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► To cite this version:

Thierry Kamionka, Pauline Leveneur. The Dynamics of Health, Employment and Working Hours. 2021. hal-03307591

HAL Id: hal-03307591

<https://hal.science/hal-03307591>

Preprint submitted on 29 Jul 2021

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The Dynamics of Health, Employment and Working Hours

Thierry Kamionka* and Pauline Leveneur†

This version : July 2021

Abstract

We investigate interactions between individual's position in the labor market and health status. We jointly model health, employment and working hours using a dynamic model. We estimate a dynamic multivariate model with random effects for the period going from 1991 to 2009 and using data from the British Household Panel Survey (BHPS). Instrumental variables are used. We consider interactions of the error terms of the model using a vector autoregressive process of the order 1. A shock on one component of the error term can have an impact on the distribution of the error term the next period of time. Individual effects - one for each equation - can be correlated. The model is estimated using simulated maximum likelihood estimator. We consider the initial conditions problem. We find that joint dynamics of health and employment is determined by the interactions of their past realizations as well as by the individual's socio-economic characteristics.

Keywords : Employment dynamics, Self-assessed health, Working hours, General physician visits, Panel data, IV estimation.

JEL Classification : C33, J21, I12, C35.

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We would like to thank Investissements d'Avenir (ANR-11-IDEX-0003/Labex Ecodec/ANR-11-LABX-0047, participants of the Journées de Microéconomie Appliquée (Annecy), of the African Meeting of the Econometric Society (AFES, Abidjan), of the Asian Meeting of the Econometric Society (AMES, Malaysia) and International Panel Data Conference (IPDC, 2021).

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1 Introduction

There is a debate in the scientific literature about the relationship between the situation on the labor market and the health status of individuals. Singularly, some empirical results suggest the existence of a correlation between being unemployed (see Thomas et al., 2005) or the movements between employment and unemployment (see Lenhart, 2018), on the one hand, and poor health, on the other hand. There are several difficulties to assess the empirical content of such a correlation.

When talking about the associations between health and employment, one usually thinks of a oneway causality where health status is an important determinant for labor market outcomes. Indeed, poor health can be seen as an obstacle to labor force participation and an hindrance to individual productivity (Lenhart (2018)). A better understanding of the relationship between health and labour market outcomes would contribute to estimate the costs of health limitations to the economy. In the context of population ageing, it is particularly important to focus on the ability of older workers to remain at work given the strong relationship between health and age (Bound et al. (1999)). However, one can also think of a reverse relationship: health might be affected by work-related factors such as labor market transitions (Thomas et al. (2005)) or working conditions.

The first aspect consists to remark that one should determine the direction of the causality. Current working conditions or unemployment status may cause future poor health and current poor health may cause a diminution of individual productivity and may be a source of psychological distress. The second aspect consists in the difficulty to untangle the mechanisms underlying to such causalities. Indeed, current mental health may be the result of the whole history of the individual on the labor market. The impact of the employment status may be heterogeneous and depending on working conditions as, for instance, the number of hours worked. Moreover, current health status is a consequence of past health care expenditures. Current health spending are the consequence of the current health status (see Riphahn et alii, 2003). The third aspect consists in the decisions the individual takes on the labor market or in terms of health care expenditures. These decisions depend on individual characteristics such as education, gender, age, family status. These decisions depend on the history of health care expenditure, labor market transitions and past and current health status.

The dependent variables we consider are continuous variables (working hours), binary variables (employment status) and ordered variables (physician visits, self assessed health). It is important when one models such data to take into account unobserved individual heterogeneity. These omitted variables can be associated with person specific psychological traits that affect the decisions (like forward looking behaviour) and with genetic frailty that may impinge health and, consequently,

health care expenditures.

In this paper we use panel data from the British Household Panel Survey (BHPS) to study the relation between health status and labor market outcomes (employment status, hours worked) for the period going from 1991 to 2009. We use a dynamic model to analyse the relationship between employment status, hours worked and health care expenditures. The model we use incorporates unobserved heterogeneity using random effects.

The main contributions of this paper is twofold. First, we propose a reduced form model to study the health and labour market transitions. We consider a non linear and dynamic panel data model. The econometric modeling allows to consider the interaction between past position on the labour market and health. The foregoing studies (e.g. Contoyannis et alii, 2004, Haan et alii, 2009 or Lenhart, 2018) do not consider interaction effects between individual's position on the labour market and health. The model allows to obtain empirical evidence of the impact of health status on the transition from non employment to employment and on job stability. We consider the impact of health status on hours worked. Second, we take into account state dependence and heterogeneity in order to model the dynamics of health and labour market transitions.

The paper plan is the following one. The related literature is presented in section 2. The econometric model is presented in section 3. The data set we use is described in section 4. The estimation results are presented in section 5. The last section concludes.

2 Related Literature

Early research has been conducted on the association between health status and labor market participation. First, labour market participation can be analyzed on several dimensions. The extensive margin measures whether individuals are in employment or not. The intensive margin measures, for the individuals in employment, the intensity of their job with the number of working hours. Other characteristics such as the wage can be studied. Lenhart (2018) uses data from the British Household Panel Survey to assess the impact of health on several labor outcomes: total labor income, total household income, being employed and weekly worked hours. Health status is more difficult to measure objectively and therefore, studying dynamics of health in itself has been the subject of several papers. Grossman (1972) developed a health capital model where utility-maximizing agents allocate time and invest resources in health, leisure and consumption. This approach links health and labour market behaviour and consider health as human capital (following Becker (1964)). This theoretical model presents how resources - such as phys-

ical activity - can be invested in health and how labor earnings and wealth can purchase indirect investments in health - such as medical care. Literature has often associated health investments with the demand for medical care.

Information on health have often been suspected to be endogenous for several reasons. First omitted variables that are correlated with control variables such as motivation or resistance to conditions can create omitted variable bias. Second, self-reported health is a subjective rate that can be subject to measurement error. Cai and Kalb (2004) talk about a "rationalisation effect" when individuals in poor health underestimate their health status to justify a difficult situation on the labor market. Third, a simultaneity bias can occur when health and workforce participation influence each other. The scientific community also debate on the choice of the indicator to measure health. Kalwij and Vermeulen (2008) use the Survey of Health, Ageing and Retirement in Europe (SHARE) to investigate the potential endogeneity of self-assessed health. They find that objective health indicators add important information to define health and therefore they consider the endogeneity as an omitted variable problem. However, results differ across countries: in some of them, self-reported health appears as a good indicator for health. Contoyannis et al. (2004) analyse the dynamics of individual health using data from the British Household Panel Survey (1991-1998). They use dynamic panel ordered probit models to study the association between health and socioeconomic status. They use self-assessed health in order to disentangle effects due to state dependence and to unobserved heterogeneity. Finally, more specific variables can also be used to analyse health investments and the demand for health care. Several studies have used panel count data estimation based on the number of hospital trips (Geil et al. (1996)), the number of visits to General Practitioners and to hospitals (Riphahn et al. (2003)), or the number of prescribed medications (Cameron et al. (1988)).

Authors have studied separately the impact of health on employment on the one hand and the effect of employment on health on the other hand. Regarding the first direction of the relationship, Lenhart (2018) addresses the endogeneity of self-assessed health by focusing on health shocks defined as decline in self-assessed health across periods or onset of a new condition. He uses propensity score matching combined with difference-in-difference models and finds that health shocks significantly affect the labor market outcomes for several years after the decline in health both for individuals who stopped working and for those who remained employed. Similarly, Miah and Wilcox-Gök (2007) use data from Health and Retirement Study in the United States of America to evaluate the impact of sickness on potential early retirement. Associated with the direct positive effect of chronic illness on early retirement, they also report a negative indirect effect due to fewer accumulation of assets by sick people during their working years. Bound et al. (1999) study the impact of the dynamics of health on labor market behaviour of

older workers. They found that both contemporaneous poor health and declines in health status are associated with retirement from the labor force.

Regarding the second direction of the relationship, Mathers and Schofield (1998) review studies analyzing the effect of unemployment on health. Longitudinal studies provide similar evidence that unemployment has a detrimental effect on health outcomes - such as the increase of mortality rates and of the use of health services. Thomas et al. (2005) study the impact of labor market transitions on mental health using the British Household Panel Survey. They implement logistic regression models with robust standard errors to predict psychological distress following employment transitions. They demonstrate that labor market transitions - especially from paid employment to unemployment or long term sick leave - are associated with deterioration of mental health. Berniell and Bietenbeck (2017) analyse the effect of working hours on health using the 35-hours workweek French reform. They find that working hours have a negative effect on self-reported health.

Some studies have modelled the two processes together. Stern (1989) studies how disability affects labor force participation. He models the two processes in a simultaneous equations system in order to address the endogeneity of self-reported disability in the employment equation. He includes a list of specific chronic conditions as instruments in the health equation. According to him, endogeneity is caused by a reverse causality: bad working conditions affect disability. Cai and Kalb (2004) study the effect of health on the labour force participation using the Household, Income and Labour Dynamics in Australia Survey. They develop Stern's specification of simultaneous equations, allowing self-assessed health to be modelled as a polychotomous variable. They find that being in good health increases the probability of being in employment. They conduct estimations on subgroups of respondents and show a differential effect of employment on health among groups - positive for older females and negative for younger males. Haan and Myck (2009) investigate the dynamics of health and labor market risks using the German Socio-Economic Panel (1996-2007). They use a dynamic bivariate logit random effects model. The outcomes jointly modelled are the health risk - being in poor health - and the labor market risk - being in non-employment. They insist on the importance of taking into account unobserved heterogeneity and their results reveal strong persistence in the dynamics of both processes.

The literature review highlights that self-reported health is potentially endogenous in the employment decision process. The effect of health on labor force participation and the effect of employment on health status have often been studied separately. This article contributes to existing research because it jointly models the dynamics of health, employment status and hours worked allowing for random effects. The model we use is distinct from the specification of Haan and Myck (2009) since, in particular, the model allows for more than two categories for the

self assessed health, introduces some dynamics of error terms and allows instantaneous correlation of error terms. The specification we use allows us to address additional technical issues because we use instruments, interaction terms of state dependence and we model the number of working hours as a third outcome.

Finally this paper addresses the following research questions:

How does health status impact labor market outcomes - employment status and number of hours worked ? Is there a reciprocal effect of employment on self-reported health ? Is there heterogeneity of effects of health (respectively, labour market outcomes) due to interactions between past realizations of health and employment ?

3 Model Specification

3.1 Model

Let us consider a dynamic model for employment (e), health (h)¹ and working hours (w). Let us consider a sample of n individuals. Hereafter, let t denote the index of time and let i denote the index of the individual in the sample. Let x_{jit} , $j \in \{e, h, w\}$, denote a vector of individual characteristics that can include marital status, education, age, citizenship, gender, region. β_j is a vector of parameters associated with observed heterogeneity in equation j , $j \in E = \{e, h, w\}$. δ_j , $j \in E$, are vectors of parameters associated with past realizations of the endogenous variables ($\delta_{jk} \in \mathbb{R}$).

The latent dependent variable y_{jit}^* is given by

$$y_{jit}^* = x'_{jit} \beta_j + z_j(y_{it-1}) \delta_j + r_{jit}, \quad (1)$$

for any $j \in E$, $t = 1, \dots, T$ and $i = 1, \dots, n$. $y_{it} = (y_{eit}, y_{hit}, y_{wit})' \in \mathbb{R}^3$ is the realization of the dependent variables at time t and for individual i . $z_j(\cdot)$ is a function of the previous realization of the dependent variables.

For individual i at time t , the decision $j = e$, is a binary variable and can be written as

$$y_{eit} = \mathbb{I}[y_{eit}^* > 0], \quad (2)$$

where $\mathbb{I}[\cdot]$ is an indicator of the event between brackets equal to 1 if the event occurs and zero otherwise.

¹We present the specification where health is the self assessed health (5 categories). The specification is similar for the number of GP visits (5 categories).

The health status for individual i at time t is a qualitative variable and can be written as

$$y_{hit} = \begin{cases} \text{"Very Poor"}, & \text{if } y_{hit}^* < c_1, \\ \text{"Poor"}, & \text{if } c_1 \leq y_{hit}^* < c_2, \\ \text{"Fair"}, & \text{if } c_2 \leq y_{hit}^* < c_3, \\ \text{"Good"}, & \text{if } c_3 \leq y_{hit}^* < c_4, \\ \text{"Excellent"}, & \text{if } c_4 \leq y_{hit}^*, \end{cases} \quad (3)$$

where c_1, c_2, c_3, c_4 are real parameters.

The log of the number of working hours at time t is

$$y_{wit} = \begin{cases} y_{wit}^*, & \text{if } y_{eit} = 1, \\ ., & \text{if } y_{eit} = 0, \end{cases} \quad (4)$$

where "." means that the number of working hours is not observed.

As the model is dynamic, for each individual, the first observation in the data set is treated specifically.

The error term r_{jit} is the realization of a random variable that summarizes the impact, in the equation j , of a constant unobserved heterogeneity term as well as the existence of a residual error term that can vary across time.

In the equation j the error term is

$$r_{jit} = \alpha_{ij} + u_{jit},$$

where α_{ij} is an individual random effect.

The individual effect α_{ij} is assumed to be independent of the observable characteristics x_i and distributed as a normal random variable with mean zero and variance $\sigma_{\alpha_j}^2$, $j \in E$. These random effects α_{ij} , for all $i \in \{1, \dots, n\}$ and $j \in E$, are independent and identically distributed.

Let u_{jit} denote an error term specific to the equation j , $j \in E$. Let us assume that²

$$u_{jit} = \rho_j u_{jit-1} + \epsilon_{jit}, \quad (5)$$

where $\alpha_{ij} \perp\!\!\!\perp \epsilon_{j'it}$, for all $j, j' \in E$. Let us assume that $\epsilon_{jit} \perp\!\!\!\perp x_i$, for all t and $j \in E$. $\epsilon_{jit} \perp\!\!\!\perp u_{j'it'}$, for all $t' < t$ and $j' \in E$. Let us assume that

$$\epsilon_{jit} \sim N(0, \sigma_{\epsilon_j}^2). \quad (6)$$

Let $\rho_{\alpha_j \alpha_k}$ denote the correlation between the random effects α_{ij} and α_{ik} specific, respectively, to equation j and to equation k , $j, k \in E$. Let ρ_{jk} denote the

²For instance, Kamionka and Lacroix (2019) makes such an assumption in a context of the relationship between homeownership and labor market transitions.

correlation between the idiosyncratic terms ϵ_{jit} and ϵ_{kit} , for all $t = 1, \dots, T$ and $i \in \{1, \dots, n\}$.

Let R_i denote the residual for individual i . The expression of this random vector can be conveniently written $R_i = (r_{ei1}, \dots, r_{eiT}, r_{hi1}, \dots, r_{hiT}, r_{wi1}, \dots, r_{wiT})'$, where T is a number of periods of observation. We obtain that the variance covariance matrix of R_i is

$$\text{Var}(R_i | x_i) = \Omega = \Sigma_\epsilon + \Sigma_\alpha,$$

where

$$\Sigma_\alpha = \begin{pmatrix} \Sigma_{ee} & \Sigma_{eh} & \Sigma_{ew} \\ \Sigma_{eh} & \Sigma_{hh} & \Sigma_{hw} \\ \Sigma_{ew} & \Sigma_{hw} & \Sigma_{ww} \end{pmatrix},$$

where $\Sigma_{jk} = \rho_{\alpha_j \alpha_k} \sigma_{\alpha_j} \sigma_{\alpha_k} \mathbb{I}_T \mathbb{I}_T'$, $j, k \in E$. $\Sigma_\epsilon = \text{Var}(\epsilon_i | x_i)$ is the conditional variance of the vector ϵ_i where $\epsilon_i = (\epsilon_{ei1}, \dots, \epsilon_{eiT}, \epsilon_{hi1}, \dots, \epsilon_{hiT}, \epsilon_{wi1}, \dots, \epsilon_{wiT})'$.

The expression of the variance-covariance matrix Σ_ϵ is given in Kamionka and Lacroix, 2019, Appendix A.

3.2 Initial Conditions

The first observation time does not correspond to the starting time of the process. Consequently, we cannot consider that the initial state $y_{i0} = (y_{ei0}, y_{hi0}, y_{wi0})'$ is independent of the individual effect $\alpha_i = (\alpha_{ie}, \alpha_{ih}, \alpha_{iw})'$.

Wooldridge (2005) proposes to consider that the distribution of the random effect $\alpha'_i = (\alpha_{ie}, \alpha_{ih}, \alpha_{iw})$ conditionally to the state y_{i0} , and a vector of exogenous variables x_i is normally distributed.

For the initial conditions corresponding to employment and working hours equations, we consider

$$\alpha_{ij} | y_{i0}, x_i \sim N(y_{ei0} \lambda_{je}, \sigma_{\alpha_j}^2), \quad (7)$$

where $j=e, w$, $\lambda_{je} \in \mathbb{R}$ and $y_{i0} = (y_{ei0}, y_{hi0}, y_{wi0})'$.

For the initial condition specific to health equation, we fix

$$\alpha_{ih} | y_{i0}, x_i \sim N\left(\sum_{k \in \{ "excellent", "good", "fair", "poor" \}} \mathbb{I}[y_{hi0}=k] \lambda_{hk}, \sigma_{\alpha_h}^2\right), \quad (8)$$

where $\lambda_{hk} \in \mathbb{R}$.

3.3 Identification

The dependent variable associated to the employment status is binary. The dependent variable corresponding to self assessed health status is qualitative and ordinal.

Consequently, we normalize the variance of the residuals in such a way that

$$\text{var}(r_{jit}) = \text{var}(\alpha_{ij}) + \text{var}(u_{jit}) = \sigma_{\alpha_j}^2 + \sigma_{u_j}^2 = 1, \text{ for } j = e, h. \quad (9)$$

Consequently, $0 < \sigma_{\alpha_j}^2 < 1$, $j = e, h$, and one can deduce that

$$\text{var}(u_{jit}) = \sigma_{u_j}^2 = \frac{\sigma_{\epsilon_j}^2}{(1 - \rho_j^2)}, \quad (10)$$

$j \in \{h, e\}$.

Using the empirical correlations between r_{jit} and $r_{jit'}$, $t, t' = 1, \dots, T$, the parameters σ_{ϵ_j} and ρ_j are identified ($T \geq 2$)³. Consequently, σ_{u_j} and, finally, σ_{α_j} are identified (see equations 9 and 10).

Finally, $\kappa_{jk} = \frac{\rho_{\epsilon_j \epsilon_k} \sigma_{\epsilon_j} \sigma_{\epsilon_k}}{(1 - \rho_j^2 \rho_k^2)}$ and $\rho_{\alpha_j \alpha_k}$, $j \neq k$, are identified using the correlations between equation j and equation k over the period of time going from time 1 to time T . Finally, the correlation $\rho_{\epsilon_j \epsilon_k}$, $j \neq k$, is identified since κ_{jk} , σ_{ϵ_j} and σ_{ϵ_k} are identified.

As, for employed people, there is no censoring on the working time, the variance $\sigma_{r_{wit}}^2$ is identified. Thus, σ_{α_w} is identified. The remaining parameters, c_1 , c_2 , c_3 and c_4 are identified using empirical probabilities to observe a level of self-assessed health (hereafter SAH) as this variable has 5 modalities.

3.4 Estimation

A contribution to the likelihood function is given by the expression

$$L_i(\theta) = \int_{A_i} \phi(r; \Omega) dr \quad (11)$$

where the region A_i depend on the vector of parameters θ , the vector of explanatory variables and the realization of the dependent variables (see Appendix).

Let us assume that $r \in A_i$ where $A_i \subset \mathbb{R}^{3T}$ and $a_{ik} \leq r_k \leq b_{ik}$, for all $k = 1, \dots, 3T$. Let L denote the total number of observations per individual ($L=3T$). Let $r = \Gamma u$ where $\Omega = \Gamma \Gamma'$ is the Cholesky decomposition of the matrix Ω .

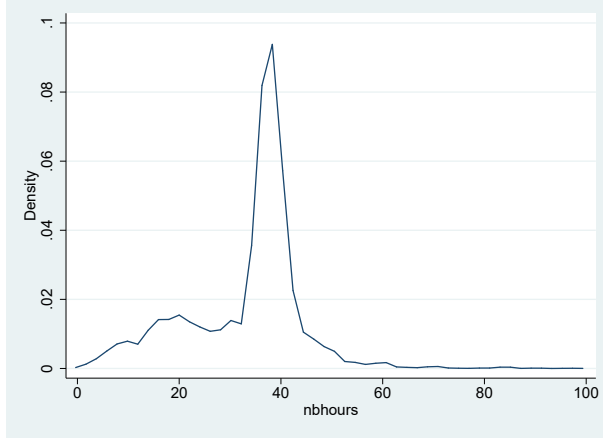
The contribution of individual i to the likelihood function (11) can be estimated using the expression :

$$\hat{p}_i^S = \frac{1}{S} \sum_{s=1}^S p(u_i^s; \theta) \quad (12)$$

³These correlations are identified in a multivariate probit.

where $u_i^s = (u_{i1}^s, u_{i2}^s, \dots, u_{iL}^s)'$ is a random draw and $r_i^s = \Gamma u_i^s$. S is the number of draws used in the estimation and p is an unbiased simulator of probability $\text{Prob}[r \in A_i \mid x_i; \theta]$, where r is the vector of error terms for a given individual (see Kamionka and Lacroix, 2019).

Figure 1: Kernel density estimation of working hours per week in 2008



4 Data set

The data we use comes from the British Household Panel Survey (BHPS). The BHPS is a longitudinal survey of households in Great Britain conducted from 1991 to 2009. Among selected households, each adult (aged 16 years old or above) is interviewed on an annual basis.

Sampling is conducted over three stages. First, 250 postcode sectors were identified as Primary Sampling Units (PSUs) and a population of 2500 addresses was implicitly stratified. Second, a systematic procedure was used to select on average 33 addresses from each PSU. Then, at most 3 households were selected for each address and a random selection procedure was implemented to select these households. The sample for the following waves consists in all eligible individuals in the households where at least one person was interviewed in the first wave. New sample members can be included in the survey: children are interviewed once they reach the age of 16, eligible individuals who separate from original households and all adult members of their new households will be also interviewed.

The initial sample consists in more than 5000 households and 10300 individuals. This initial sample was completed in 1999 by two samples of 1500 households

Table 1: Sample characteristics

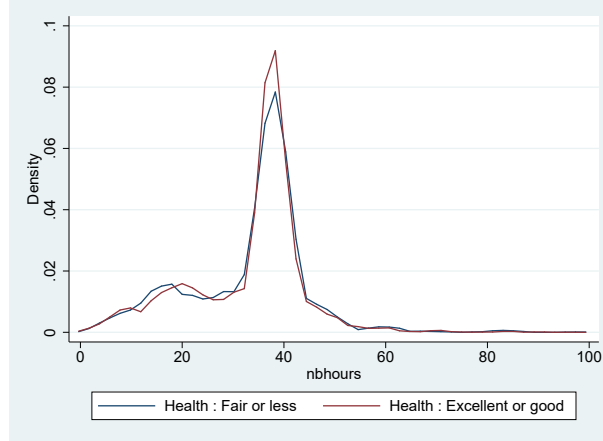
	1991	2008
Dependent variables		
Health - Excellent	28.57	22.17
Health - Good	44.98	47.55
Health - Fair	18.07	21.02
Health - Poor	6.25	7.54
Health - Very Poor	2.14	1.72
Employed	57.85	56.74
Working hours (>0)	33.91	33.28
Instrument		
Stomach	5.52	7.75
Migraine	7.76	6.79
Diabetes	1.75	4.84
Allergy	10.24	11.68
Education level		
Primary	33.79	21.99
Low secondary	4.13	1.02
3c : low sec-voc	30.44	30.72
3a : hisecc-mivoc	9.10	14.61
5b : higher voc	15.25	16.82
5a : first degree	6.06	11.62
6 : higher degree	1.24	3.21
Gender		
Women	52.91	54.41
Men	47.09	45.59
Region		
North England and Yorkshire	26.82	15.57
Midlands and East of England	25.12	15.87
London	10.65	4.30
South England and Channel Islands	22.90	13.81
Wales	5.19	17.88
Scotland	9.32	17.17
North Ireland	0.00	15.39
Biography elements		
Age ≤ 25	17.56	16.31
$26 \leq \text{Age} \leq 36$	22.28	16.75
$37 \leq \text{Age} \leq 44$	15.05	15.40
$45 \leq \text{Age} \leq 51$	11.26	12.20
$52 \leq \text{Age} \leq 59$	9.87	11.80
Married or living in couple	65.11	63.84
Country of birth		
UK	92.89	95.85
Other Country	7.11	4.15
Number of individuals	10264	14420

Note : BHPS 1991-2008. Percentages except for working hours (average).

in Scotland and Wales and, in 2001, by a sample of 2000 households in Northern Ireland.

This longitudinal panel covers multidisciplinary subjects with detailed information on health, socio-economic status and employment. Demographic characteristics such as age, gender, education, marital status and ethnicity are available. Detailed information is available regarding employment such as the current economic activity and the number of hours worked per week. Individuals were also asked to define their health status over the last 12 months - from "excellent" to "very poor" - and to inform about their use of health services such as the number of visits to General Physicians (GP) or to the hospitals.

Figure 2: Kernel density estimation of working hours per week in 2008



The percentage of employed individuals in 1991 observed on our sample (57.85%, see Table 1) is slightly constant over the period (56.74% in 2008). Average working hours per week is rather low (33.91 in 1991). However, the distribution of working hours for working individuals has two modes : one for 40 hours and the other for 20 hours (see Figure 1). Figure 2 shows the distribution of the working hours according to health status (2008). Differences in distributions are not important : healthy people seem to work frequently around 40 hours per week.

We use the international standard classification of education (ISCED 1997) to define the level of education. In 2008, 21.99% of the individuals (see table 1) have a primary education (Primary school in UK and or Elementary School in USA). 45.33% have a secondary education (College for UK or High School for USA). Only 3.21% have higher degree (at least a Bachelor Degree for UK or College

Undergraduate for USA)⁴.

The sample includes 54.41% of women in 2008 (52.91% in 1991)⁵. 63.84% of people declare to be married or to live in couple. Only 4.3% of the individuals in the sample were living in 2008 in London (14.2% of the UK population, 2011 census). 33.98% of the sample is living in the South or East of England or in Midlands or in London in 2008. 95.85% of the individuals in the sample are born in the UK in 2008 and 92.89% in 1991 (87% in 2014 according to the estimate of Office for National Statistics).

In our sample, 9.26% of the individuals declare to have a poor or very poor health status. On the contrary, 22.17% declare to be in an excellent health. A majority of individuals have an intermediate perception of their health status: they declare to have a fair health (21.02%) or a good health (47.55%). We have defined 6 age groups. These age groups are fairly balanced: the only exception consists in individuals aged greater or equal to 60 years old who represent 27.5 percent of the sample.

The proportion of people with stomach problems represents 7.75 percent of the sample. We use this variable in the analysis as well as dummies of allergy problems, problems of diabetes and migraine. These variables are correlated with the health status but they do not limit the activity of the individual on the labor market.

5 Results

The results are presented in tables (2) and (3). Ten specifications are estimated. All specifications incorporate the lagged values of employment and self assessed health (hereafter SAH) in the health and employment equations. The first one incorporates the lagged value of employment in the equation governing employment and lagged value of health (as a binary variable⁶) in the equation modeling the health status. In the second specification, impact of the lagged value of health is distinguished according to position on the labour market in the employment and health equations. In the third specification, we add an instrument in the health equation. We use this information as control of health status. In this specification, we add controls for age in all the equations of the model and the unemployment rate in the employment equation. We replace the variable smoker (employment equation) by a dummy of problem with stomach (specification 4). In the next specification,

⁴Low secondary education correspond to High School or Secondary for UK. It is similar to Middle school or Junior High for USA.

⁵50.9% of the population of the UK (2011 census).

⁶The variable is set to 1 if the self assessed health is excellent or good and to 0 otherwise.

we control by lagged value of health status in health equation (specification 5). In the specification (6) we add additional controls for geographical region in the employment and health equations. In specification (7) we include state dependence for work hours and the variable 'born abroad'. We add three other instruments (dummies for allergy, diabetes, migraine) in the last specification (specification 8). Two additional specifications are added to model the number of GP visits (see column (I) and (II) of table 3). These last specifications are similar to specification (8).

Let us consider the results that are common to all the specifications.

For the health status (see panel 1), the impact of diploma is increasing with the level of the diploma. Individuals with a higher level of diploma have accumulated larger human capital and have larger expected earnings. The increase of health with the expected income can be the consequence of several effects. It may be the consequence of better prevention (informational effect) or the consequence of larger health expenditures. A better prevention can consist in practicing sport regularly (see Kamionka, 2021), adopt more responsible attitudes (do not smoke, take less risk, decrease alcohol consumption), have a better food, see a general practitioner regularly. It can be the result of individual preferences (people with higher education have specific attitude towards risk) or a better access to information (sport would help stay healthy). It can be due, for instance, to the fact that higher education institutions promote practice of sport. Some studies indicate that an important cause of mortality may be lifestyle-related disease and illness like diabetes (DM2), cardiovascular disease and colon cancer (Deek et alii, 2009).

Married individuals are more likely to consider they are healthy. Indeed, married people may take fewer risk and eat better. They maintain social relations whereas depression is generally considered to be more frequent for single people. They have a more responsible behavior and, singularly, they may consult a GP more frequently than single individuals⁷. We do not find any statistically significant difference in self assessed health with respect to gender. Singularly, some people can consider that some pathologies are more frequent for women or men like osteoporosis that is associated with menopause. But these pathologies may be under-diagnosed in the other gender.

The impact of age on the self assessed health is decreasing with age indicating that the health status of individuals can deteriorate with age. Singularly, many diseases are associated with age (osteoporosis, Alzheimer's disease). Sport practice can be fruitful for health but declines with age (Kamionka, 2021).

The initial conditions indicate that people with high initial self assessed health

⁷Some evidence that married individuals are healthier have been found using panel data for a sample of women in the U.S. (Waldron et alii, 1996).

(SAH) have better SAH on all the periods of observation. Consequently, initial conditions are informative of unobserved heterogeneity. The omission of these initial conditions would bias the estimates of lagged values of SAH. We estimate the presence of a true state dependence for health: the results show that a shock on health has a temporary effect.

For a given year and healthy individuals, actual position on the labour market does not have a significant impact on the self assessed health the next period of time. Among sick people a given year, unemployed individuals are more likely to declare a state of health deteriorated the next year. For sick people, to be unemployed may be an additional source of problems. Singularly such a situation can generate some anxiety, some anguish or even cause mental distress.

Past working hours have no significant impact on current distribution of self assessed health. The variables used to instrument health have a negative impact on self assessed health. Being born abroad has no significant impact on self assessed health.

Geographic variables attest to the existence of regional disparities in self assessed health (SAH). Indeed, people living in North England, East England, Yorkshire and Midlands have lower SAH compared to the south of England.

For employment (see panel 2), the impact of diploma is increasing with the level of the diploma. This is consistent with the neoclassic labour supply model. Married individuals are more likely to be employed. This result can be explained for instance by a larger search intensity. This does not exclude the fact that among married people some - women with children - can work on average a smaller number of hours. The impact of age is increasing then decreasing: this is consistent with the evolution of the observed employment rate with age. For instance, in 2009 (Jan-Mar) in the UK, the employment rate is lower for younger (60.6%, 18-24 age group) and older (65.3%, 50-64 age group) compared to adults (79.1%, 25-34 age group and 81.9%, 35-49 age group)⁸. As expected, the conditional probability to be employed is decreasing with the unemployment rate. Women have a lower probability to be employed that can be explained partly by a lower participation to the labour market⁹. Initial status is informative of unobserved heterogeneity distribution: people initially employed are more likely to be employed later. We estimate a true state dependence: employed individuals a given year are more likely to be employed the next year (see model (1)). Indeed, the employment status at the previous time is informative of the employability which is correlated with the expected earning stream. When one lives in the part of the UK corresponding to

⁸Source: Office of National Statistics, <https://www.ons.gov.uk/>.

⁹77.7% of all people in the UK aged 16-64 were participating to the labour market (last quarter, 2014). 74.5% of women in the UK aged between 16 and state pension age were participating to the labour market (2014, last quarter). Source: Office of National Statistics.

North England and Yorkshire, Wales, Scotland, North England she/he is less likely to be employed compared to someone living in South England. It is a consequence of the difference of unemployment rates in these two parts of the UK¹⁰.

In all the specifications, unemployed people the previous year are less likely to be currently employed. Among unemployed individuals, healthy people are more likely to be reemployed the next year.

In the specifications 2-8, people who were already employed the previous year and healthy are more likely to be currently employed compared to individuals who were already employed last year but unhealthy. Health status may have an impact on productivity. Among unemployed individuals, healthy people are more likely to be employed the next year. Once again, healthy individuals may be more productive and have, consequently, a larger search intensity (specifications 2-8). People born abroad are not significantly less employed.

For the log of working hours (see panel 3, tables 2 and 3), the impact of diploma is increasing with the level of the diploma. This result is consistent with the presence of positive return to education. Consequently, the opportunity cost of an additional working hour is increasing with diploma. To be born abroad has no significant impact on working hours. Working hours are decreasing with age after 52 y.o.. This result can be a choice of older workers (they prefer to reduce working hours) or some of them may prefer to work more and firms choose to reduce working hours of less productive or most costly workers. Women have shorter conditional expectation of working time. Singularly, women can reduce working hours when they have a young child. Married individuals have a lower expectation of working hours. Once again, this result can be the consequence of women choices in terms of fertility when they consider child care costs and compensation for an additional hour of work.

In the specifications 6-8, previous self assessed health - one year before - has no significant impact on working hours. Among individuals who were previously employed last year, working time has a negative impact on the current conditional expectation of working time. This indicate the presence of a negative state dependence.

Individuals who were already previously employed have a larger conditional expectation of working hours: indeed, these individuals are more likely to benefit from the presence of a kind of positive returns to seniority.

In all specifications, the initial conditions are informative of the unobserved heterogeneity in the equation of the log of working hours. An individual who

¹⁰To illustrate this, the unemployment rate in the UK is 4% (Sep-Nov, 2018). It is only equal to 3.2% in the South East of England and to 3.1% in the South West of England. It is equal to 5.5% in the north east of England and 5% in Yorkshire and The Humber. Source : Office of National Statistics.

is initially employed is more likely to have a higher conditional expectation of working hours. This accounts, in particular, for individual preferences.

The error term of the employment, SAH and working hours equations are positively correlated in all the specifications (see panel 4). The variance of the random effect specific to the log of working hours is relatively large indicating the presence of an important - unobserved - heterogeneity among workers.

The unobserved heterogeneity components specific to employment, SAH and working hours are positively correlated in all the specifications. Singularly, the correlation between unobserved components specific to employment and working hours is relatively large. The error term of SAH and employment equations are positively autocorrelated implying that a shock a given a year is likely to affect the following year positively. The error term of the employment equation is negatively and significantly autocorrelated.

6 Discussion and conclusions

In this paper, we model jointly health status, employment and working hours using a dynamic model with random effects for the period going from 1991 to 2009 and using data from the British Household Panel Survey (BHPS). The model we consider allows to make interact past realizations of health and employment to characterize their joint dynamics. The model we use incorporates unobserved heterogeneity, allows for state dependence and an own dynamic of error terms.

The dynamics of health depend on individual's socioeconomic characteristics such as diploma and marital status indicating the presence of some informational effects and heterogeneity in the attitude towards risk of individuals. Singularly, more educated individuals may have a better access to information and adopt practices that maintain or improve their health (eat better, play sports, do not smoke). We highlight the presence of a true state dependence and current environment may have a long term impact. But initial conditions are informative of the distribution of unobserved components: initially healthy individuals are more likely to declare to be healthy later.

We find evidence that health and employment interact. Thereby, if among healthy individuals, employed or unemployed people are equally likely to be healthy later, among unhealthy individuals, unemployed people are less likely to be healthy later. Unemployment can be a source of anxiety among unhealthy individuals which prevents them from recovering as much as other people.

Socioeconomic status is informative of the conditional probability to be employed. For instance, consistently with classic labour supply theory, individuals with higher education are significantly more employed. Among previously em-

Table 2: **Health, Employment and Number of Working Hours**

	Health					
	(1)	(2)	(3)	(4)	(5)	(6)
c_1	-2.0366*** (0.0112)	-2.0385*** (0.0112)	-2.0785*** (0.0155)	-2.0764*** (0.0155)	-1.9855*** (0.0152)	-1.9877*** (0.0152)
c_2	-1.2991*** (0.0081)	-1.3004*** (0.0081)	-1.3141*** (0.0110)	-1.3137*** (0.0111)	-1.2535*** (0.0110)	-1.2553*** (0.0110)
c_3	-0.4906*** (0.0065)	-0.4911*** (0.0065)	-0.5389*** (0.0089)	-0.5389*** (0.0090)	-0.5128*** (0.0089)	-0.5128*** (0.0090)
c_4	0.7187*** (0.0069)	0.7199*** (0.0069)	0.6674*** (0.0092)	0.6660*** (0.0092)	0.6435*** (0.0092)	0.6451*** (0.0092)
Woman	0.0002 (0.0054)	0.0035 (0.0057)	0.0053 (0.0076)	0.0060 (0.0075)	-0.0031 (0.0072)	-0.0012 (0.0073)
Married	0.0189*** (0.0054)	0.0158*** (0.0055)	0.0222** (0.0084)	0.0242*** (0.0084)	0.0166** (0.0083)	0.0174** (0.0082)
Second Education	0.0539*** (0.0065)	0.0511*** (0.0065)	0.0245*** (0.0091)	0.0249*** (0.0091)	0.0204** (0.0089)	0.0212** (0.0089)
High Education	0.0843*** (0.0076)	0.0776*** (0.0077)	0.0484*** (0.0100)	0.0535*** (0.0099)	0.0507*** (0.0096)	0.0520*** (0.0097)
Aged 26 to 36			0.0167** (0.0085)	0.0164* (0.0085)	0.0070 (0.0083)	0.0103 (0.0083)
Aged 45 to 51			-0.0225*** (0.0086)	-0.0225*** (0.0085)	-0.0298*** (0.0085)	-0.0271*** (0.0085)
Aged 52 to 59			-0.0572*** (0.0095)	-0.0554*** (0.0095)	-0.0647*** (0.0095)	-0.0650*** (0.0095)
Smoker			-0.0195** (0.0076)			
Health problem (Stomach) no limit to daily activities				-0.1210*** (0.0130)	-0.1171*** (0.0122)	-0.1169*** (0.0122)
North England & Yorkshire						-0.0678*** (0.0125)
East England & Midlands						-0.0301** (0.0124)
London						-0.0310** (0.0168)
Wales						-0.0189 (0.0130)
Scotland						-0.0153 (0.0124)
North Ireland						-0.0114 (0.0131)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or

"Good" the previous year. Health problem: Stomach or digestion

Table 2: **Health, Employment and Number of Working Hours**

	Health (continued)					
	(1)	(2)	(3)	(4)	(5)	(6)
State dependence						
$Health_{t-1}$	-0.1694*** (0.0073)		-0.1549*** (0.0096)	-0.1596*** (0.0096)		
Emp_{t-1}						
$Health_{t-1} \times Emp_{t-1}$		-0.1821*** (0.0085)				
$Health_{t-1} \times (1 - Emp_{t-1})$		-0.1974*** (0.0093)				
$(1 - Health_{t-1}) \times (1 - Emp_{t-1})$		-0.0426*** (0.0083)				
$Emp_{t-1} \times (Hours_{t-1} > 45)$			-0.0006 (0.0148)	-0.0023 (0.0148)	0.0034 (0.0140)	0.0077 (0.0141)
$Emp_{t-1} \times (Hours_{t-1} \leq 45)$			0.0009 (0.0080)	0.0036 (0.0080)	0.0080 (0.0075)	0.0090 (0.0078)
Health						
$Excellent_{t-1}$					-0.4903*** (0.0117)	-0.4882*** (0.0117)
$Good_{t-1}$					-0.1985*** (0.0081)	-0.1959*** (0.0081)
$Poor_{t-1}$					0.1035*** (0.0116)	0.1032*** (0.0116)
$Very\ Poor_{t-1}$					0.2745*** (0.0197)	0.2722*** (0.0198)
Initial Conditions						
Health						
$Excellent_0$	0.0510*** (0.0109)	0.0724*** (0.0118)	0.0769*** (0.0171)	0.0756*** (0.0167)	0.3270*** (0.0169)	0.3435*** (0.0184)
$Good_0$	0.0552*** (0.0097)	0.0779*** (0.0107)	0.0725*** (0.0159)	0.0699*** (0.0154)	0.1490*** (0.0145)	0.1662*** (0.0164)
$Fair_0$	-0.0377*** (0.0086)	-0.0108 (0.0101)	-0.0124 (0.0149)	-0.0143 (0.0145)	0.0187 (0.0140)	0.0358** (0.0158)
$Poor_0$	-0.0362*** (0.0120)	-0.0050 (0.0135)	0.0108 (0.0191)	0.0092 (0.0163)	-0.0379** (0.0188)	-0.0190 (0.0197)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 2: **Health, Employment and Number of Working Hours**

	Employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-1.3921*** (0.0165)	0.3002*** (0.0265)	1.0383*** (0.0453)	1.0395*** (0.0459)	1.0350*** (0.0445)	1.1374*** (0.0528)
Woman	-0.0946*** (0.0122)	-0.0961*** (0.0123)	-0.2313*** (0.0170)	-0.2281*** (0.0170)	-0.2287*** (0.0170)	-0.2304*** (0.0171)
Married	0.0618*** (0.0117)	0.0627*** (0.0118)	0.0853*** (0.0183)	0.0864*** (0.0184)	0.0870*** (0.0184)	0.0842*** (0.0185)
Second Education	0.3002*** (0.0143)	0.2983*** (0.0145)	0.1485*** (0.0200)	0.1395*** (0.0201)	0.1405*** (0.0200)	0.1479*** (0.0202)
High Education	0.4940*** (0.0163)	0.4951*** (0.0165)	0.2254*** (0.0215)	0.2255*** (0.0217)	0.2279*** (0.0216)	0.2349*** (0.0217)
Aged 26 to 36			-0.1126*** (0.0187)	-0.1100*** (0.0188)	-0.1110*** (0.0188)	-0.1134*** (0.0189)
Aged 45 to 51			-0.0494*** (0.0188)	-0.0428** (0.0190)	-0.0425** (0.0190)	-0.0518*** (0.0190)
Aged 52 to 59			-0.3557*** (0.0193)	-0.3545*** (0.0194)	-0.3551*** (0.0194)	-0.3645*** (0.0195)
Unemp. Rate			-0.0185*** (0.0036)	-0.0186*** (0.0036)	-0.0185*** (0.0037)	-0.0238*** (0.0039)
North England & Yorkshire						-0.0723*** (0.0274)
East England & Midlands						-0.0337 (0.0270)
London						-0.0632* (0.0363)
Wales						-0.0751** (0.0299)
Scotland						-0.0893*** (0.0283)
North Ireland						-0.1508*** (0.0317)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 2: **Health, Employment and Number of Working Hours**

	Employment (continued)					
	(1)	(2)	(3)	(4)	(5)	(6)
State dependence						
$Health_{t-1}$						
Emp_{t-1}	1.7642 (0.0218)					
$Health_{t-1} \times Emp_{t-1}$		0.1034*** (0.0160)	0.1028*** (0.0210)	0.0985*** (0.0211)	0.1180*** (0.0210)	0.1215*** (0.0211)
$Health_{t-1} \times (1 - Emp_{t-1})$		-1.6515*** (0.0251)	-1.6644*** (0.0343)	-1.6578*** (0.0356)	-1.6561*** (0.0320)	-1.6502*** (0.0370)
$(1 - Health_{t-1}) \times (1 - Emp_{t-1})$		-1.8117*** (0.0267)	-1.8949*** (0.0364)	-1.8977*** (0.0379)	-1.9192*** (0.0333)	-1.9095*** (0.0399)
Initial Conditions						
$Employed_0$	0.6587*** (0.0170)	0.6677*** (0.0171)	0.6082*** (0.0245)	0.6097*** (0.0249)	0.6073*** (0.0235)	0.6052*** (0.0256)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 2: **Health, Employment and Number of Working Hours**

	Number of Working Hours					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	3.0064*** (0.0112)	3.0072*** (0.0112)	3.2123*** (0.0143)	3.1941*** (0.0146)	3.1949*** (0.0147)	3.1836*** (0.0145)
Woman	-0.3368*** (0.0072)	-0.3369*** (0.0072)	-0.4115*** (0.0078)	-0.4091*** (0.0078)	-0.4090*** (0.0078)	-0.4118*** (0.0078)
Married	0.0016 (0.0050)	0.0016 (0.0050)	-0.0313*** (0.0058)	-0.0312*** (0.0059)	-0.0314*** (0.0059)	-0.0298*** (0.0058)
Second Education	0.0808*** (0.0086)	0.0808*** (0.0086)	0.0519*** (0.0089)	0.0665*** (0.0092)	0.0669*** (0.0092)	0.0663*** (0.0091)
High Education	0.2234*** (0.0093)	0.2237*** (0.0093)	0.0796*** (0.0092)	0.0925*** (0.0095)	0.0923*** (0.0095)	0.0936*** (0.0095)
Aged 26 to 36			-0.0034 (0.0047)	-0.0036 (0.0047)	-0.0036 (0.0047)	-0.0048 (0.0047)
Aged 45 to 51			0.0074 (0.0046)	0.0091 (0.0046)	0.0092** (0.0046)	0.0076* (0.0046)
Aged 52 to 59			-0.0176*** (0.0062)	-0.0150** (0.0062)	-0.0150** (0.0062)	-0.0174*** (0.0062)
State dependence						
<i>Excellent</i> _{<i>t</i>-1}						0.0055 (0.0034)
<i>Good</i> _{<i>t</i>-1}						0.0044 (0.0028)
<i>Poor</i> _{<i>t</i>-1}						-0.0001 (0.0052)
<i>VeryPoor</i> _{<i>t</i>-1}						-0.0022 (0.0120)
Initial Conditions						
<i>Employed</i> ₀	0.4651*** (0.0085)	0.4649*** (0.0085)	0.4212*** (0.0114)	0.4250*** (0.0114)	0.4246*** (0.0114)	0.4349*** (0.0113)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. *Health*_{*t*-1} means "Excellent" or "Good" the previous year.

Table 2: Health, Employment and Number of Working Hours (continued)

Residuals						
$r_{jit} = \alpha_{ij} + u_{jit}$						
$u_{jit} = \rho_j u_{jit-1} + \epsilon_{jit}$						
$j \in \{h, e, w\}$						
h stands for health, e stands for employment, w stands for working hours						
	(1)	(2)	(3)	(4)	(5)	(6)
Standard errors of individual effects (α_{ij})						
$\sigma_{\alpha_h} = \frac{\exp(v_h)}{1+\exp(v_h)}$	-1.0342*** (0.0151)	-1.0303*** (0.0151)	-1.1000*** (0.0192)	-1.1065*** (0.0194)	-0.9524*** (0.0232)	-0.9504*** (0.0231)
$\sigma_{\alpha_e} = \frac{\exp(v_e)}{1+\exp(v_e)}$	-0.2811*** (0.0302)	-0.2470*** (0.0310)	-0.0478 (0.0434)	-0.0479 (0.0470)	-0.0108 (0.0353)	-0.0220 (0.0517)
$\sigma_{\alpha_w} = \exp(v_w)$	0.8821*** (0.0306)	0.8834*** (0.0306)	1.0047*** (0.0282)	1.0003*** (0.0274)	1.0009*** (0.0274)	1.0136*** (0.0276)
Correlations between individual effects (α_{ij})						
$\rho_{\alpha_h \alpha_e} = \tanh(c_{he})$	0.4228*** (0.0143)	0.3305*** (0.0163)	0.4548*** (0.0248)	0.4550*** (0.0250)	0.4435*** (0.0259)	0.4348*** (0.0255)
$\rho_{\alpha_h \alpha_w} = \tanh(c_{hw})$	0.1336*** (0.0165)	0.1216*** (0.0166)	0.1055*** (0.0184)	0.1109*** (0.0185)	0.1150*** (0.0190)	0.1013*** (0.0195)
$\rho_{\alpha_e \alpha_w} = \tanh(c_{ew})$	0.8533*** (0.0341)	0.8662*** (0.0348)	0.4784*** (0.0270)	0.4938*** (0.0272)	0.4956*** (0.0275)	0.5084*** (0.0283)
Auto-Correlation of error terms (u_{jit})						
$\rho_h = \tanh(d_h)$	0.4109*** (0.0068)	0.4106*** (0.0068)	0.3927*** (0.0084)	0.3944*** (0.0085)	0.6025*** (0.0099)	0.6021*** (0.0099)
$\rho_e = \tanh(d_e)$	-0.2745*** (0.0091)	-0.2762*** (0.0091)	-0.2802*** (0.0123)	-0.2644*** (0.0126)	-0.2645*** (0.0124)	-0.2653*** (0.0125)
$\rho_w = \tanh(d_w)$	0.9432*** (0.0114)	0.9431*** (0.0114)	0.9724*** (0.0127)	0.9678*** (0.0125)	0.9671*** (0.0125)	0.9602*** (0.0124)
Correlations between error terms (ϵ_{jit})						
$\rho_{he} = \tanh(f_{he})$	0.0833*** (0.0067)	0.0946*** (0.0068)	0.1156*** (0.0091)	0.1172*** (0.0092)	0.1223*** (0.0095)	0.1270*** (0.0095)
$\rho_{hw} = \tanh(f_{hw})$	0.0189 (0.0047)	0.0200*** (0.0047)	0.0198*** (0.0054)	0.0126** (0.0054)	0.0113** (0.0053)	0.0125** (0.0056)
$\rho_{ew} = \tanh(f_{ew})$	0.2013*** (0.0064)	0.2010*** (0.0064)	0.0753*** (0.0077)	0.0695*** (0.0077)	0.0685*** (0.0077)	0.0717*** (0.0079)
Standard error of log of number of hours (u_{nit})						
$\sigma_{u_w} = \exp(g)$	-0.8809*** (0.0096)	-0.8809*** (0.0096)	-1.1067*** (0.0108)	-1.1078*** (0.0106)	-1.1080*** (0.0106)	-1.1117***
Number of obs.	22087	22087	11953	11898	11898	11820

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. Specifications (3) to (6) are restricted to the 26 to 59 years old age group.

Table 3: **Health, Employment and Number of Working Hours**

	Health		GP visits	
	(7)	(8)	(I)	(II)
c_1	-1.9881*** (0.0153)	-2.0051*** (0.0154)	-1.3450*** (0.0109)	-1.3452*** (0.0108)
c_2	-1.2555*** (0.0110)	-1.2650*** (0.0111)	-0.8980*** (0.0094)	-0.8982*** (0.0094)
c_3	-0.5129*** (0.0090)	-0.5159*** (0.0090)	-0.3193*** (0.0083)	-0.3195*** (0.0083)
c_4	0.6453*** (0.0092)	0.6473*** (0.0092)	0.5819*** (0.0087)	0.5817*** (0.0087)
Woman	-0.0009 (0.0073)	-0.0104 (0.0074)	-0.0409*** (0.0075)	-0.0411*** (0.0075)
Married	0.0177** (0.0083)	0.0181** (0.0083)	0.0245*** (0.0080)	0.0239*** (0.0080)
Second Education	0.0208** (0.0089)	0.0249*** (0.0089)	0.0289*** (0.0090)	0.0282*** (0.0090)
High Education	0.0525*** (0.0097)	0.0578*** (0.0097)	0.0431*** (0.0097)	0.0418*** (0.0097)
Aged 26 to 36	0.0105 (0.0083)	0.0079 (0.0082)	-0.0212** (0.0084)	-0.0213** (0.0084)
Aged 45 to 51	-0.0271*** (0.0085)	-0.0250*** (0.0085)	-0.0268** (0.0088)	-0.0270*** (0.0088)
Aged 52 to 59	-0.0651*** (0.0095)	-0.0592*** (0.0095)	-0.0567*** (0.0097)	-0.0567*** (0.0097)
Born abroad	-0.0177 (0.0160)	-0.0150 (0.0159)	-0.0470*** (0.0165)	-0.0467*** (0.0165)
Health problem (Stomach) no limit to daily activities	-0.1169*** (0.0122)			
Health problem (Stomach)		-0.1998*** (0.0103)	-0.1921*** (0.0110)	-0.1921*** (0.0110)
Health problem (Allergy)		-0.0453*** (0.0090)	-0.0546*** (0.0093)	-0.0547*** (0.0093)
Health problem (Diabetes)		-0.1748*** (0.0209)	-0.2557*** (0.0228)	-0.2559*** (0.0228)
Health problem (Migraine)		-0.1078*** (0.0096)	-0.0718*** (0.0101)	-0.0718*** (0.0101)
Ref. South England				
North England & Yorkshire	-0.0691*** (0.0125)	-0.0676*** (0.0125)	-0.0193 (0.0120)	-0.0197 (0.0121)
East England & Midlands	-0.0307** (0.0124)	-0.0302** (0.0124)	0.0363*** (0.0120)	0.0359*** (0.0120)
London	-0.0286* (0.0169)	-0.0254 (0.0169)	0.0322* (0.0168)	0.0317* (0.0168)
Wales	-0.0197 (0.0129)	-0.0100 (0.0129)	0.0680*** (0.0125)	0.0676*** (0.0125)
Scotland	-0.0160 (0.0123)	-0.0082 (0.0122)	0.0187 (0.0118)	0.0181 (0.0118)
North Ireland	-0.0120 (0.0129)	-0.0071 (0.0130)	0.0288** (0.0126)	0.0284** (0.0126)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or

"Good" the previous year. Health problem: Stomach or digestion

Table 3: Health, Employment and Number of Working Hours

	Health (continued)		GP visits	
	(7)	(8)	(I)	(II)
State dependence				
$Emp_{t-1} \times (Hours_{t-1} \geq 45)$	0.0081 (0.0142)	0.0084 (0.0140)	-0.0055 (0.0152)	-0.0029 (0.0151)
$Emp_{t-1} \times (Hours_{t-1} < 45)$	0.0092 (0.0076)	0.0069 (0.0076)	0.0071 (0.0078)	0.0099 (0.0078)
Health				
$Excellent_{t-1}$	-0.4879*** (0.0117)	-0.4899*** (0.0117)		
$Good_{t-1}$	-0.1957*** (0.0081)	-0.1983*** (0.0081)		
$Poor_{t-1}$	0.1029*** (0.0117)	0.1188*** (0.0116)		
$Very\ Poor_{t-1}$	0.2724*** (0.0198)	0.3117*** (0.0199)		
0 visit $t-1$			-0.2494*** (0.0077)	-0.2503*** (0.0077)
3 to 5 visits $t-1$			0.1508*** (0.0078)	0.1532*** (0.0078)
6 to 10 visits $t-1$			0.2563*** (0.0112)	0.2556*** (0.0112)
> 10 visits $t-1$			0.4017*** (0.0141)	0.3992*** (0.0141)
Initial Conditions				
$Excellent_0$	0.3446*** (0.0185)	0.3497*** (0.0186)		
$Good_0$	0.1669*** (0.0165)	0.1801*** (0.0166)		
$Fair_0$	0.0368** (0.0159)	0.0671*** (0.0160)		
$Poor_0$	-0.0178 (0.0206)	0.0373** (0.0201)		
0 visit $_0$			0.1272*** (0.0106)	0.1271*** (0.0106)
3 to 5 visits $_0$			-0.0740*** (0.0109)	-0.0756*** (0.0109)
6 to 10 visits $_0$			-0.1286*** (0.0150)	-0.1282*** (0.0150)
> 10 visits $_0$			-0.2059*** (0.0168)	-0.2039*** (0.0168)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 3: **Health, Employment and Number of Working Hours**

	Employment			
	(7)	(8)	(I)	(II)
Constant	1.1543*** (0.0527)	1.1410*** (0.0522)	0.9390*** (0.0523)	1.0976*** (0.0526)
Woman	-0.2321*** (0.0171)	-0.2389*** (0.0172)	-0.1417*** (0.0177)	-0.1441*** (0.0178)
Married	0.0843*** (0.0185)	0.0818*** (0.0186)	0.1023*** (0.0186)	0.1017*** (0.0187)
Second Education	0.1481*** (0.0201)	0.1453*** (0.0203)	0.1768*** (0.0204)	0.1780*** (0.0206)
High Education	0.2372*** (0.0218)	0.2351*** (0.0172)	0.2895*** (0.0220)	0.2897*** (0.0222)
Aged 26 to 36	-0.1122*** (0.0189)	-0.1122*** (0.0189)	-0.0801*** (0.0189)	-0.0768*** (0.0190)
Aged 45 to 51	-0.0519*** (0.0190)	-0.0529*** (0.0190)	-0.0609*** (0.0189)	-0.0608*** (0.0190)
Aged 52 to 59	-0.3641*** (0.0195)	-0.3637*** (0.0195)	-0.3577*** (0.0196)	-0.3587*** (0.0197)
Born abroad	-0.0526 (0.0353)	-0.0546 (0.0356)	-0.0391 (0.0363)	-0.0440 (0.0364)
Unemp. Rate	-0.0242*** (0.0039)	-0.0243*** (0.0039)	-0.0201*** (0.0039)	-0.0205*** (0.0039)
Ref. South England				
North England & Yorkshire	-0.0735*** (0.0275)	-0.0762*** (0.0277)	-0.0945*** (0.0281)	-0.0969*** (0.0283)
East England & Midlands	-0.0353 (0.0270)	-0.0281 (0.0273)	-0.0353 (0.0277)	-0.0359 (0.0279)
London	-0.0563 (0.0366)	-0.0534 (0.0368)	-0.0797** (0.0371)	-0.0840** (0.0374)
Wales	-0.0778*** (0.0300)	-0.0762** (0.0301)	-0.0849*** (0.0305)	-0.0866*** (0.0307)
Scotland	-0.0910*** (0.0284)	-0.0923*** (0.0286)	-0.0766*** (0.0290)	-0.0757*** (0.0292)
North Ireland	-0.1523*** (0.0317)	-0.1518*** (0.0319)	-0.1359*** (0.0323)	-0.1391*** (0.0325)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 3: **Health, Employment and Number of Working Hours**

	Employment (continued)			
	(7)	(8)	(I)	(II)
State dependence				
$Health_{t-1} \times Emp_{t-1}$	0.1216*** (0.0211)	0.1171*** (0.0210)	0.1620*** (0.0192)	
$Health_{t-1} \times (1 - Emp_{t-1})$	-1.6624*** (0.0365)	-1.6356*** (0.0353)	-1.6407*** (0.0346)	
$(1 - Health_{t-1}) \times (1 - Emp_{t-1})$	-1.9222*** (0.0392)	-1.8895*** (0.0379)	-1.7453*** (0.0345)	
(0 visit and not employed) $_{t-1}$				-1.7891*** (0.0397)
(1 to 2 visits and not employed) $_{t-1}$				-1.7903*** (0.0361)
(3 to 5 visits and not employed) $_{t-1}$				-1.8527*** (0.0399)
(6 to 10 visits and not employed) $_{t-1}$				-1.9457*** (0.0451)
(> 10 visits and not employed) $_{t-1}$				-1.9854*** (0.0445)
(0 visit and employed) $_{t-1}$				0.0198 (0.0221)
Ref: (1 to 2 visits and employed) $_{t-1}$				
(3 to 5 visits and employed) $_{t-1}$				-0.0766*** (0.0232)
(6 to 10 visits and employed) $_{t-1}$				-0.2484*** (0.0301)
(> 10 visits and employed) $_{t-1}$				-0.3625*** (0.0357)
Initial Conditions				
$Employed_0$	0.5960*** (0.0254)	0.6132*** (0.0250)	0.6674*** (0.0252)	0.6766*** (0.0252)

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. $Health_{t-1}$ means "Excellent" or "Good" the previous year.

Table 3: **Health, Employment and Number of Working Hours**

	Number of Working Hours per Week			
	(7)	(8)	(I)	(II)
Constant	3.1540*** (0.0149)	3.1533*** (0.0152)	3.1450*** (0.0151)	3.1451*** (0.0151)
Woman	-0.4330*** (0.0082)	-0.4342*** (0.0083)	-0.4296*** (0.0085)	-0.4296*** (0.0085)
Married	-0.0304*** (0.0059)	-0.0296*** (0.0059)	-0.0304*** (0.0058)	-0.0305*** (0.0058)
Second Education	0.0650*** (0.0094)	0.0660*** (0.0094)	0.0687*** (0.0094)	0.0688*** (0.0094)
High Education	0.0919*** (0.0097)	0.0917*** (0.0098)	0.0978*** (0.0097)	0.0979*** (0.0097)
Aged 26 to 36	-0.0014 (0.0048)	-0.0003 (0.0047)	0.0000 (0.0047)	0.0001 (0.0047)
Aged 45 to 51	0.0063 (0.0046)	0.0067 (0.0046)	0.0064 (0.0046)	0.0065 (0.0046)
Aged 52 to 59	-0.0179*** (0.0063)	-0.0186*** (0.0063)	-0.0186*** (0.0063)	-0.0185*** (0.0063)
Born abroad	0.0273 (0.0173)	0.0195 (0.0172)	0.0281 (0.0171)	0.0276 (0.0171)
State dependence				
<i>Excellent</i> _{t-1}	0.0039 (0.0034)	0.0044 (0.0034)		
<i>Good</i> _{t-1}	0.0034 (0.0027)	0.0038 (0.0027)		
<i>Poor</i> _{t-1}	0.0015 (0.0051)	0.0011 (0.0051)		
<i>VeryPoor</i> _{t-1}	0.0012 (0.0118)	0.0017 (0.0117)		
nb hours _{t-1} > 0	0.3001*** (0.0174)	0.3040*** (0.0172)	0.3093*** (0.0171)	0.3087*** (0.0172)
ln(nb hours _{t-1}) × <i>I</i> [nb hours _{t-1} > 0]	-0.0647*** (0.0053)	-0.0665*** (0.0053)	-0.0681*** (0.0052)	-0.0679*** (0.0052)
0 visit _{t-1}			0.0019 (0.0022)	0.0019 (0.0022)
3 to 5 visits _{t-1}			-0.0043 (0.0025)	-0.0041 (0.0025)
6 to 10 visits _{t-1}			-0.0122*** (0.0037)	-0.0124*** (0.0037)
> 10 visits _{t-1}			-0.0155*** (0.0050)	-0.0162*** (0.0050)
Initial Conditions				
<i>Employed</i> ₀	0.4074*** (0.0121)	0.4114*** (0.0122)	0.4217*** (0.0122)	0.4215*** (0.0122)

Table 3: **Health, Employment and Number of Working Hours (continued)**

Residuals				
$r_{jit} = \alpha_{ij} + u_{jit}$				
$u_{jit} = \rho_j u_{jit-1} + \epsilon_{jit}$				
$j \in \{h, e, w\}$				
h stands for health, e stands for employment, w stands for working hours				
	(7)	(8)	(I)	(II)
Standard errors of individual effects (α_{ij})				
$\sigma_{\alpha_h} = \frac{\exp(v_h)}{1+\exp(v_h)}$	-0.9510*** (0.0231)	-0.9562*** (0.0229)	-0.5746*** (0.0256)	-0.5690*** (0.0258)
$\sigma_{\alpha_e} = \frac{\exp(v_e)}{1+\exp(v_e)}$	-0.0108 (0.0503)	-0.0600 (0.0464)	-0.1086** (0.0447)	-0.1052** (0.0443)
$\sigma_{\alpha_w} = \exp(v_w)$	1.0539*** (0.0345)	1.0516*** (0.0346)	1.0881*** (0.0361)	1.0878*** (0.0360)
Correlations between individual effects (α_{ij})				
$\rho_{\alpha_h \alpha_e} = \tanh(c_{he})$	0.4352*** (0.0257)	0.4357*** (0.0253)	0.4029*** (0.0258)	0.3478*** (0.0273)
$\rho_{\alpha_h \alpha_w} = \tanh(c_{hw})$	0.1058*** (0.0210)	0.1049*** (0.0209)	0.0409* (0.0224)	0.0394* (0.0235)
$\rho_{\alpha_e \alpha_w} = \tanh(c_{ew})$	0.5127*** (0.0319)	0.4947*** (0.0312)	0.4775*** (0.0319)	0.4810*** (0.0322)
Auto-Correlation of error terms (u_{jit})				
$\rho_h = \tanh(d_h)$	0.6014*** (0.0098)	0.5964*** (0.0097)	0.6157*** (0.0094)	0.6179*** (0.0094)
$\rho_e = \tanh(d_e)$	-0.2630*** (0.0124)	-0.2558*** (0.0125)	-0.2595*** (0.0126)	-0.2636*** (0.0125)
$\rho_w = \tanh(d_w)$	1.0595*** (0.0166)	1.0636*** (0.0165)	1.0757*** (0.0166)	1.0748*** (0.0166)
Correlations between error terms (ϵ_{jit})				
$\rho_{he} = \tanh(f_{he})$	0.1264*** (0.0095)	0.1198*** (0.0095)	0.1787*** (0.0093)	0.1860*** (0.0094)
$\rho_{hw} = \tanh(f_{hw})$	0.0128** (0.0053)	0.0144*** (0.0054)	0.0140*** (0.0051)	0.0140*** (0.0051)
$\rho_{ew} = \tanh(f_{ew})$	0.0610*** (0.0079)	0.0611*** (0.0079)	0.0629*** (0.0080)	0.0609*** (0.0080)
Standard error of log of number of working hours (u_{nit})				
$\sigma_{u_w} = \exp(g)$	-1.0444*** (0.0140)	-1.0427*** (0.0139)	-1.0333*** (0.0140)	-1.0340*** (0.0140)
Number of obs.	11820	11832	11831	11831

(*) Significant at 10%. (**) Significant at 5%. (***) Significant at 1%. Specifications are restricted to the 26 to 59 years old age group. Specification (I) and (II) are such that the number of GP visits is considered to be observed only if the interval length since the last survey is less or equal to 495 days.

employed - the last year - healthy individuals are more likely to be employed the next year. Among unemployed individuals healthy individuals are more likely to be employed the next year. Healthy people may have a larger search intensity. These findings suggest health conditions have an impact for both employed and unemployed individuals. The presence of a state dependency for residuals implies that current bad health conditions can have a negative impact on employment status for several years.

Findings illustrate that health conditions have an important impact on employment status of individuals. Policymakers should try to reduce risk factors on health encouraging the practice of sports, encourage people to stop smoking (via tax policy, advertising campaigns), to reduce alcohol consumption, encourage people to eat better (e.g. try to reduce sugar consumption), walk enough every day. Policymakers should try to develop occupational medicine for employed worker (develop prevention and early treatment of diseases) and regular medical follow-up of the unemployed (prevention, effective access to care).

References

- BECKER, G. (1964). – “Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education”, Columbia University Press: New York.
- BERNIELL I. and J. BIETENBECK (2017). – “The Effect of Working Hours on Health”, IZA Discussion Papers.
- BOUND J., M. SCHOENBAUM, T. R. STINEBRICKNER and T. WAIDMANN (1999). – “The dynamic effects of health on the labor force transitions of older workers”, *Labour Economics*, 6, 179–202.
- CAI L. and G. KALB (2004). – “Health status and labour force participation: evidence from Australia”, *Health Economics*, 15, 241–61.
- CAMERON A. C., P. K. TRIVEDI, F. MILNE and J. PIGGOTT (1988). – “A Microeconomic Model of the Demand for Health Care and Health Insurance in Australia”, *The Review of Economic Studies*, 55, 85–106.
- CONTOYANNIS P., JONES A. M. and N. RICE (2004). – “The Dynamics of Health in the British Household Panel Survey”, *Journal of Applied Econometrics*, n° 19, 473–503.
- DEEKS, A., C. LOMBARD, J. MICHELMORE and H. TEEDE (2009). – “The effects of gender and age on health related behaviors”, *BMC Public Health*, 1–8.
- GEIL, P., A. MILLION, R. ROTTE and K. F. ZIMMERMANN (1996). – “Economic Incentives and Hospitalization in Germany”, *Gerontologist*, 311–321.
- GROSSMAN M. (1972). – “On the Concept of Health Capital and the Demand for Health”, *Journal of Political Economy*, 80, n°2, 223–255.
- HAAN P. and M. MYCK (2009). – “Dynamics of health and labor market risks”, *Journal of Health Economics*, 1116–1125.
- KALWIJ, A. and F. VERMEULEN (2008). – “Health and labour force participation of older people in Europe: What do objective health indicators add to the analysis”, *Health Economics*, 17, 619–638.
- KAMIONKA T. (2021). – “Sporting Activity, Employment Status and Wage ”, to be published in *Revue d’Economie Politique*.
- KAMIONKA T. and G. LACROIX (2019). – “Homeownership, Labour Market Transitions and Earnings”, <https://hal.archives-ouvertes.fr/hal-03290646>.
- LENHART O. (2018). – “The Effects of Health Shocks on Labor Market Outcomes: Evidence from UK Panel Data”, *The European Journal of Health Economics*, <https://doi.org/10.1007/s10198-018-0985-z>.

- MIAH, M. S. and V. WILCOX-GÖK (2007). – “Do the sick retire early? Chronic illness, asset accumulation and early retirement”, *Applied Economics*, 39, 1921–1936.
- MATHERS C. and D. SCHOFIELD (1998). – “The health consequences of unemployment: the evidence”, *Medical Journal of Australia*, 168, 178–82.
- RIPHAHN R.T., WAMBACH A. and A. MILLION (2003). – “Incentive Effects in the Demand for Health Care: A Bivariate Panel Count Data Estimation”, *Journal of Applied Econometrics*, 18, 387-405.
- STERN S. (1989). – “Measuring the Effect of Disability on Labor Force Participation”, *The Journal of Human Resources*, 24, 361–395.
- THOMAS C., BENZEVAL M. and S.A. STANSFELD (2005). – “Employment Transitions and Mental Health: an Analysis from the British Household Panel Survey”, *Journal of Epidemiology and Community Health*, 59, 243-249.
- WALDRON I., HUGUES M.E. and T. BROOKS (1996). – “Marriage Protection and Marriage Selection - Prospective Evidence For Reciprocal Effects of Marital Status and Health”, *Soc. Sci. Med.*, 43-1, 113-123. 20-1, 39–54.
- WOOLDRIDGE J.M. (2005). – “Simple Solutions to the Initial Conditions Problem in Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity”, *Journal of Applied Econometrics*, 20-1, 39–54.

Appendix : Region of integration A_i

The integral is calculated over the set

$$A_i = \{r \in \mathbb{R}^{3T} : r = (r_{e1}, \dots, r_{eT}, \dots, r_{w1}, \dots, r_{wT}) \text{ and } a_{jit} \leq r_{jt} \leq b_{jit}\}$$

The expressions of the boundaries a_{jit} and b_{jit} are fixed, for $t=1, \dots, T$, as follows:

$$\begin{cases} a_{eit} = -\infty, \text{ if } y_{eit} = 0, \\ b_{eit} = +\infty, \text{ if } y_{eit} = 1, \\ a_{eit} = -x'_{eit} \beta_e - z_e(y_{it-1})' \delta_e - y_{ei0} \lambda_{je}, \text{ if } y_{eit} = 1, \\ b_{eit} = -x'_{eit} \beta_e - z_e(y_{it-1})' \delta_e - y_{ei0} \lambda_{je}, \text{ if } y_{eit} = 0, \end{cases}$$

for $1 \leq t \leq T$.

For the number of working hours, let us remark that the realization of this variable cannot be observed when the individual is not employed ($y_{wit} = .$). Then we have

$$\begin{cases} a_{wit} = -\infty, \text{ if } y_{wit} = ., \\ b_{wit} = +\infty, \text{ if } y_{wit} = ., \\ a_{wit} = b_{wit} = y_{wit} - z_w(y_{it-1})' \delta_w - y_{wi0} \lambda_{we}, \text{ if } y_{wit} \neq ., \end{cases}$$

where $1 \leq t \leq T$.

For the SAH the limits are such that

$$\begin{cases} a_{hit} = -\infty, \text{ if } y_{hit} = \text{"Very Poor"}, \\ b_{hit} = +\infty, \text{ if } y_{hit} = \text{"Excellent"}, \\ a_{hit} = c_{k_i} - x'_{hit} \beta_h - z_h(y_{it-1})' \delta_h - \sum_{k \in \{\text{"excellent"}, \text{"good"}, \text{"fair"}, \text{"poor"}\}} II[y_{hi0}=k] \lambda_{hk}, \\ \text{if } y_{hit} \neq \text{"verypoor"}, \\ b_{hit} = c_{k_i+1} - x'_{hit} \beta_h - z_h(y_{it-1})' \delta_h - \sum_{k \in \{\text{"excellent"}, \text{"good"}, \text{"fair"}, \text{"poor"}\}} II[y_{hi0}=k] \lambda_{hk}, \\ \text{if } y_{hit} \neq \text{"excellent"}, \end{cases}$$

for $1 \leq t \leq T$. Let us assume that $k_i = 1$ if $y_{hit} = \text{"Poor"}$, $k_i = 2$ if $y_{hit} = \text{"Fair"}$, $k_i = 3$ if $y_{hit} = \text{"Good"}$, $k_i = 4$ if $y_{hit} = \text{"Excellent"}$. c_1, c_2, c_3 and c_4 are real parameters.