Relevance of economic theory for improving economic evaluation in public health: case of physical activity

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Abstract

Rationale: There is a growing need to evaluate the efficiency of interventions designed to increase physical activity. The complexity of preferences and demand for behavioural change interventions challenges accepting QALYs as an outcome measure in economic evaluation. For example, physical activity: has investment and consumption characteristics; may reflect an unavoidable life style or active choice; could be related to working hours and the demand for leisure; may influence household welfare and derived demand for health. Prior to valuing the benefits of interventions it is important to know what to measure and consider how. *Aims*: We reviewed empirically tested economic theories focussing on leisure-consumption decisions, household allocation of time and labour supply, as well as household production and health behaviour applicable to the complex demand for physical activity. *Methods*: A systematic search revealed 31 papers. 27 data extraction questions captured; the specification of models, population focus, characteristics of decision-maker(s), main findings and given critiques, as well as facilitated consideration of the relevance to household demand for physical activity. Results: The models focussed on individuals or households (two people or one representative agent) with time having single or multiple uses, very occasionally at the same time. Benefits measured included externalities at the household level, income earning potential through increased hours and QALYs, but job characteristics can also determine valuation of benefits. *Discussion*: Our discussion considers how well physical activity is proxied by this literature and the potential nature of demand for physical activity. We end by raising questions for broader discussion on the role that willingness to pay could play in capturing the broader benefits of physical activity interventions.

Keywords: economic evaluation, public health, physical activity, economic theory

Public health in the UK has been criticised for failing to deal with health problems such as obesity, smoking, excessive alcoholism and physical inactivity among others (Jochelson, 2005). Given the expected cost-effectiveness of doing so, the Wanless report (2004) recommended that the public health agenda be redirected to a "fully engaged scenario". This scenario implied a major increase in resources would be needed in the short run. However, the paucity of evidence about the effectiveness and efficiency (Wanless, 2004) of alternative health promotion activities provided little

indication of how best to spend current resources, let alone major increases in resources.

The *White Paper* (2004) highlighted decreasing levels of physical activity over the last 25 years as a major public health concern. However, the promotion of physical activity, like other lifestyle interventions, is complex. The complexity of demand for physical activity is likely to include investment characteristics, impacts on the time available for productive activities as well as consumption characteristics, and utility as a result of better health in the context of risk and demand within a household. The dominant approach to economic evaluation of health interventions in the UK is to judge the relative efficiency of health programmes using cost per QALY. However, in the context of public health interventions to increase physical activity, this approach is likely to be biased as QALYs miss key benefits (e.g. value attached to different processes of care, non-health benefits) and analysis would be limited because economic evaluation does not tend to explore why uptake of interventions vary.

Programmes designed to increase physical activity, if successful, require individuals to change the way they allocate their time and money and choices of individuals may not match the understanding or interests of public health professionals. Economics can play a key part in developing an understanding of how and why people engage in physical activity. However, to date, these theories have been drawn upon rarely within health economics to value benefits or explain behavioural change and little has been considered in relation to lifestyle interventions of public health programmes. Our overarching research objective is to consider what benefits of physical activity interventions should be valued and how. However, an early search of databases showed that few specific papers have been written.

This paper therefore reviews a range of empirically tested economic theories (leisure-consumption decisions, household allocation of time, labour supply, household production and health behaviour) likely to cover the complexity of demand for physical activity and reflects on: (a) their potential ability to explain

the demand for physical activity interventions and (b) their potential contribution to improving economic evaluation of such interventions.

Methods

The methodology is formulated to locate theories that have variables that could be proxies for physical activity. Of course, some of the models were not originally created to explain the demand for physical activity. However, we have set out to interpret the main dependent variables like leisure and health as suitable proxies for physical activity.

Search strategy

The literature search, which was undertaken between 10th March and 8th September 2006, involved 6 electronic databases (Web of knowledge, Scopus[1], IBSS, Econlit, JSTOR, and Econpapers)[2] and textbooks[3]. The free text terms presented in Appendix 1 were developed by the authors and included two terms ('exercise' and 'fitness') used in searches by NICE (2006). Search terms were contrived to retrieve studies on behaviour related to physical activity, health, leisure and allocation of time. The search terms were modified to suit searches in individual databases, given the nature of the search engines. For example IBSS and Web of Knowledge allow only a limited number of search terms. Other databases returned search terms such as "need*", "want*", "model", "theor*" with too many general and irrelevant papers. Other terms such as "not sociolog*", "not psycholog*", "not agricult" were also introduced to avoid irrelevant returns (see Appendix 1 for details).

Selection criteria

A selected paper had to satisfy all the requirements of the following criteria.

- Economic theory that explains demand for leisure, health, physical activity or their combination.

[1] Which includes 100% coverage of Medline
[2] CINHAL was rejected because it generated only papers on psychological, sociological and medical models, which are not the focus of this paper.
[3] We acknowledge advice of Alan Manning (LSE), Yiannis Georgellis (Brunel) and Ralitza Dimova (Brunel) in selecting the textbooks.

- The theory must be empirically tested and the data for the empirical testing should come from a high income country.[4]
- A study should set out a model and test it empirically not vice versa. This is to avoid studies primarily based solely on atheoretical empirical analysis.
- Papers written in English language, because there were no resources for translation.

Search results

Titles and abstracts of 3507 papers produced by the search were screened using the selection criteria. 126 abstracts were selected and managed by the *Refworks reference manager* to find duplicates, after which 70 papers were identified for retrieval. The retrieved papers were further examined for inclusion using the selection criteria. A total of 37 papers did not merit inclusion. 2 papers were requested via the inter-library loan but have not yet been received. Appendix 3 lists the 31 papers reviewed.

Review questions

27 questions were used to review the papers. These questions extracted information in six main areas: specification of model, population focus, characteristics of decision making unit, main findings, model's relevance to the demand for physical activity and critique of the study. Appendix 2 provides the full set of review questions.

The questions related to the specification of model were designed to highlight the basic characteristics of the papers, the arguments of their models and to reveal variables influencing economic behaviour. Questions on population

[4] Since the focus of the research is public health in the UK, theories tested in countries in the same income bracket like UK are more likely to be easily applicable. The analogy stems from the fact that there is an inverse relationship between GDP and leisure (www.treasury.gov.au/documents/). The Human Development Index (HDI) was used as the criterion for identifying high-income countries. Countries with HDI of 0.8 are classified in the high-income bracket. HDI is used by the UNDP (United Nations Development Programme) to measure the standard of living of countries. Gross Domestic Product (GDP) is one its main dimensions. 2005 report was used as main index of selection (http://en.wikipedia.org/wiki/Human_Development_Index).

focus help identify the adaptability of models to sections of a population and potential datasets for future research.

Questions on characteristics of the decision-making unit underlined how individuals and households undertake decisions. Knowledge about how the different types of decision making units make choices is essential to the interpretation of diverse economic behaviour as it will help understand how the interests of others (e.g. children) and attributes of the representative agent affect decision making. Data extracted on time use categorisation and the results of the studies constituted the main findings.

Since the models tended to be originally formulated for a different context, it was important to discuss their applicability to our research objective. A model's relevance to the demand for physical activity was considered using the strengths and weaknesses of research proffered by authors, our views on the positive and negative characteristics of potential proxies for physical activity within a model as well as our assessment of these studies, both generally and with respect to our research objective.

Results

Background

The papers spanned 4 continents with 19 papers from the US, 9 from Europe (2 each from UK, Holland and France; and I each from Denmark, Germany and Sweden), 2 studies from Japan and 1 from Australia. The majority of studies reviewed were published between 1991 and 2000. Theories of leisure-consumption were most numerous (32%) followed by health behaviour (29%), allocation of time (16%), labour supply (13%) and household production (10%). The empirical analysis of the theories centres on individuals (65%) and households (35%) as representative agents. All empirical applications of the literature considered the working population, with only six including the non-working population.

Specification of models

The utility models employed were all based on a utility function comprising leisure and consumption goods (as well as health[5] in some cases). The utility function was constrained by the prices of the arguments of the utility, the wage income and non-labour income available to the consumer as well as total time, which is allocated between the alternative uses[6]. The main dependant variables were leisure, consumption goods and health with the independent variables being wage, non labour income and prices of consumption goods and health inputs. In practice: consumption goods were specified as durables, non-durables and semi durables; leisure was seen as non working time; health was self reported measurement; non labour income was regarded as the difference between total income and wage income; and wage was represented by labour earnings. The prices of the consumption goods were mainly retrieved from price index data and the price of health inputs was represented by medical fees. There were, however, differences between the broad types of theories with regard to the structure and components of the utility function as well as the construction of the constraint facing the utility of the representative agent (Appendix 4 provides a descriptive summary of the models) and the next section outlines the main differences.

Components of the utility function

Leisure consumption theories introduced peculiar arguments in the utility function. For example Owen (1971) referred to market recreation (specified in practice as motion picture admissions, sporting goods, television sets, radios, phonographs, and other recreational goods and services) in the utility function). Atroistic (1982) also noted that the utility function was not made of only leisure and consumption goods but also the job characteristics (denoted in practice as responsibilities, training, aspirations, targets and financial benefits of current job) of the representative agent.

[5] Health was conceptualised as either professional or self care/both (eg. Bentzen et al., 1989; Propper, 2000)

[6] The alternative uses could be dual (i.e. time is used for either labour or leisure) or multi (i.e. time is used for labour, leisure and household).

The health of a child and goods affecting it, were described as arguments in the utility function by the health behaviour category. Rosenweig et al (1983) illustrated the goods affecting the child's health as cost per packet of cigarettes (including excise tax) and price per quart of milk.

The household production theories mainly typified the consumption goods in the utility function as home produced goods and market goods. Household production is usually constrained by a technology parameter which indicates that time inputs of members of the household and market inputs are combined to produce home goods. Market goods consist of intermediate goods and finished products. Time spent on child care services[7] could be an argument in the utility function. For example the time input of the mother with regards to the production of care for her sick child (Van Den Brink et al., 1997).

The particular features of the labour supply theories are the introduction of joint household care level (Klaveren et al., 2000) and public domestic good (Couprie, 2003) in the utility function. No detail was provided on the practical specification of joint household care level but public domestic good was specified in practice as household produced good whose consumption by one member of the household does not affect its consumption by other members.

One study in the allocation of time category had a wide variety of components in the utility function. Bhat (2004) described the individual as maximising the sum of utilities accrued from allocating time to five activities (i.e. home social activities[8], home recreational activities[9], out of home social activities[10], out of home recreational activities[11], out of home shopping activities[12]).

Structure of the utility function

[7] It was measured by the time spent by the mother on child care and pegged at 23 hours per week
[8] conversation at home
[9] watching TV, exercising, hobbies undertaken at home
[10] visiting family and friends
[11] Same activities as home recreational activities but undertaken outside home
[12] non grocery shopping activities

Only the leisure-consumption category showed diversity in approaches to the structure of the utility function. For example, Barnett (1979) described a two-stage model that sees the consumer as maximising a utility function of consumption-leisure choice constrained by the income level at full employment level which covers the expenditure on leisure and consumption. The underlying assumption of this utility function is the "shadow world" (i.e. under Kuhn Tucker conditions the price of leisure is equal to wage rate and income level adjusted to full employment where the per capita of labour supply is not constrained by the per capita labour demanded). The above utility function was split into a labour supply function (where the consumer allocates full income over leisure and aggregate commodity consumption expenditure) and consumption function (the consumer allocates aggregate expenditure over goods subject to a budget constraint). However, since conditions for the two-stage model do not exist, a Rotterdam model[13] unifying both consumption decision function and the labour supply function is estimated at the aggregate level.

Utility Constraints

Three[14] broad types of models introduced different constructions of the constraints facing the utility function. The health behaviour models (eg. Cameron et al., 1998) characterised the constraint facing the utility function in stages: without knowledge of his health state, the individual allocates exogenous income between insurance and savings; when he realises his health state, he then shares his saved income between contingent consumption and assets that yields an interest between the 2 time periods; the income he receives at the end of the second period that accrues from the value of assets is allocated between consumption for the second period and net health expenditures (i.e. prices of health care services and the reimbursement of the insurance premium).

[13] It shows the share of average expenditure on set of goods in transition period (i.e. period before the present year and the present year) which must be equal to the total real per capita income during that period plus the price of the set of goods consumed.

[14] Allocation of time category, household production category and health behaviour category

Solberg and Wong (1991)[15] also introduced the price of commuting to the work place as a component of the constraints facing the utility function and represented non labour income with the weekly income of children in the household. They cited data inadequacies for their unique specification of non labour income.

Arronson (2001)[16] composed the constraint facing the utility function in a unique way. He described the agent's share of the household full income which consist of wage and non wage income, and influenced by characteristics of the household and EEP (i.e. extra environmental parameters-interpreted as the opportunity cost of marriage) as constraining the utility function. However, if the household produced good is marketable, a price variable (representing the shadow price of the market consumption good) also constraints the utility function.

Characterisation of decision making

The theoretical analysis of 20/31 papers focussed on the individuals, with the rest (11/31) focussing on households. All papers analysed the observed behaviour of the representative agents. The composition of the household tended to vary among studies: 60% described a two-person household[17] where there was mostly "interconnectedness" of decisions. For example Klaveren van et al. (2006) found that wage increases lead to forward bending labour supply curves for workers but a backward sloping supply curves for their spouses.

17/31[18] papers observed that the presence of others (e.g. children, spouse) affect decisions by individuals or households. For example, individuals with several adult members in their households have a higher propensity to allocate more time to home recreational activities (Bhat, 2004). Couprie

[15] Allocation of time theory
[16] Household production theory
[17] 40% specified a one-person household
[18] Differences exist between how the broad types of theories characterised the decision making process. The household production models addressed the interests of others and individual attributes more frequently but leisure-consumption models tend to consider those aspects of decision making less frequently

(2003) also discovered a positive relationship between the number of children in a household and the leisure[19] preference of women.

Nature of data used

All empirical applications of theories used secondary data. The main sources of data were state-organised surveys (e.g. Moon Kee Kong (1998) and Asano Seki (1997) used data compiled by US Federal National Income reserve and the Japanese Ministry of Labour respectively). The majority of studies (n=27) used less restricted samples, suggesting they could be generalised for population wide interventions. In contrast, 4/31 papers[20] (Wales and Woodland, 1977; Rosenweig 1983; Atroistic 1982; Havemann et al., 1994) had several restrictions on their samples thus raising questions about their generalisability. For example Atroistic (1982) tested his model only on white male twins born between 1917 and 1927, having served in the military: who are alive and responded to NAS-NRC[21] 1974 survey; married with children; not multiple jobholders; and always give report on their job situation.

Challenges faced by authors

Half the studies (16/31) revealed the potential constraints that challenged either their methods or interpretation. 12/16 papers[22] cited lack of data and restrictions on population samples as having affected the specification of variables and the generalisability of results. For example Solberg and Wong (1991) had to use the weekly income of children to measure non-labour, due to lack of data. Another set of papers (3/16) lamented highly restricted assumptions. For instance, Phlips (1978) described his assumption that money and leisure are substitutes to all goods as overly restrictive. Gronau (1997) also noted that his assumption that work at home accrues same marginal utility as work in the market could be criticised, and acknowledged

[19] It should however be observed that women were found to report the caring for children as part of leisure

[20] Such papers were scattered among the literature

[21] National Academy of Sciences-Research National Council

[22] (Lecoq, 2000; Darrough, 1997; Van Den Brink et al., 1997; Solberg and Wong, 1991; Kooreman et al., 1987; Cameron et al., 1988; Propper, 2000; Rosenweig et al., 1993; Arronson et al., 2001; Wales and Woodland, 1977; Atroistic, 1982; Asano, 1997)

that he should have considered joint production and consumption in his theoretical analysis.

Discussion

The discussion considers how well physical activity is proxied by this literature and the potential nature of demand for physical activity. At the end questions for broader discussion are raised on the role that willingness to pay could play in capturing the broader benefits of physical activity interventions.

How well was physical activity proxied across the diverse literature?

Generally, we selected leisure as the most frequent proxy (21/31) followed by health investment (9/31). The theories described these proxies as active choices since there is a conscious effort by the representative to engage in leisure or to demand health. None of the proxies however had a specification that fully matches the complexity[23] of physical activity. One of the common weaknesses with their specification was that the proxies were measured as only time inputs[24]. This was mostly characteristic of papers from which we selected leisure as a proxy. Leisure was seen as pure time input (non-working time). Conversely, the proxy used from health behaviour theories was mainly viewed as a production commodity created by combining time and market inputs.

Only one paper reviewed sought to explain the demand for physical activity directly and as a dependent variable. Wu and Porrel (2000) investigated one factor that affects the engagement in physical activity during non-working time. They concluded that the physical activity required in a person's job has a positive relationship with the level of physical activity during non-working time. This does appear to be a very partial view to explaining demand for physical activity.

[23] See section 1.0 pg 1
[24] Physical activity is viewed as a combination of time and market inputs, in our context

What type of good is physical activity?

Based on the findings of the review, physical activity[25] as a good was given different descriptions. (Phlips, 1978) described it as a habit forming good with a positive marginal propensity to consume, while others saw it as a normal good (Barnett 1979; Atroistic 1982). However Darrough (1997) found current leisure to be an inferior good and future leisure to be a luxury. The relationship between leisure and other goods was investigated; leisure was found to be a substitute to the consumption of other goods (Asano, 1997) and elasticity of substitution between leisure and consumption is very high (Koskevic, 1999). Gender participation in leisure differs. While a negative relationship exists between time spent on sports (including hobbies) and the wage rate of men, Kooreman et al., (1987) found a positive relationship in the among women. Given such diverse findings, it appears that there is little agreement on the type of good leisure is. Therefore it is also difficult to be conclusive on the type of good, physical activity is. Whether future physical activity is a good or bad is also not conclusive given Eichenbaum et al's conclusions that the acquisition of leisure today leads to future leisure disservices (Eichenbaum et al, 1988).

What is the demand for physical activity likely to encompass?

The decision of an economic agent[26] to engage in physical activity is determined by the perceived benefits and costs. The valuation of these costs and benefits may depend on the job characteristics of the agent. Workers who expend higher energy levels at work tend to undertake vigorous physical activity during non working time (Wu and Porrel, 2000).

Generally, the costs of physical activity could be categorised into time costs and costs of market inputs. This idea hinges on the assumption that physical activity like health investment is a combination of time and market inputs, as exemplified by Dustmann and Windmeijer (2000) with respect to health investment. The opportunity costs of time however depend on the alternative time uses at the disposal of the economic agent. The multiplicity of time costs

[25] In the context of the proxies
[26] It could refer to either a family or an individual

could therefore range from wage rate (Koskievic, 2000; Phlips, 1978), time for child care (Van Den Brink et al., 1997; Arronson et al., 2001; Kooreman et al., 1987), time spent in the household production (Klaveren van et al., 2006) and travel time to market work (Solberg and Wong, 1991).

Time costs could also be captured in the form of negative externalities when there is a spill over negative effect of the economic agent's engagement in physical activity on the spouse or children. For example if the time spent by the husband in the gym is at the expense of the time spent with the spouse. As found by Couprie (2003), time spent with the husband has a positive impact on the welfare of a married woman. Klaveren van et al. (2006) also showed that married women accrue utility from joint household production with the husband. The costs of market inputs say kit for the gym are the prices of these inputs. The weight of the costs of market inputs is of a varying degree as it could be very high or very low, depending on the type of physical activity in question.

The benefits of physical activity include, at least, health and economic benefits. The health impacts include the (un)healthy[27] time that accrues to the exerciser, decomposed into changes in quantity and quality of life. Dustmann and Windmeijer (2000) established that health investment leads to healthy time. As an economic benefit, engagement in physical activity affords the agent strength to undertake market work. Physical activity participation has an income earning potential and current work hours are partly determined by the prior health of the worker (Havemann et al,. 1994). Benefits could also be captured in the form of positive spill over effects of an economic agent's participation in physical activity. Wu and Porrel (2000) found, for example, that white collar workers who have healthier lifestyles tended to have spouses who exercise regularly.

[27] The possibility of benefits and harms

How should the utility function for physical activity be characterised?

This review has identified some useful ideas on the characterisation of the utility function. Based on these, we might attempt to characterise the utility function of a representative agent regarding physical activity. The agent of the household could be assumed to maximise a Stone Geary[28] utility function comprising consumption goods, physical activity and demographic characteristics, subject to budget (total income of the household should be equal to the purchase of market goods), time (time could be used for market work, household work, physical activity and other leisure activities such as sleeping) and technology constraint (the production of household goods and physical activity is a function of the education and number of years spent producing them). The main dependent variable is physical activity (produced by combining market inputs and time) which is influenced by stocks of habits that is variable over time. It is assumed that the demographic variables constitute socio economic characteristics of the household (e.g. age and presence of children, spouse) and the job characteristics of the representative agent. Based on this utility function, the demand function for physical activity could be a function of market inputs, demographic variables, habit, and time.

Such a demand function however presents a number of challenges. To extent can we incorporate the complexity of the demand for physical activity in a WTP study aimed at capturing a broader set of benefits? None of the papers was able to fully capture the complexity of demand for physical activity. A review of non-economic theories could contribute to a more fully explicable model of demand for physical activity, although it is unlikely to reduce the complexity of modelling or demand for data collection. We look forward to the discussion of our paper moving more closely towards its rather hopeful title!

[28] According to Phlips (1978) this allows the introduction of physical stocks of habits that influence the dependent variables in the function.

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Appendix 1: Final Search terms and results

Database	Search terms	Hits	Selected papers
JSTOR	(leisure OR "physical activit*" OR health) AND (demand OR price*) AND ("time budget" OR "allocation of time" OR "time use") NOT (psychological OR psychology) NOT (sociological OR sociology) NOT (agricultural OR agriculture)	395	17
IBSS	(leisure OR physical activit* OR keep fit OR health OR fitness) AND (demand OR preferenc* OR choic* OR pric*) AND (model* OR theor* OR time budget OR allocation of time OR time use OR household) NOT (abortion[29] OR sociolog* OR psycholog*) limit to ENGLISH	357	17
SCOPUS	(leisure OR "physical activit*" OR health) AND (demand OR pric*) AND(model* OR theor* OR "time budget" OR "allocation of time" OR "time use" OR household) limit to ECONOMICS and HEALTH subject areas	1196	23
Econ Lit	(leisure OR "physical activit" OR fitness) AND (demand OR pric*) AND ("time budget" OR "allocation of time" OR "time use" OR household")	312	32
Web of Knowledge	(leisure OR "physical activit*"OR health OR exercis*) AND (demand OR pric*) AND("time budget" OR "allocation of time" OR "time use" OR household)	356	19
Econ Papers	(leisure OR physical activit* OR sports OR sport OR health OR exercising OR exercise) AND (demand OR preferenc* OR pric* OR behave) AND(time budget OR allocation of time OR time use OR household)	891	18
Total		507	126

Appendix 2: Review questions

Headings	Review questions
Specification of model	1. Authors 2. Year 3. Aim 4. Description of the model 5. What are the assumptions? 6. Independent variables 7. How are the independent variables specified in practice? 8. Dependent variables 9. How are the dependent variables specified in practice? 10. What is the relationship between the dependent variables?
Population focus of the model	11. What population group/groups is the model focused on? 12. Which other population groups might the model be relevant to? 13. Are there are any population groups the model might not be applicable to? 14. Source of data
Characteristics of decision making unit	15. What is the decision making unit covered in the model? -Single person as individual -Single person as household -Multi-person -Intra-household -Other 16. What attributes of the decision-making unit was considered? 17. How are other members of the household accounted for in the model?

[29] To exclude papers on abortion

Main findings	18.Main findings 19.How was time use categorised 20. Does the model consider uncertainty?
Model's relevance to the demand for physical activity	21. Which ideas from the paper might be useful to our study? 22. Which variable might be the best proxy for physical activity? 23. What will be the positive implications if we substitute physical activity for the proxy in the model 24. What will be the negative implications if we substitute physical activity for the proxy in the model
Critique of studies	25. What weaknesses will we want to address before transferring the model to our study? 26. Strengths (Author stated) 27. Weaknesses (Author stated)

Appendix 3: Included papers

1. Alenezi, M. & M.L. Walden. (2004). A new look at husbands' and wives' time allocation. *Journal of Consumer Affairs 38*, 81-106.
2. Aronsson, T., S.O. Daunfeldt & M. Wikstrom. (2001). Estimating intrahousehold allocation in a collective model with household production. *Journal of Population Economics 14*, 569-584.
3. Asano, S. (1997). Joint allocation of leisure and consumption commodities: A Japanese extended consumer demand system 1979-90. *Japanese Economic Review 48*, 65-80.
4. Atrostic, B.K. (1982). The Demand for Leisure and Nonpecuniary Job Characteristics. *American Economic Review 72*, 428-40.
5. Barnett, W.A. (1979). The Joint Allocation of Leisure and Goods Expenditure. *Econometrica 47*, 539-63.
6. Bentzen, N., T. Christiansen & K. Moller Pedersen. (1989). Self-care within a model for demand for medical care. *Social Science and Medicine 29*, 185-193.
7. Bhat, C.R. (2005). A multiple discrete-continuous extreme value model: formulation and application to discretionary time-use decisions. *Transportation Research*
8. Cameron, A.C., P.K. Trivedi & F. Milne. (1988). A Microeconometric Model of the Demand for Health Care and Health Insurance in Australia. *55*, 85-106.
9. Couprie, H. (2003). Time Allocation within the Family:Welfare Implications of life in a Couple.
10. Darrough, M.N. (1977). A Model of Consumption and Leisure in an Intertemporal Framework: A Systematic Treatment Using Japanese Data. *International Economic Review 18*, 677-96.
11. Dowd Kevin. (1992). Consumer Demand, "Full Income" and Real Wages. *Empirical Economics 17*, 333-45.
12. Dustmann Christman and Windmeijer Frank. (2000). Wages and the Demand for Health-A Life Cycle Analysis. *Discussion Paper from Institute for the Study of Labor*, 2000.
13. Eichenbaum, M.S. (1988). A Time-Series Analysis of Representative Agent Models of Consumption and Leisure Choice under Uncertainty. *Quarterly Journal of Economics 103*.
14. Feather, P.M. & W.D. Shaw. (2000). The demand for leisure time in the presence of constrained work hours. *Economic Inquiry 38*, 651-661.
15. Gronau, R. (1995). Leisure, Home Production, and Work--The Theory of the Allocation of Time Revisited. *Labor Economics.Volume 1.Labor Supply and Labor Demand*, 32-56.
16. Haveman, R., B. Wolfe, B. Kreider & M. Stone. (1994). Market work, wages, and men's health. *Journal of Health Economics 13*, 163-182.
17. Klaveren van Chris and Praag Bernard. (2006). A Collective Household Model of Time Allocation-A Comparison of Native Dutch and Immigrant Households in the Netherlands.
18. Kong, M.-. & H.-. Lee. (1999). Demand for medical care, consumption and cointegration. *Economics Letters 62*, 325-330.
19. Kooreman, P. (1987). A Disaggregated Analysis of the Allocation of Time Within the Household. *Journal of Political Economy 95*.
20. Koskievic, J. (1999). An Intertemporal Consumption-Leisure Model with Non-expected Utility. *Economics Letters 64*, 285-89.
21. Lecocq, S. (2001). The allocation of time and goods in household activities: A test of separability. *Journal of Population Economics 14*, 585-597.

22. Maassen van den Brink, Henriette & W. Groot. (1997). A Household Production Model of Paid Labor, Household Work and Child Care. *De Economist 145*, 325-43.
23. Owen, J.D. (1971). The Demand for Leisure. *Journal of Political Economy 79*, 56-76.
24. Phlips, L. (1978). The Demand for Leisure and Money. *Econometrica 46*, 1025-43.
25. Propper, C. (2000). The demand for private health care in the UK. *Journal of Health Economics 19*, 855-876.
26. Rosenzweig, M.R. & T.P. Schultz. (1983). Estimating a Household Production Function: Heterogeneity, the Demand for Health Inputs, and Their Effects on Birth Weight. *The Journal of Political Economy 91*, 723-746.
27. Sickles, R.C. & A. Yazbeck. (1998). On the dynamics of demand for leisure and the production of health. *Journal of Business & Economic Statistics 16*, 187-197.
28. Wales, T.J. & A.D. Woodland. (1977). Estimation of the Allocation of Time for Work, Leisure, and Housework. *Econometrica 45*, 115-32.
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Appendix 4: Aims and summary of models reviewed

Type of Model	Papers	Aim	Summary of model
Leisure-consumption choice category	Philips (1978)	To construct and estimate an augmented system of dynamic demand equations in which the demand for leisure and the demand for transactions balances are embedded.	The consumer maximises a Stone Geary[30] utility function of the expenditure of a consumption good, leisure and real money stock for transaction purposes subject to a constraint of the prices of consumption good and leisure and real cash balances.
	Koskevic (1999)	Test an intertemporal consumption-leisure model with non expected utility	The agent maximises a current period lifetime utility function comprising consumption and leisure. The utility function is constrained by the wealth of the agent for the period between the current period and the period beyond, which is a function of the real returns from holding security and real wage.
	Darrough(1997)	Develop a neo classical framework based on intertemporal allocation of consumption, savings and leisure to explain Japanese experience of allocating resources between consumption and leisure.	The consumer maximises a utility function made of 4 current goods (current food, current consumer durables, current leisure, current miscellaneous) and 2 future goods (future leisure and future composite good) aggregated by a Leontief aggregation method[31] into a single variable ("x"). The utility function is constrained by "full" lifetime wealth and prices.
	Owen (1971)	Establish the relationship between the demand for market recreation and the demand for leisure.	The utility maximisation function of the individual is represented by leisure, market recreation and other consumer goods subject to the maximum full income constraint of price of leisure and wage income as well as a time constraint.
	Barnet t(1979)	Test conditions for separation of the consumer's labour/leisure decision from his consumption expenditure allocation decision.	The agent maximises a utility function of consumption-leisure choice constrained by income level and the prices of leisure and consumption goods.
	Koo rem	To model the demand for goods and allocation of time	The household maximises a utility function of time spent by members and consumption goods constrained by budget and time constraints.
	Eichenb aum et	To empirically investigate a model of aggregate consumption and leisure decisions in which utility accruing from goods and leisure is non-time separable	The agent has consumption services and leisure services as arguments of his utility function. The decisions about leisure and consumption are constrained by income and information.
	Atroistic (1982)	To estimate a demand system whose goods are leisure, non pecuniary job characteristics and other goods, based on individual-level data	The utility function has leisure, goods, and job characteristics, as its main arguments; subject to full income constraint and wage-job characteristics.
	Asano (1997)	To estimate the parameters of a household expenditure function that includes a joint choice of leisure and consumption of commodities without separability assumption	The consumer maximises utility from a joint consumption of leisure and commodity constrained by the prices of consumption good and income level.
	Dow d	To test a model of consumer behaviour in which income and leisure are simultaneously chosen	The household has a utility function with leisure and consumption as its arguments, subject to budget and time constraints.
Health behaviour category	Sickles et al. (1998)	To investigate the production of health that is affected by changes in leisure demand and health related expenditure	The utility maximising individual has a lifetime utility function of consumption goods, leisure and health. This is subject to constraints of non-labour income, wage income and expenditure on goods as well as time.
	Bentzen et al. (1989)	To incorporate self-care in a model of demand for medical care	The health behaviour of the individual is modelled into a 3 stage decision model; where stage one refers to whether ill or not. The second stage depicts the decision to seek professional care, pure self care or a combination of both, when sick. The last stage concerns the volume of professional care utilised.

[30] Allows the introduction of state parameters (i.e. physical stocks of habit that influences the demand for the dependent variables)

[31] It consider commodities normally consumed in fixed proportions as a single commodity

	Havemann et al. (1994)	To investigate the complex interrelations among work time, wages and health identified in the Grossman model of the demand for health	A 3 equation structural model describes the interrelationship between health, wages and work hours. Health in a stated period is determined by the individual's work hours, both personal and job characteristics (i.e. job hazards). Work hours of the individual is determined by prior health, wages, personal characteristics (i.e. number of children in the family) and job characteristics (i.e. self employed or not).
	Dustmann & Windmeijer	To present a life cycle model for the demand for health and derive empirical specifications that distinguishes between permanent and transitory wage responses	The utility function of the individual is composed of consumption goods and healthy time. The individual is faced with a time constraint function that allocates available time between labour and time input for health investment, prices of goods, wage income and non labour income.
	Cameron	To model the interdependent demand for health insurance and health care	The representative consumer maximises a 2-period expected utility function with health and consumption arguments subject to a budget constraint.
	Propper (2000)	To model the use of private health care as a function of its cost and benefits relative to state care and no care	The model denotes that a potential health care user chooses alternative sources of health care (i.e. no care, NHS, private care) depending on the relative costs and benefits.
	Rosenweig et al.(1983)	To estimate a household health production function using information on one important early health indicator: birth weight and a set of behavourial variables considered to be important determinants of birth outcomes in the medical literature (i.e. prenatal medical care, working and smoking by the pregnant mother, number of births by mother and her age)	The utility of the household comprises consumption of goods, goods that affect child health production and the health of child. The utility function is subject to the production function of child's health which is influenced by the goods that affect the child's health, health inputs and the health endowments of the family as well as exogenous income and prices of goods.
	Moon-Kee (1998)	To provide, in the context of co-integration, a justification for employing the variables in the usual macroeconomic demand for medical care by examining the health capital model	The consumer's lifetime utility function is composed of consumption goods and health constrained by wage income, expenditure on the arguments of utility and labour income.
	Wrick	A simultaneous equation to measure the forces that influence the consumption of health services	The demand for health services is determined by need, realization of need, financial resources, motivation and availability of health services
Household production category	Lecoq (2000)	To test for the weak separability hypothesis of household production model between goods and time inputs used in the production of different goods	A household's utility function comprises goods produced in the household, quantity of meals produced outside home and leisure time of both agents. The utility function is subject to budget constraint, time constraint and technological constraint.
	Arronson (2001)	Using an extended collective model to estimate the intra family allocation of income, household production and individual demand for leisure	A household maximises a utility function which has leisure, market produced goods, and home produced goods as its arguments, subject to budget and time constraints.
	Van Den Brink et al.	To formulate a household production model including four activities: market work, housework, leisure, child care	A utility function comprises consumption goods, time spent on child care services and leisure, subject to budget and time constraints.
Labour supply category	Klaveren van et al.	To estimate a collective household labour supply model for 3 different population samples of Dutch, Turkish descents and Surinamese.	The household utility function which is the sum of two utility functions of male and female. The main arguments of the utility function are leisure time, time spent in the household, joint household care level, subject to income and time constraints.
	Couprie (2003)	To explain the impact of family status on female labour supply.	The household maximises a collective utility model of aggregate consumption goods, leisure and a public domestic good; subject to both income and time constraint.

	Wu and Porrel	An empirical analysis of factors associated with physical leisure activity level that has direct implications with regards to the alternative theories of work and leisure.	The individual's decision to exercise is determined by the expected benefits and the opportunity costs of time and energy.
	Feather (2000)	To formulate a labour supply model to address overemployment and underemployment.	The individual's utility function consists of leisure and market goods, subject to budget and time constraints.
Allocation time category	Wales and Woodland	Formulate a household model that allocates available between labour, leisure and housework; where leisure is defined as net of time spent on housework	The household maximises a utility function consisting of the leisure of wife and husband and composite goods. The utility function is subject to budget and time constraints. The original model was modified to derive 4 different specifications[32].
	Bhat (2004)	To formulate a utility theory based model for a discrete/continuous choice that assumes diminishing marginal utility as the level of consumption of any particular alternative increases	An individual maximises a sum of utilities accrued from time activities subject to time constraint which allows the participation in one or two activities at a time.
	Gron au	To extend Becker(1965) Allocation of time theory by dividing non market work into leisure and home production	The household maximises consumption time (i.e. leisure) and goods utility function subject to budget and time constraints
	Solberg and Wong	To present a formal model of the allocation of time in the manner of Gronau(1977) and derive its comparative static predictions in order to test them against recent data on family time use	The household's utility function comprises leisure and consumption goods, subject to time and budget constraints.
	Alene zi	To take a new look at the husband's and wives decisions about market and housework time allocations	The household's utility function consists leisure, consumption of both market and home produced goods; subject to budget, time and technology constraints.

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[32]The alteration involved subjecting housework to different definitions: model A(housework was incorporated into leisure), Model B (housework is exogenously determined), model C (housework is not exogenously determined), model D(housework is stochastic not deterministic and regarded as endogenous)