Model I	Model II	
(*ln*) mother's gross hourly wage	3.550**[4.64]	3.611**[3.94]	
(*ln*) child care price	-10.241**[-5.86]	-18.037**[-5.65]	The coefficient of child care price is jointly significant with its interaction with income at 5% level. ($\chi^2(2) = 45.82$)
(*ln*) income excl. mother's earnings	-0.154[-1.24]	-2.363**[-2.87]	
child care price × income		1.428**[2.73]	
Age of the child	-0.774**[-2.22]	-0.779**[-2.35]	
Dummy, sex of the child, 1 if boy	-1.303*[-1.72]	-1.338*[-1.93]	The coefficient of income is jointly significant with its interaction with price at 5% level. ($\chi^2(2) = 8.68$)
Indicator that the child is in school	-22.038**[-14.61]	-21.963**[-14.30]	
Dummy, presence of a younger sibling	3.115**[2.36]	3.132**[2.51]	
Dummy, presence of an elder sibling	-3.236**[-3.55]	-3.249**[-3.35]	
No. of children aged 0 to 5	-2.160**[-2.73]	-2.133**[-2.96]	
No. of children aged 6 to 12	-2.535**[-4.33]	-2.546**-4.34]	
No. of children aged 13 to 15	-2.086**[-1.98]	-2.048**[-2.12]	
Age of the youngest child	1.113**[3.18]	1.127**[3.27]	
Mother's age	0.308**[4.38]	0.308**[4.84]	
Dummy, mother received higher edu.	1.292[1.11]	1.212[1.13]	
Dummy, mother received vocational edu.	1.094[1.04]	1.014[1.02]	
Dummy, mother did not finish Year 12	-2.255**[-2.03]	-2.327*[-1.95]	
Dummy, father received higher edu.	0.466[-0.40]	0.419[-0.40]	
Dummy, father received vocational edu.	-1.930*[-1.79]	-1.968**[-2.12]	
Dummy, father did not finish Year 12	-3.047**[-2.59]	-3.035**[-2.63]	
At least one of the parents not Aus-born	0.277[0.29]	0.229[0.26]	
None of the parents Aus-born	-0.503[-0.36]	-0.374[-0.31]	
Dummy, presence of extra female adult	-4.654**[-2.78]	-4.605**[-2.59]	
% of child care staff w/t exp. (state avg.)	-1.853**[-6.11]	-1.874**[-6.27]	
% of child care staff w/t qual. (state avg.)	0.366**[2.55]	0.373**[2.72]	
State dummies	Yes		
Year dummies	Yes		
Std. error of the model ($\hat{\sigma}$)	21.348(0.41)	21.338(0.44)	
Likelihood	-9,893.4	-9889.7	
Obs. (number of children)	7,682		

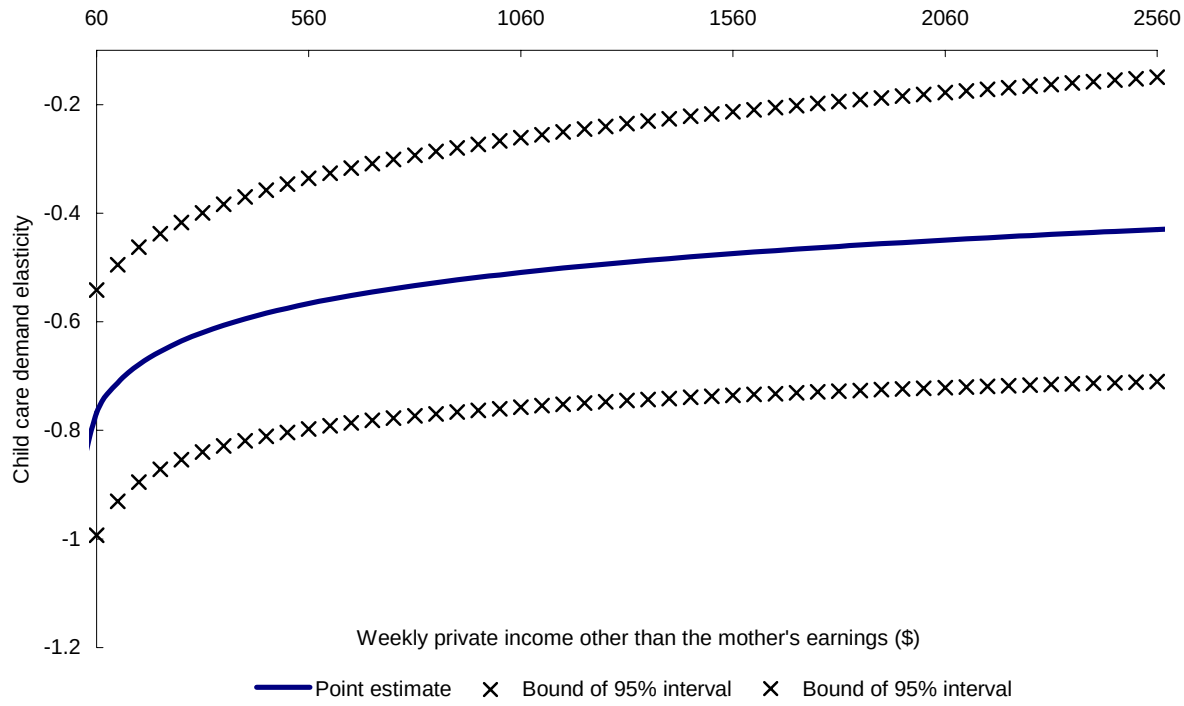
Bootstrapping methods are used for calculating the standard errors. The number of repetitions is 200. *t*-values (standard errors) are in the brackets (parentheses), * significant at 10%; ** significant at 5%. The reference groups for dummies are children in families with no sibling, no-extra female adult, both parents born in Australia, both parents finished Year 12, from NSW and in Year 2005.

The coefficient estimates for the demographic variables in Tables A.5.2 and A.5.3 (for the 2005-2007 Sample) are mostly in line with the literature. For example, the greater the number of dependent children in the family, the lower the mother's labour supply. Also, more dependent children in the family results in less demand for formal child care. This is explained by having more children in the family increasing the value of the mother's time at home and also decreasing the shadow price of informal child care (by siblings). The negative effect of the presence of extra female adults on child care demand may also indicate similar

effects on informal child care. Meanwhile, the younger are the children, the lower is the mother's labour supply, but greater is the child care demand — in such cases, the mother's time may be devoted to the younger child and the need for child care increases as well.

Chart A.5.1 Employment elasticity with respect to child care prices

Chart A.5.2. Child care's own price elasticity



A.6 VALIDATION

The extended labour supply model is also estimated using waves 2, 3 and 4 of the `in-confidence' version of HILDA for validation purposes (hereafter, 'the 2002-2004 Sample').[23] However, the available child care data for this period are less detailed than for the 2005-07 Sample. In particular, the data on non-employment-related child care usage are aggregated for children in two age groups (not-yet-in-school and school age) in the family. We thus only select families with at most one child in each age group in which employment-related and non-employment-related child care usages and costs could be matched for each child. This results in a notably smaller sample of 2,111 mothers of 2,661 children. In addition, because the ABS Gross Child Care Price Index is not available for this earlier period, we have to use the CPI as the deflator for child care prices. This is likely to be less accurate than use of a specific child care price index and will thus contribute more to the measurement error in the child care price variable in the pooled data. The child care policy environment was also a little different in 2002-04 compared to 2005-07. In particular, the Child Care Tax Rebate had not been announced in this period. These data issues need to be borne in mind when the results are compared with those for the later period.

Nevertheless, the labour market variables for the 2002-04 period are not too far apart from those in the later period. For example, the mothers in the 2002-2004 sample worked on average around 18 hours per week and had an employment rate of 64 per cent; comparable to the 2005-07 period. The hourly wages are about $20.0 for the mothers and $24.2 for the fathers (all at June 2005 price

23 Wave 1 of HILDA is left out because households were only asked about employment-related child care.

levels). Non-labour income was $939 per week for the 2002-2004 Sample (also at June 2005 price levels).

Detailed sample statistics and parameter estimates for the alternative model/samples are presented in the tables below for comparison with those in Appendix 5.

Table A.6.1 Sample statistics of the restricted samples of the married mothers

Variables	The 2002-04 sample Mean (Std. dev.)	The 2005-07 sample Mean (Std. dev.)
Hours worked per week by the mother	18.20 (17.0)	19.98 (17.4)
Wage rate of the mother (at June 2005 price)	20.00 (9.5)	22.00 (15.1)
Unearned private income of the mother (at June 2005 price)	939.0 (890.5)	1036.6 (1116.0)
Mean median child care prices (at June 2005 price)	2.28 (0.7)	4.73 (0.8)
Age of the mother	36.73 (7.2)	36.90 (7.7)
No. of children aged 0 to 5	0.65 (0.6)	0.62 (0.6)
No. of children aged 6 to 12	0.59 (0.5)	0.60 (0.5)
No. of children aged 13 to 15	0.32 (0.5)	0.31 (0.5)
Age of the youngest child	5.23(4.2)	5.39 (4.3)
Dummy, presence of extra female adult	0.09	0.10
At least one of the couples not Aus-born	0.25	0.24
None of the couples Aus-born	0.12	0.13
NSW	0.31	0.28
VIC	0 .26	0.25
QLD	0.21	0.23
SA	0.09	0.08
WA	0.08	0.10
TAS	0.03	0.03
NT	0.0	0.01
ACT	.02	0.02
Obs. (number of married mothers)	2,111	7,862

Tables A.6.2, which presents the parameter estimates of our model using 2002-2004 data, is for comparison with Table A.5.2.

Table A.6.2 Tobit estimates of the labour supply equation (the 2002-2004 Sample)

Variables	Model I	Model II	
(*ln*) wage of the mother	7.221**[4.45]	7.212**[4.47]	
(The average of ln) child care prices	-3.743*[-1.76]	-10.372**[-2.74]	The coefficient of child care price is jointly significant with its interaction with income at 5% level. ($\chi^2(2) = 8.80$)
(*ln*) income excl. the mother's earnings	0.408**[2.24]	-0.552[-0.92]	
child care price × income		1.242*[1.80]	
Age	0.134[1.09]	0.129[1.14]	The coefficient of income is jointly significant with its interaction with price ($\chi^2(2) = 7.34$)
No. of children aged 0 to 5	-1.662[-0.86]	-1.636[-0.88]	
No. of children aged 6 to 12	2.301[1.45]	2.410[1.36]	
No. of children aged 13 to 15	-2.236*[-1.72]	-2.280**[-2.21]	
Age of the youngest child	1.274**[4.16]	1.278**[3.84]	
Dummy, presence of extra female adult	-5.457**[-3.37]	-5.526**[-2.81]	
At least one of the couples not Aus-born	-	-	
None of the couples Aus-born	-0.359[-1.32]	-0.202[-0.16]	
Constant	-18.210[-2.86]	-12.983*[-1.93]	
State dummies		Yes	
Year dummies		Yes	
Std. error of the model ($\hat{\sigma}$)	-23.631(0.41)	23.607(0.47)	
Likelihood	-6810.8	-6808.9	
Obs. (number of married mothers)		2,111	

t-values (standard errors) are in the brackets (parentheses),
** significant at 5 per cent. The reference groups for dummies are women in families with no-extra female adult, both couples born in Australia, from NSW in Year 2005.
* significant at 10 per cent.
Bootstrapping methods are used for calculating the standard errors. The number of repetitions is 200.

Table A.6.3 Parameter estimates of Connelly (1992) model (the 2005-2007 full Sample)

Variables	Two-stage child care costs model			Structural labour force participation equation
	Bivariate probit model (first stage)		OLS for child care costs (second stage)	
	Paying for child care	Reduced-form participation		
(*ln*) wage of the mother	0.140**[2.98]	-	3.157**[3.93]	0.969**[12.43]
(The average of ln) child care prices	-	-	-	-0.019[-0.35]
(*ln*) income excl. the mother's earnings	0.003[0.41]	0.013*[1.78]	0.045[0.77]	0.010[1.29]
No. of children aged 0 to 5	0.177**[4.19]	-0.192**[-4.48]	2.201**[2.67]	-0.182**[-3.98]
No. of children aged 6 to 12	-0.155**[-5.28]	-0.089**[-3.14]	-1.224[-1.43]	-0.093**[-3.24]
No. of children aged 13 to 15	-0.257**[-4.83]	-0.185**[-3.94]	-2.360[-1.55]	-0.231**[-4.68]
Ae of the mother	-	0.001[0.16]	-	-0.003[-0.82]
Dummy, presence of extra female adult	-0.230**[-2.43]	-0.185**[-2.23]	-2.132[-1.35]	-0.229**[-2.63]
Age of the youngest child	-0.037**[-3.70]	0.088**[8.38]	-0.449**[-2.22]	0.081**[6.54]
Mother received higher education	-	0.403**[6.26]	-	-
Mother received vocational education	-	0.060[0.95]	-	-
Mother did not finish Year 12	-	-0.369**[-5.88]	-	-
At least one of the couples not Aus-born	0.063[1.20]	-0.096*[-1.84]	0.564[1.19]	-0.107*8[2.01]
None of the couples Aus-born	-0.073[-1.02]	-0.324**[-4.70]	0.004[0.01]	-0.259**[-3.65]
constant	-0.843**[-4.84]	0.275*[1.73]	-17.839*[-1.71]	-2.449**[-10.70]
ρ		0.395(-0.03)	-	
λ	-	-	10.158[1.39]	
State dummies	Yes			
Year dummies	Yes			
R^2		-	0.17	-
Likelihood		-4510.5		-2252.4
Obs. (number of married mothers)		4,194	915	4,048

Bootstrapping methods are used for calculating the standard errors. The number of repetitions is 200. *t*-values (standard errors) are in the brackets (parentheses), * significant at 10%; ** significant at 5%. The reference groups for dummies are women finished Year 12 in families with no-extra female adult, both couples born in Australia, from NSW in Year 2005. For details of the model, see discussions in Rammohan and Whelan (2005) or Connelly (1992).