ORIGINAL ARTICLE

Human capital and the intertemporal substitution for leisure: empirical evidence for Spain

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Abstract

In this paper we provide the first estimate of the intertemporal substitution for lei-sure in Spain, accounting for the impact of human capital accumulation. This would allow uncovering whether the intertemporal labour supply of Spanish workers is affected by human capital. Our empirical strategy consists of estimating the equation for the intertemporal substitution of leisure with and without accounting for human capital, what allows to detect hypothetical estimation biases associated to omitting the impact of human capital. To that end, we build a pseudo-panel data set combin-ing the Spanish Family Expenditure Survey and the Labour Survey over the period 1987–1997. While the model that ignores human capital accumulation provides an estimate of the intertemporal elasticity of substitution for leisure about 0.25, com-parable to previously available estimates for Spain and other economies, the model with human capital provides an estimate about 0.5, what confirms the existence of a bias in the former estimates. Finally, this bias is larger for the younger cohorts than for the older ones.

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1 Introduction

The empirical research on the elasticity of intertemporal substitution for leisure with individual data has typically yielded very low estimates, as compared to the values used for this elasticity in macroeconomic models (Keane 2011; Chetty et al. 2011, 2013). Additionally, the few estimates that are available using aggregate data do not produce reliable outcomes (Mankiw et al. 1985, for the US economy, or Cutanda 2019, for Spain using regional data). This disparity between the parameters considered in many theoretical (and simulated) macroeconomic models and the empirical evidence is a relevant topic for discussion in both literatures and for policy purposes.

The analysis of how individuals labour supply respond to wages and how it affects labour market aggregate changes greatly depends on the value of the elasticity of intertemporal substitution for leisure that the researcher is considering. Depending on the presumptions used in its analytical derivation, there are various techniques to estimate this elasticity. Thus, using a life cycle model setting and assuming that the marginal utility of wealth is constant, one can derive the Frisch elasticities. This method of analysing the behaviour of the labour supply throughout the life cycle is, in our opinion, the most accurate one.[1] Moreover, to estimate it, one has to consider that the intertemporal condition is less demanding than the intratemporal condition in terms of information (as this last one uses information on both consumption and leisure, even when utility is assumed separable). However, the intratemporal condition is less reliable, provided that it only requires information for one period to estimate a life-cycle structural parameter governing the individual's labour supply behaviour across time.

The traditional empirical approach for the estimation of the elasticity of intertemporal substitution for leisure has experienced an impulse due to two facts. First, there are new attempts to estimate this elasticity, see for example Imai and Keane (2004), or Bredemeier et al. (2019). Second, Shaw (1989), Imai and Keane (2004), Keane (2016) and related papers, claim that previous results might suffer from a downward bias as do not consider the effect of human capital. Finally, there exists a renewed interest to study the effect of taxes on labour supply, with the aim of explaining the different behaviour of the US and the European labour markets (see, for example, Silva 2008).[2]

In this paper, we study the effect of human capital on the estimation of the elasticity of intertemporal substitution for leisure to evaluate the bias incurred when not considering it. For this purpose, we will follow Cutanda and Sanchis-Llopis (2021), who provide the first estimates of the intertemporal leisure and consumption elasticities for Spain using micro data, to estimate the elasticity of intertemporal substitution for leisure with and without accounting for human capital. It is important

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[1] It is also possible to derive the Hicksian and the Marshallian elasticities. However, these are more limited as both depend on assuming that either the utility or wealth remain constant when wages are changing.

[2] See the influential survey by Keane (2011) on the empirical labour supply research.

noticing, that differently to previous empirical research on this issue, we will analyse this effect through the intertemporal equation of optimization, instead of the intratemporal equation. As discussed in Shaw (1989) and Imai and Keane (2004), as wages increase over the life-cycle individuals have incentives to increase their labour supply (by the substitution effect), while the diminishing returns of human capital produces the reverse effect. Therefore, the combined result of these two effects is to flatten the labour supply curve, what explains that estimation of the intertemporal elasticity of leisure ignoring human capital might be downward biased. However, differently to these works, that use the intratemporal condition, our analysis is based on the intertemporal first order condition for leisure of the optimization program. We consider that the intratemporal equation might have serious drawbacks, as it relates only variables dated in the same period to estimate a life-cycle parameter that determines how individuals choose leisure (or work) across different periods.

We use a pseudo-panel data set for the empirical study in this paper (see Browning et al. 1985). This data set spans 41 quarters and has been built by combining data from the Spanish Family Expenditure Survey (the *Encuesta Continua de Presupuestos Familiares*, ECPF), which gives data on individual consumption and income, with data from the Spanish Labour Force Survey, which offers data on individual labour supply (*Encuesta de Población Activa*, EPA). We have generated this data set given that up until 2002 Spain lacked a microeconomic survey collecting data on consumption, income and labour.[3] The lack of estimates for this parameter in Spain is explained by this fact.[4] In our study, we estimate the log-linearized version of the Euler equation of leisure for the individual optimization problem.[5] Using simulation methods, Attanasio and Low (2004) and Alan et al. (2009) prove that log-linearized estimating procedures with sufficiently big datasets may be used to consistently estimate the elasticity of intertemporal substitution of consumption. We consider that our study falls in this category because we use a lengthy (pseudo) panel in our empirical research.

As regards the estimation results, we estimate the intertemporal equation derived from an optimization model with and without human capital accumulation. In this last case, we get estimates for the elasticity of intertemporal substitution for leisure between 0.25 and 0.28. These results are comparable to previously available estimates for other economies (MaCurdy 1981; Altonji 1986; Blundell et al. 2016) and recently for Spain (Cutanda and Sanchis-Llopis 2021). These values have prompted a serious debate, given the larger values traditionally used for this parameter in

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[3] In 1998, the methodology of the ECPF experienced an important change, as household income was reported as intervals. The lack of the real value of income makes matching unfeasible after 1998.

[4] The Survey of Household Finances (*Encuesta Financiera de las Familias*, EFF), launched in 2002, provides information on household income, although this survey has been designed to study individual savings and wealth. The sample design of the EFF is less appropriated to study the intertemporal behaviour of consumption and leisure as it oversamples the wealthier households. Additionally, it does not record income and consumption as the needed detailed level.

[5] See, for example, Bredemeier et al. (2019) and Cutanda et al. (2020).

business cycle macroeconomic models.[6] This low value could be attributed to the high persistence of the Spanish unemployment rate and/or the high rate of temporary workers.[7] Further, another reason could be attributable to ignoring the impact of human capital, that implies that the estimate of the intertemporal substitution of leisure/labour is estimated with a bias. Our results show that this bias is relevant as it amounts to 100% of the estimated elasticity, or even more. The specifications that account for human capital provide an estimate for the elasticity about 0.5. In any case, it is important to highlight that this larger estimate is not enough to explain the gap between the usual estimates of the elasticity with individual data and the values traditionally considered for it in macroeconomic analyses.

The rest of the paper is organised as follows. In Sect. 2, we develop the theoretical model and discuss the main aspects related to the model. In Sect. 3, we present the data used and how we build the pseudo-panel data set. In Sect. 4, we report the results and in Sect. 5 we conclude.

2 The intertemporal model and the empirical specifications

We consider an individual who chooses rationally her/his levels of leisure and consumption in period t in order to maximize her/his life-cycle expected utility. We follow the approach used in Shaw (1989) and Imai and Keane (2004), who modify the intertemporal labour supply model of MaCurdy (1981, 1983) to incorporate human capital. So, the optimization problem we consider is:

$$\underset{C_t,L_t}{\text{Max}}\ U = E_t \sum_{\tau=t}^{T} \beta^\tau u(L_\tau, C_\tau) \tag{1}$$

where and L_τ and C_τ, are leisure and non-durable consumption, respectively. We assume that the utility function U is intra and intertemporally separable,[8] and $u(.)$

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[6] Keane (2011) surveys 12 influential studies and reports an average estimate of 0.83 with a median estimate of 0.17, although these numbers are upward biased due to, at least, a clear outlier. More importantly, Chetty et al. (2013) conclude, from an exhaustive meta-analysis of fifteen empirical studies, that the mean intertemporal elasticity of leisure is around 0.25.

[7] In the period we analyse, the Spanish unemployment and temporary average rates reached 17.19% and 30.17%, respectively. The Portuguese job market shows a similar behaviour as described by Cabral Vieira (2005). It is expected that temporal workers restrict their intertemporal substitution of leisure, what might explain, at least partially, the lower estimated we obtain. In relation to this, one of the primary objectives of Spanish labour market reform in 2021 was to significantly reduce the Spanish temporary rate.

[8] Intratemporal separability implies that decisions on current consumption do not influence current (and future) decisions on leisure, and vice versa, while intertemporal separability implies that past values of consumption or leisure do not influence current decisions on either of them, Barro and King (1984). Although these assumptions might have an effect on the relative responses of consumption and leisure to changes in relative prices and in permanent income, they do not restrict the size of the intertemporal substitution effects of consumption and/or leisure. Thus, the intertemporal first-order conditions are quite convenient for empirical research. In particular, the empirical equations only depend on the current level of either leisure or consumption. Further, does neither depend on leisure (consumption) nor on any past values of consumption or leisure. Therefore, this makes the empirical research less demanding in terms of data and quite feasible, what explains the extensive empirical research on intertemporal economic behaviour.

corresponds to the utility in a specific period, assumed to be increasing and concave in its arguments. E_t is the mathematical expectations operator conditional on the information set available in period t, and β is the discount rate. The intertemporal budget constraint follows usual expression (2):

$$A_{t+1} = R_t \left[A_t + W_t N_t - P_t C_t \right] \tag{2}$$

where A_t is the individual's financial non-human wealth; R_t is given by $R_t = 1 + r_t$, where r_t is the nominal interest rate;[9] W_t is the hourly wage in time t; $N_t = L^* - L_t$ is the amount of hours worked at time t, being L^* the maximum total number of hours available to work each period; C_t and P_t are, respectively, the individual real consumption and their nominal price at time t, that we assume exogenous.

Following Shaw (1989) and Imai and Keane (2004), we assume that the observed wage is the product of the human capital stock, K_t, times the rental rate for a unit of this stock, R_t^K:

$$W_t = R_t^K K_t \tag{3}$$

The rental rate R_t^K is the market price of services for a unit of human capital. We assume a perfect market for human capital. Hence, in any period t, all agents face the same rental rate.

From (3), Shaw (1989) considers the wage as an endogenous variable, given that individuals can modify their wage through changes in their human capital. Thus, she assumes that the individual's value function depends on the stock of assets, the wage rate and the rental value of human capital, and not on the value of the human capital stock. Shaw (1989) proposes this value function as she is interested in the life-cycle human capital accumulation process.[10] Differently, Imai and Keane (2004) consider that the value function depends both on the human capital stock and on the stock of the assets. They specify the value function in that way given that their main interest lies on the individual's intertemporal allocation of consumption and leisure along the life-cycle. In any case, both studies assume that the individual's human capital investment function is limited to *learning-by-doing*.

Assuming no legacies ($A_T = 0$), the life cycle budget constraint in time t is then given by:

$$\sum_{j=0}^{T-t} R_t^{-j} P_{t+j} C_{t+j} = A_t + \sum_{j=0}^{T-t} R_t^{-j} W_{t+j} N_{t+j} \tag{4}$$

Finally, we assume, as usual, perfect financial markets.

Following Imai and Keane (2004), we assume that the stock of human capital evolves according to their accumulation rule $g(.)$, that depends on the labour supply hours, the current human capital, and a multiplicative wage shock $\varepsilon_{W,t+1}$:

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[9] We generically name R_t as the interest rate.

[10] In Shaw (1989) human capital develops in a learning-by-doing process, therefore there is no difference between the potential wage and the observed wage. This assumption is necessary to estimate a closed-form solution of the intra or intertemporal equations of (leisure). However, we think it is not plausible using Shaw (1989) solution in the Spanish case, due to the high unemployment rates suffered in the recent years.

$$K_{t+1} = g\left(N_t, K_t\right)\varepsilon_{W,t+1} \tag{5}$$

From the above equations, we can define the value function V, which represents the maximum utility expected from consumption and leisure by the individual in period $t+1$, as:

$$V_{t+1}\left(A_{t+1}, K_{t+1}\right) = MaxE_{t+1}\{\sum_{j=1}^{T-t} \beta^j u(C_{t+j}, L_{t+j})\} \tag{6}$$

According to the Bellman's optimality principle, our optimization problem is equivalent to this expression,

$$V_t\left(A_t, K_t\right) = \max_{C_t, L_t}\left\{u\left(C_t, L_t\right) + \beta E_t V_{t+1}\left(A_{t+1}, g\left(N_t, K_t\right)\varepsilon_{W,t+1}\right)\right\} \tag{7}$$

from where we get the first order condition for leisure (see Shaw 1989), given by:

$$\frac{\partial u}{\partial L_t} = \beta R_t W_t E_t \frac{\partial V_{t+1}}{\partial A_{t+1}} + \beta E_t \frac{\partial V_{t+1}}{\partial K_{t+1}} \frac{\partial K_{t+1}}{\partial L_t} \tag{8}$$

where:

$$\frac{\partial V_t}{\partial A_t} = R_t \beta E_t \frac{\partial V_{t+1}}{\partial A_{t+1}} \tag{9}$$

$$\frac{\partial V_t}{\partial K_t} = \beta E_t \frac{\partial V_{t+1}}{\partial K_{t+1}} \frac{\partial K_{t+1}}{\partial K_t} \tag{10}$$

The expression (8) is the Euler equation for leisure obtained from this optimization problem. As it is well known, assuming that expectations are rational, this equation constitutes a very convenient way to test the intertemporal allocation leisure model that avoids the usual problems in estimating labour supply functions in presence of uncertainty, with very few data requirements.

It is important noting that that expressions (8) and (10) depend on the particular accumulation rule for human capital, defined in expression (5). Further, expression (8), the intertemporal equation for leisure, has an extra term (as compared to the standard expression with non-human capital) that depends on the derivative of the value function with respect to the human capital stock. This term reflects the discounted increase in welfare for all future periods associated to human capital accumulation. As Imai and Keane (2004) point out "if we only allow for the substitution effect and not the human capital effect, the i.e.s. is identified primarily from the covariation of the wages and hours over the life cycle. Then, we will falsely conclude that the i.e.s. is low, simply because labour supply remains roughly constant over the life cycle even though wages increase". Therefore, if there is human capital accumulation, ignoring this term in the empirical model might produce biased estimates for the elasticity of intertemporal substitution of leisure. A corollary of this result is that the bias in the estimation of the elasticity of intertemporal substitution

for leisure will decrease with age, given that the second term in the right-hand side of expression (8) would be larger for younger workers, see Shaw (1989).

Both, Shaw (1989) and Imai and Keane (2004), consider the intratemporal equation in their analysis. This condition allows analysing the relationship between consumption and leisure in the same time period but we consider this might be less appropriate to study the intertemporal substitution of leisure between periods. Thus, differently to them, we research the effect of human capital accumulation in the intertemporal equation of leisure, expression (9), as this seems to be the appropriate framework, given that it relates the values of the variables of interest in different time periods. However, this is troublesome, as this expression depends on the human capital accumulation rule. To solve this drawback, we will assume the following expression for the accumulation rule defined in (5):

$$K_{t+1} = (1 - \delta)K_t + \frac{1}{\alpha}N_t^\alpha = (1 - \delta)K_t + \frac{1}{\alpha}\left(L^* - L_t\right)^\alpha \tag{11}$$

where δ is the yearly depreciation rate for human capital and $\frac{1}{\alpha}N_t^\alpha$ is the particular production function we assume for human capital, being α a positive parameter. This expression is not very different from those assumed by Shaw (1989) and Imai and Keane (2004), although they propose highly complicated functions.

In order to obtain a testable expression for the intertemporal equation for leisure, we take condition (7) and apply the envelope conditions (9) and (10). After rearranging terms, we obtain the following expression for the intertemporal condition of leisure:

$$\frac{\partial u}{\partial L_t} = E_t\left[\frac{\beta W_t R_t}{W_{t+1}}\frac{\partial u}{\partial L_{t+1}} - \frac{1}{\partial K_{t+1}/\partial K_t}\frac{\partial V_t}{\partial K_t}\left(\frac{W_t R_t}{W_{t+1}}\frac{1}{\partial K_{t+2}/\partial K_{t+1}}\frac{\partial K_{t+2}}{\partial L_{t+1}} - \frac{\partial K_{t+1}}{\partial L_t}\right)\right] \tag{12}$$

As this expression depends on many unobservable variables, we have to make some assumptions in the empirical analysis. Thus, we assume that $\partial K_{t+j+1}/\partial K_{t+j} = 1$ and $\partial K_t/\partial N_{t-1} = -\partial K_t/\partial L_{t-1} \cong N_{t-1}$. Note from (11) that the first assumption is equivalent to assume no depreciation of human capital and the second implies to assume $\alpha = 2$.[11] We consider these assumptions are not very restrictive, given that in our empirical work we use a sample of men always working in a relatively short period, as most of the studies in the literature. Further, our assumptions will also affect the "marginal utility of human capital", as it is given by expression (10).

Therefore, under these assumptions, Eq. (12) becomes,

$$\frac{\partial u}{\partial L_t} = E_t\left[\frac{\beta W_t R t_t}{W_{t+1}}\frac{\partial u}{\partial L_{t+1}} + \frac{\partial V_t}{\partial K_t}\left(\frac{W_t R_t}{W_{t+1}}N_{t+1} - N_t\right)\right] \tag{13}$$

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[11] In our study, to measure the stock of human capital we use the accumulation of worked hours. From expression (11) in the paper, the marginal increase in the stock of human capital at the end of each period will be equal to the number of worked hours during this specific period. Assuming that $\alpha = 2$ indicates that the rule of human capital accumulation in the labour supply (worked hours) is quadratic, what is a standard procedure in the literature, see Shaw (1989). Further, using this quadratic function provides an easy testable empirical equation from expression (12).

This expression is empirically more tractable; however, it still depends on the "marginal utility of human capital", that is unobservable. This expression will be used to check if the elasticity of intertemporal substitution, estimated with the standard form in the literature,[12] changes when we consider the accumulation of human capital, that will consider expression (13) with all the components. To this end, in the empirical exercise we will assume that "marginal utility of human capital" does not change when individuals decide about their allocation of leisure between periods.

3 Empirical specifications and estimation

To derive a testable model, we consider a generalization of the standard CRRA utility function that depends on both consumption and leisure.[13] Given that we estimate our specifications with individual data, we add an exponential term to the specification, that enters multiplicatively and incorporates the effect of demographic variables (the vector θ_t), as follows:

$$u\left(C_t, L_t\right) = \frac{1}{1-\gamma}\left[d\frac{L_t^{1-\phi}-1}{1-\phi} + \frac{C_t^{1-\alpha}-1}{1-\alpha}\right]^{1-\gamma} e^{\lambda\theta t} \tag{14}$$

where γ, ϕ, α, λ and d are parameters to be estimated. This function encompasses the separable (in leisure and consumption) case when $\gamma=0$. As it is well known, this is the most studied case in the empirical analysis of both consumption and labour supply. So, $1/\phi$ and $1/\alpha$ are, respectively, the elasticities of intertemporal substitution for leisure and consumption.

Using the above utility function (14) in the separable case, we take logs in the first order condition (13) to obtain the empirical testable expression without human capital (i.e., ignoring the second term of the right-hand side). We estimate this expression using (cohort) data. Our empirical approach is different to Mankiw et al. (1985), as they use nonlinear estimators with aggregate US data. After taking logs, we rewrite the equation adding an individual subscript and applying the rational expectations assumption in the usual way:

$$\Delta ln\left(L_{it+1}\right) = k_o + k_1 ln\left(\frac{W_{it}R_t}{W_{it+1}}\right) + k_2\Delta\theta_{it+1} + \varepsilon_{it+1} \tag{15}$$

where ε_{it+1} is an error term independent of all variables dated in t or before. The model represented by Eq. (15) is static in an econometric sense. In particular, it

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[12] The standard method to estimate the elasticity of intertemporal substitution for leisure consists in estimating only the first term in the right side of expression (13).

[13] The traditional quadratic utility function considered by Hall (1978) in his "consumption random walk model", has been substituted in the analysis by the CRRA utility function, given that this function is more realistic and has more convenient properties and implications than the quadratic utility function, especially to analyse consumption or leisure behaviour in the presence of uncertainty. See Blanchard and Fisher (1989), among others, for the disadvantages associated to using the quadratic utility.

means that the empirical model to estimate this equation does not include any lag of the endogenous variable in the set of explicative variables (see Zeldes 1989 and Runkle 1991, for a similar approach for consumption). Notwithstanding, our model is dynamic on theoretical macroeconomists grounds, given that it analyses the consumption or leisure behaviour across time. Further, all time invariant demographic variables vanish as the vector of demographic variables (θ_{it}) enters in the specification in first differences. Finally, the reduced form expressions for the coefficients in expression (15) are: $k_o = \frac{1}{\phi} ln\beta$ and $k_1 = k_2 = \frac{1}{\phi}$. It is important to note that k_1 is the intertemporal elasticity of substitution for leisure if the utility function is intratemporally separable in leisure and consumption, i.e., when $\gamma = 0$. Otherwise, the expression for the Euler condition, expression (15), will depend on both consumption and leisure in t and $t + 1$.

According to Eq. (15), we will estimate the Frisch elasticity for labour supply, as it is considered the relevant one in an intertemporal setting, whereas the Hicksian and Marshallian elasticities are more appropriate for a static framework. Hicks elasticity provides a lower bound for Frisch elasticity (Chetty 2012) and, as Marshall elasticity, can be retrieved from the static intratemporal equation, while retrieving Frisch elasticity requires to use the Euler condition.[14] Shaw (1989) and Imai and Keane (2004) obtain the Frisch elasticity for labour supply from an estimation of the static intratemporal equation. Mankiw et al. (1985) established the difference between short and long run elasticities in an intertemporal setting. Keane (2011) provides a complete and updated survey of the results obtained in the literature for these different elasticities.[15]

Turning to the effect of human capital, once we estimate Eq. (15) without human capital, to verify whether the obtained estimates are robust to its effect, we will estimate Eq. (13). This equation, will depend on the "marginal utility of human capital", that is unobservable. Thus, we will assume that it remains constant, as we have no variable to proxy for it in our dataset. We consider this is a reasonable assumption provided that we are analysing a particular kind of human capital (that one acquired by workers on-the-job). Therefore, to test for the impact of human capital, we will expand Eq. (15) by adding as a regressor the logarithm of the second term in expression (13). This will allow checking whether the estimated intertemporal elasticity of substitution of leisure changes with human capital. This approach follows the procedure put forward in Keane and Rogerson (2012), and Keane (2016), and applied to the US by Imai and Keane (2004).

We need to remark some relevant points for the estimation of Eq. (15). First, to empirically test our model implies the fulfilment of the first order condition (15). Therefore, we need to assume no violations of the canonical model of intertemporal

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[14] Hicksian and Marshallian elasticities are more appropriate to analyse economic behaviour in a static intratemporal setting (just considering one period), while the Frisch elasticity is more appropriate to analyse economic behaviour in an intertemporal setting (considering the individual's life cycle).

[15] See Table 6 (page 1042) in Keane (2011), where there is an exhaustive compendium of the values obtained for these elasticities in literature.

choice, such as, for example, involuntary unemployment.[16] Second, we will treat the variable k_o as an individual fixed effect, given that this term includes the unobservable discount rate, that might be potentially correlated with the regressors.[17] We will apply robust estimation techniques to account for this correlation: the two-step generalized method of moments (GMM).[18] Further, we will include a constant term in the specification, that could be interpreted as the *autonomous* discount rate, common to all the individuals in the economy. Finally, in the empirical analysis, we will test for the goodness of fit with a Hansen's test of overidentifying restrictions.

A further point to consider is that income might be (potentially) affected by measurement error. However, given the time span we have available (41 quarters) we consider that the intertemporal elasticity of substitution is consistently estimated (Attanasio and Low 2004). Further, the usual procedure to obtain data on wages (in dataset where it is not available) is dividing income by hours worked, what might be another source of measurement error (Altonji 1986). Thus, to prevent measurement error problems we follow Griliches and Hausman (1986), and avoid using as instruments current values of income, expenditure, interest rates, hours, wages or any variable directly related to household's income level, such as the number of income earners in the household. However, we assume that the error term is first-order autocorrelated, what implies that we can use the second or further lags of these variables as instruments. As regards the demographic variables, we will consider them as exogenous, what allows using them directly (or lagged) as instruments.

Finally, in the analysis of the effect of wage changes on labour supply, it is important to distinguish between the intensive and extensive margins (Rogerson and Wallenius 2009). The first refers to the change in hours worked in response to a wage changes, while the second refers to changes in labour market participation. This is a key issue in this literature, given the difficulty in distinguishing between individuals who voluntarily choose not to work and those involuntarily unemployed, using the available statistical information. The common practice to face this problem is using sampling selection procedures to obtain a sample of individuals who a priori will not drop from the labour market (i.e., males in a range of ages head of their household and always working). We follow this approach, as explicitly considering the participation decision would be a troublesome issue in the empirical analysis.[19] Analysing female labour participation is out of the scope of this paper, as this is a much more complex empirical exercise that we leave for future work.

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[16] This would imply discarding households where the head is unemployed, what would have implications for the empirical sample used. Further, there might be individuals suffering (potentially) from liquidity constraints, such as young individuals with low income.

[17] Imai and Keane (2004) do not allow for unobserved heterogeneity, although they recognize persistence in wages, assets and hours. Further, Shaw (1989) only introduces individual heterogeneity in Eq. (3), i.e., the process determining wages.

[18] We have estimated the model by using the *gmm* Stata command.

[19] There are few studies addressing this issue, especially with pseudo-panel data. See Blundell et al. (2018).

4 The data

In this study, we estimate the first order intertemporal condition for leisure using Spanish cohort data, both with and without taking into consideration human capital. We construct a cohort data set as we need information on both individual income and hours worked (or wages). The Family Expenditure Survey (*Encuesta Continua de Presupuestos Familiares*, ECPF) is the primary survey with panel information on consumption for Spain. However, neither earnings nor hours worked are included in this survey. The only data available on the labour force is whether any household member works more (or less) than one third of the typical weekly working hours. According to the many sources of income, these figures classify households' income into distinct categories. Income data is aggregated at the household level and no specific information is available regarding which household member makes up the income. The Spanish Labour Survey (*Encuesta de Población Activa*, EPA), provides information on labour supply.[20] Given that respondents cannot be followed over time, it is not a panel data set. As a survey of labour market information, it offers no statistics on individual income or wages.

We construct the same pseudo-panel using the age of the head of the household in both surveys, in order to merge the data from the two statistical sources. Once we have the same pseudo-panel from the income and consumption (ECPF) and labour (EPA) surveys, we combine both data sets. It is crucial to keep in mind that these surveys are representative for the behaviour of consumption and labour supply in Spain, during the time under analysis. By integrating these two surveys, we ensure that the final data set is representative. For both data sets, we only include households in the pseudo-panel that include a man (not retired) as the only member earning a wage. By using this selection criterion, we can be sure that we can combine the labour income reported in the ECPF by these men with the hours reported in the EPA.[21] These two surveys are conducted every quarter. We have 41 data points because the initial period is the first quarter of 1987 and the last one is the first quarter of 1997.[22] The pseudo-panel is composed by eight households of 5-year bands for the head of the household, being the minimum and maximum ages 18 and 57, respectively. However, we will only use six cohorts of five years bands in the empirical analysis, being the minimum and maximum ages 23 and 52, inclusive, in 1987 (34 and 63, respectively in 1997).[23] Given that the definition and scope of the variables specific to households are uniform across both data sets, we have taken the variables directly from the surveys.

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[20] Although it is possible to determine a person's income through careful sample selection, the loss of observations is a relevant issue we must deal with. The sample of households with just one worker seems to be the most sensible choice.

[21] The lack of Spanish data for the studying household consumption and labour supply is also raised by Lugilde et al. (2018).

[22] It is crucial to note that our time frame includes the 1992 recession, which the Spanish economy experienced between two long expansionary peiods.

[23] We apply the typical filters used in these kinds of investigations. Therefore, both in the ECPF and the EPA, we have eliminated households that did not provide information on expenses, income, hours worked, or any other relevant variables. Additionally, we have removed from the ECPF all households with incomes in the first and last percentiles of the distribution in accordance with standard procedure.

We should consider household labour supply similarly to Blundell and Walker (1986), because the ECPF only gathers family income. The ECPF sample sizes allow for the selection of only those households where the male head of the household is not self-employed and his wife or any other household member is not employed.[24] Due to their higher reliance on the economic cycle and uncertainty for their income, there are factors to support the idea that self-employed workers behave differently than other workers.[25] Additionally, we eliminated any households whose head claimed to be retired or unemployed. As a result, with this fairly adjusted profile we believe we are able to investigate the Spanish male labour supply, which sounds sensible given the low participation of women in the labour market throughout the study period.[26]

The average size of the population in each of the two pseudo-panels we constructed for our investigation is shown in Table 1. The numbers we obtain, especially in the smaller pseudo-panel (cohorts 2 to 7), are consistent with the typical results in this literature. To ensure that we accurately calculate the wages we utilise in our empirical approach, we have to employ a rather tight sample selection criterion.[27]

We describe the variables we use in estimating in what follows (see Table 5 in the Appendix for a more detailed description of these variables). The nominal wage was calculated by dividing the head of the household's quarterly labour income, from the ECPF, by the effective hours reported in the EPA. The quarterly leisure hours were calculated by deducting the number of hours actually worked from the total number of hours available. The number of days in the quarter multiplied by 16 h equals the total number of hours that are available. The weekly effective hours declared in the EPA are multiplied by 12 to determine the effective hours worked.

Following Cutanda et al. (2020), we use the nominal interest rate of the Spanish bank deposits. We calculate a Stone price index for each cohort in the sample, using the non-durable expenditure, in order to determine the price index required to achieve the real interest rate. As a result, even though the nominal interest rate does not vary across cohorts, the real interest rate does since the cohort price index is variable across cohorts.

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[24] Additionally, and for similar reasons, Lugilde et al. (2018) only include households with an employee as the reference person in their sample, albeit they place no restrictions on the partner's employment status. But we are aware that the household perspective matters for employment decisions (see for example, Blundell et al. 2016, 2018).

[25] In the EPA, the average number of hours worked by self-employed is consistently higher than the average for employees. The empirical literature on consumption also focuses on this group of self-employed workers, very especially in the analysis of the effect of uncertainty on their consumption.

[26] The average cell size in the sample of households with a female wage earner head throughout the time we analyse is 74.

[27] This problem with selection is rather typical in this literature. For instance, Blundell and Walker (1986) employed a sample of 1378 people, but MaCurdy (1983) used a sample of 121 people. These sample numbers can indicate that sample selection error has to be corrected in some way. According to Keane (2011), it is typical in this research to "ignore selection on the grounds that the vast majority of adult non-retired people participate in the labour market".

Table 1 Average number of individuals within each age cohort

N. of Cohort	Age of head of house. in 1987	Age of head of house. in 1997	ECPF	EPA
1	18–22	29–33	41	622
2	23–27	34–38	94	1373
3	28–32	39–43	118	1876
4	33–37	44–48	126	1988
5	38–42	49–53	116	2133
6	43–47	54–58	82	1868
7	48–52	59–63	58	1622
8	53–57	64–68	47	1288
Mean 1–8			85	1596
Mean 2–7			99	1810

In the ECPF we select only households whose head is a man and has income as employee (i.e., we discard all households whose head declares to be self-employed, unemployed or pensioner), and whose wife has not income as employee or as self-employed. In the EPA we select male households whose head declares to be an employee and whose wife declares not to be.

Our estimation sample is composed by cohorts 2 to 7, that are framed in the table

5 Results

In this section we present the estimation results for the intertemporal elasticity of leisure using the different specifications discussed above. We start providing estimates for the intertemporal specification not considering the effect of human capital. And second, we estimate the same intertemporal condition including the effect of human capital, what will allow testing for the relevance of for human capital on the intertemporal elasticity of leisure. Finally, we will check whether the impact of human capital varies across different age groups.

In Table 2 we report the estimation results for the intertemporal substitution of leisure (*EISL*) for Spain. We use two specifications, being the difference between them the fact that we add three education variables in the second one (see column 2). The results reported for the two specifications estimated are quite suitable, in terms of the *EISL*. We obtain an estimated value for this parameter between 0.25–0.28, being statistically significant in both specifications reported. These estimates are potentially comparable to Cutanda (2019), who estimated a similar model with regional Spanish data, or to Mankiw et al. (1985), with aggregate US data, although in both cases they fail to obtain a statistically significant estimate for the *EISL*. Further, the values we find are also similar to those obtained (using microeconomic data) for other economies and for Spain (see Cutanda and Sanchis-Llopis 2021) for the Frisch elasticity, as we will discuss below.[28]

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[28] Cutanda and Sanchis-Llopis (2021) estimate jointly all the intertemporal optimizing conditions of the model to get the intertemporal elasticities (for leisure and consumption) simultaneously. This empirical strat-

Table 2 Euler equation for leisure

$$\Delta ln\left(L_{it+1}\right) = k_{ol} + k_{1l}ln\left(\frac{W_{it}R_t}{W_{it+1}}\right) + k_{2l}\Delta\theta_{it+1} + \varepsilon_{ilt+1}$$

	(1)	(2)
Constant (k_{ol})	–0.026***	–0.051***
	(0.007)	(0.015)
EISL (k_{1l})	0.247***	0.284***
	(0.061)	(0.041)
Age head	–0.011	–0.067
	(0.037)	(0.045)
Age head squared	0.000	0.001
	(0.000)	(0.001)
Number of members	–0.010	0.032
	(0.053)	(0.048)
Number of adults	–0.004	–0.020
	(0.020)	(0.017)
Pre-school and/or primary education	-	0.006
		(0.048)
High School	-	0.023
		(0.017)
College	-	0.102**
		(0.047)
N. observations	228	228
Test overidentifying restriction		
Hansen's J Chi2(1)	0.317	3.090
p-value	0.573	0.542

We instrument specification (1) with the second and third lags of the interest rate and the third lag of the increase in the number of members of the household and the rest of covariates. For specification (2), we add to the previous set the added covariates with respect to Eq. (1), and the second lag of the logarithm of the hours worked by the head of the household

** and *** mean statistically significant at the 1, 5 an 10%, respectively

It is important to stress that the estimation of this parameter has been traditionally controversial. Keane (2011), after reviewing 14 empirical studies that use microeconomic data, concludes that the estimated average value for the *EISL* is about 0.83. However, the exclusion of two potential outlier values would reduce the average to 0.34, which provides a value much closer to our estimates. Additionally, Reichling and Whalen (2012), in a revision of the empirical literature, conclude that this elasticity ranges between 0.27 and 0.53 for the US. It is important to underline that these

Footnote 28 (continued)

egy was aimed at testing whether the joint estimation of both elasticities provided different results than the separate estimation. In our case, given that we are interested in the intertemporal substitution of labour in presence of human capital accumulation, we do only consider the intertemporal equation for leisure.

reported values correspond to estimates using the entire working population. When they consider a more restricted sample, closer to the sample used in our study (i.e., working men aged between 25 and 54), they conclude that "most estimates…tend to be close to 0.2, but the range of estimates runs from zero to 0.8".

As regards the other covariates, we do not obtain a significant effect of the demographic variables in any of the specifications, except for the variable *College*. Finally, the Hansen test for the overidentifying restrictions in the two specifications considered provide appropriate results, as we obtain in both cases a significance level above 50%.

As previously stated, the main interest in this research consists on checking for the existence of a bias in the estimation of the *EISL*, as claimed by Shaw (1989), Imai and Keane (2004), Wallenius (2011), Keane and Rogerson (2012) and Keane (2016). These authors argue that not incorporating human capital in the basic intertemporal optimization consumption-leisure model produces a downward biased elasticity of intertemporal substitution of leisure.

In Table 3 below, we report the results accounting for human capital, in order to test whether the *EISL* is estimated with a bias. To perform the test requires including an extra regressor to proxy for the last term in expression (11), that depends on N_{t+1} (the hours worked).[29] This regressor, after assuming that the "marginal utility of human capital" is constant, is specifically $log\left(\frac{W_t R_t}{W_{t+1}} N_{t+1} - N_t\right)$.[30] We have estimated the model using the same instrument set as the one reported in Table 2.[31]

From our results, we observe, as expected, that the estimated *EISL* increases significantly with respect to the estimated values reported in Table 2. Specifically, in the wider specification estimates, we get an estimated *EISL* above 0.5, that almost doubles our previous result. Additionally, the added regressor is, jointly with the interest rate adjusted by inflation in wages, the only statistically significant variable. We find that all the other regressors are not significant in all specifications reported. Further, we also get that the constant loses its significance, as compared to Table 2. Finally, although the Hansen test worsens somehow, we still get acceptable values (above 0.27).

Finally, we study whether the bias varies for different age groups. To this end, we separate the sample in two groups: the younger cohorts (cohorts 2 and 3 in Table 1) and the rest. In Table 4 we present these estimates: in column (1), we present the estimation results for the younger cohorts; and, in column (2) the estimates for the rest of cohorts. As it can be checked, the *EISL* is slightly larger for the young cohorts (and the contrary occurs for the older cohorts), as compared to the estimated

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[29] We have tried different mathematical expressions to compute the added regressor, all of them depending on the real interest rate adjusted by the inflation in wages and hours worked, but the results are very similar to those presented in Table 3.

[30] This extra regressor is called *Human capital bias* in Table 3. This term includes variables that would only be statistically significant if human capital is relevant.

[31] Adding the human capital variable implies that we lose some observations. However, we have checked that the results in Table 2 do not change when we use the same number of observations used to produce the results reported in Table 3.

Table 3 Human capital bias in the intertemporal condition for leisure

$$\Delta ln\left(L_{it+1}\right) = k_{ol} + k_{1l}ln\left(\frac{W_{it}R_t}{W_{it+1}}\right) + k_{2l}\Delta\theta_{it+1} + k_{3l}ln\left(\frac{W_{it}R_t}{W_{it+1}}N_{t+1} - N_t\right) + \varepsilon_{ilt+1}$$

	(1)	(2)	(3)	(4)
Constant (k_{ol})	−0.009	−0.017**	−0.018	−0.038
	(0.005)	(0.006)	(0.014)	(0.014)
EISL (k_{1l})	0.371**	0.316***	0.562**	0.443***
	(0.105)	(0.078)	(0.110)	(0.062)
Number of members	−0.039	−0.026	0.026	0.027
	(0.049)	(0.045)	(0.054)	(0.048)
Age head	−0.012	−0.012	−0.060	−0.053
	(0.033)	(0.032)	(0.044)	(0.040)
Number of adults	0.009	0.003	−0.016	−0.016
	(0.018)	(0.017)	(0.020)	(0.017)
Age head squared	0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Pre-school and/or primary education	-	-	−0.010	0.004
			(0.045)	(0.045)
High School	-	-	0.005	0.015
			(0.019)	(0.016)
College	-	-	0.056	0.086
			(0.041)	(0.042)
Human capital bias (k_{3l})	−0.023**	−0.012**	−0.038***	−0.019**
	(0.008)	(0.005)	(0.010)	(0.005)
Bias	0.50	0.28	0.98	0.56
N. observations	228	228	228	228
Test overidentifying restriction				
Hansen's J Chi2(1)	0.309	0.338	5.083	2.351
p-value	0.577	0.560	0.278	0.671

We instrument specification (1) by the second and third lags of the interest rate, the third lag of the increase in the number of members of the household and the rest of covariates. In the case of specification (2), we add the second lag of the human capital bias. For specification (3), the instrument set increases that of specification (1) with the second lag of the logarithm of the hours worked by the head of the household and the second lag of the proxy for human capital bias

The bias is calculated as the percentage change of the *EISL* in this table with respect to the corresponding value in Table 2

** and *** mean statistically significant at the 1, 5 an 10%, respectively

parameter with the total sample. In columns (3) and (4) we provide the estimates accounting for human capital for the young and old cohorts, respectively. The inclusion of human capital implies that the estimates for the *EISL* are larger (as compared to the values in columns 1 and 2). Further, we also observe that the bias is larger for the young than for the old cohorts, according to the theoretical model.

Table 4 Human capital bias in the intertemporal condition for leisure

$$\Delta ln\left(L_{it+1}\right) = k_{ol} + k_{1l}ln\left(\frac{W_{it}R_t}{W_{it+1}}\right) + k_{2l}\Delta\theta_{it+1} + k_{3l}ln\left(\frac{W_{it}R_t}{W_{it+1}}N_{t+1} - N_t\right) + \varepsilon_{ilt+1}$$

	(1)	(2)	(3)	(4)
Constant (k_{ol})	−0.031	−0.022***	−0.028	−0.006
	(0.025)	(0.007)	(0.022)	(0.006)
EISL (k_{1l})	0.286*	0.208***	0.641*	0.316***
	(0.187)	(0.061)	(0.421)	(0.120)
Number of members	0.081	−0.066	0.067	−0.109
	(0.102)	(0.069)	(0.088)	(0.081)
Age head	−0.122	−0.015	0.014	0.001
	(0.112)	(0.053)	(0.141)	(0.049)
Number of adults	−0.030	0.008	−0.021	0.029
	(0.033)	(0.027)	(0.031)	(0.030)
Age head squared	0.002	−0.001	−0.001	−0.001
	(0.002)	(0.001)	(0.002)	(0.001)
Human capital bias (k_{3l})	-	-	−0.038	−0.020**
			(0.027)	(0.010)
Bias			1.24	0.52
N. observations	76	152	76	152
Test overidentifying restriction				
Hansen's J Chi2(1)	1.490	0.006	0.083	0.079
p-value	0.222	0.936	0.772	0.778

Columns (1) and (3) use in estimation only the two younger cohorts, i.e., cohorts 2 and 3 in Table 1. Columns (2) and (4) use in estimation only the four older cohorts, i.e., cohorts 4 to 7 in Table 1

We instrument columns (1) and (2) by the second and third lags of the interest rate, the third lag of the increase in the number of members of the household and the rest of covariates. In the case of columns (3) and (4), we add the second lag of the human capital bias

The *EISL* in columns (1) and (3) are statistically significant at 15%

*, ** and *** mean statistically significant at the 1, 5 an 10%, respectively

We consider that the results obtained splitting the sample by age groups give support to the hypothesis raised by Imai and Keane (2004), Wallenius (2011), Keane and Rogerson (2012) and Keane (2016). Therefore, we confirm that it is important to account for the effect of human capital in individual wages to get a reliable estimate of the elasticity of intertemporal substitution for leisure.[32] However, we would like to point that the estimate for the Spanish economy is still far from the estimate obtained by Imai and Keane (2004) for the US economy, and from the values of this parameter used in most of the studies within the real business cycle literature.

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[32] Nevertheless, this result might also be explained through the effect of borrowing constraints, as put forward by Domeij and Flodén (2006) or Bredemeier et al. (2019).

6 Conclusions

This paper studies the intertemporal substitution of leisure/labour in Spain with individual data. We have estimated the first order conditions of an intertemporal optimization labour and consumption model, aiming at estimating the elasticity of intertemporal substitution of leisure considering only the intertemporal optimizing condition of leisure and under the assumption of separability between consumption and leisure. Further, we explore if ignoring human capital in the analysis can account for the gap between the (usually) estimated values for this parameter with microeconomic data, and those usually considered in macroeconomic analyses. This elasticity is a key parameter as it measures labour supply responses to wage changes. For this purpose, we use a Spanish cohort data set constructed by combining the information of two different statistical sources, the ECPF and the EPA.

We get an estimate for the *EISL* about 0.2/0.3, that is similar to values estimated in other countries and Spain with similar samples (households where the head is a man always working). Our results confirm that human capital, as put forward by Shaw (1989) and Imai and Keane (2004), affects the estimated intertemporal elasticity for leisure. Using a proxy approach, we verify that this parameter increases (to more than 0.5), when we consider the effect of human capital. Therefore, this result confirms the bias obtained by Imai and Keane (2004). Nevertheless, despite the fact that the estimated elasticity, obtained from the model that accounts for human capital, increases, the value estimated is still far from the values usually considered in macro analyses. Additionally, we confirm a bigger bias in the estimation of the elasticity for younger individuals.

Finally, these results corroborate that there is scope to modify the Spanish consumption and employment behaviour by changing the relative intertemporal prices and wages through fiscal policy, in line with the results presented in Silva (2008).

Appendix

Table 5 Variables used in the analysis

C_{it}	Non-durable consumption.
N_{it}	Worked hours.
L_{it}	Leisure hours.
W_{it}	Wage per hour.
$W_{it}N_{it}$	Labour income.
P_{it}	Nominal price of a unit of C_{it}.
$R_{t-1}+r_t$	Nominal interest rate.
θ_{it}	This is a vector of demographic variables. In particular, we include the number of members of the household, the number of adults of the household (individuals 14 years old or older), and a set of educational dummies: pre-school and/or elementary education; high school; and, college. The category college includes university education and other professional degrees. The omitted educational category is middle school.

Availability of data and material All the data used in this study are publicly available in the following page webs of Spanish public entities: https://www.ine.es/, for the ECPF and the EPA. https://www.bde.es/bde/es/, for the interest rate used.

Code availability Not applicable.

Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

References

Alan S, Attanasio OP, Browning M (2009) Estimating Euler equations with noisy data: Two exact GMM estimators. J Appl Economet 24:309–324

Altonji JG (1986) Intertemporal substitution in labor supply: Evidence from micro data. J Pol Econ 94(3, Part 2: Hoover Institution Labor Conference):S176-S215

Attanasio O, Low H (2004) Estimating Euler equations. Rev Econ Dyn 7:405–435

Barro RJ, King RG (1984) Time-separable preferences and intertemporal-substitution models of business cycles. Q J Econ 99(4):817–839

Blanchard OJ, Fischer S (1989) Lectures on Macroeconomics. The Mit Press

Blundell R, Pistaferri L, Saporsta-Ecksten I (2016) Consumption inequality and family labor supply. American Economic Review 106–2:387–435

Blundell R, Pistaferri L, Saporsta-Eksten I (2018) Children, time allocation and consumption insurance. J Pol Econ 126(S1):S73-S115

Blundell R, Walker I (1986) A Life-Cycle consistent empirical model of family labour supply using cross-section data. Rev Econ Stud 53–4:539–558

Bredemeier C, Gravert J, Juessen F (2019) Estimating labor supply elasticities with borrowing constraints of couples. J Law Econ 37–4:1215–1265

Browning M, Deaton AS, Irish M (1985) A Profitable approach to labor supply and commodity demands over the life-cycle. Econometrica 53:503–543

Cabral Vieira JA (2005) Low-wage mobility in the Portuguese labour market. Port Econ J 4:1–14

Chetty R (2012) Bounds on elasticities with optimization frictions: a synthesis of micro and macro evidence on labor supply. Econometrica 80(3):969–1018

Chetty R, Guren A, Manoli D, Weber A (2011) Are micro and macro labor supply elasticities consistent? A review of evidence on the intensive and extensive margins. Am Econ Rev 101(3):471–475

Chetty R, Guren A, Manoli D, Weber A (2013) Does indivisible labor explain the difference between micro and macro elasticities? A meta-analysis of extensive margin elasticities. NBER Macroecon Annu 2012(27):1–56

Cutanda A (2019) intertemporal substitution in the spanish economy: Evidence from regional data. Metroeconomica 70(1):209–229

Cutanda A, Labeaga JM, Sanchis-Llopis JA (2020) Aggregation biases in empirical Euler consumption equations: Evidence from Spanish data. Empir Econ 58–3:957–977

Cutanda A, Sanchis-Llopis JA (2021) Joint estimation of intertemporal labor and consumptions decisions: Evidence from Spanish household headed by working men. Eurasian Econ Rev 11:611–629

Domeij D, Flodén M (2006) The labor-supply elasticity and borrowing constraints: Why estimates are biased? Rev Econ Dyn 9:242–262

Griliches Z, Hausman JA (1986) Errors in variables in panel data. J Econom 31:93–118

Hall RE (1978) Stochastic implications of the life cycle-permanent income hypothesis: Theory and Evidence. J Polit Econ 86(6):971–987

Imai S, Keane MP (2004) Intertemporal labor supply and human capital accumulation. Int Econ Rev 45–2:601–641

Keane MP (2011) Labor supply and taxes: a survey. J Econ Lit 49(4):961–1075

Keane MP (2016) Life-cycle labour supply with human capital: Econometric and behavioural implications. Econ J 126:546–577

Keane MP, Rogerson R (2012) Micro and macro labor supply elasticities: a reassessment of conventional wisdom. J Econ Lit 50–2:464–476

Lugilde A, Bande D, Riveiro D (2018) Precautionary saving in spain during the great recession: Evidence from a panel of uncertainty indicators. Rev Econ Household 16:1151–1179

MaCurdy TE (1981) An empirical model of labor supply in a life-cycle setting. J Polit Econ 89(6):1059–1085

MaCurdy TE (1983) A simple scheme for estimating an intertemporal model of labor supply and consumption in the presence of taxes and uncertainty. Int Econ Rev 24(2):265–289

Mankiw NG, Rotemberg JJ, Summers LH (1985) Intertemporal substitution in macroeconomics. Q J Econ 100(1):225–251

Reichling F, Whalen C (2012) Review of estimates of the Frisch elasticity of labour supply. Working Paper Series, CBO

Rogerson R, Wallenius J (2009) Micro and macro elasticities in a life cycle model with taxes. J Econ Theory 144–6:2277–2292

Runkle DE (1991) Liquidity constraints and the permanent-income hypothesis. J Monet Econ 27:73–98

Shaw KL (1989) Life-cycle labor supply with human capital accumulation. Int Econ Rev 30–2:431–456

Silva AC (2008) Taxes and labour supply: Portugal, Europe and the United States. Port Econ J 7:101–124

Wallenius J (2011) Human capital accumulation and the intertemporal elasticity of substitution of labor: How large is the bias? Rev Econ Dyn 14:577–591

Zeldes SP (1989) Consumption and liquidity constraints: an empirical investigation. J Polit Econ 97:305–346

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