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Abstract

This paper investigates the role of pain dynamics in subsequently affecting dynamics in self-reported work disability and the dynamics of employment patterns of older workers in the US. Not only is pain prevalence quite high, there also are many transitions in and out of pain at these ages We investigate pain and its relationship to health (work disability) and work in a dynamic panel data model, using six biennial waves from the Health and Retirement Study. We find that the dynamics of the presence of pain are central to understanding the dynamics of self-reported work disability and through this pathway, pain dynamics are also a significant factor in the dynamic patterns of employment.

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Reported rates of work disability are key determinants of employment later in life (Stapleton and Burkhauser, 2003, Autor and Duggan, 2003, Bound and Burkhauser, 1999, and Deleire, 2000). However, much less well documented is that individual self-reports of work disability indicate that a substantial fraction of people change their self-assessed work-limiting disability status from one year to the next. For example, in the original Health and Retirement Study (HRS) cohort of individuals who were 51-61 years old in 1992, forty-five percent report having a work disability at least once over the next ten years. Half of the group with at least one work disability report subsequently said that they were not work disabled.

In this paper we use the original HRS cohort, which includes individuals at an age when they are most susceptible to work disability problems, in order to study the relation between the dynamics of employment at older ages and the parallel dynamics of work-limiting disability. In doing so, we document for the first time to our knowledge the central importance of one highly salient reason for the dynamics in reporting work disability- the presence, persistence, and most importantly the irregularity of the experience of pain.

Unlike many illnesses of middle age, pain prevalence is very high, with chronic pain affecting 90 million Americans (Strine et al, 2005). People with persistent pain are more than twice as likely to have difficulty working (Gureje et al, 1998). In the HRS sample referred to above, half of the respondents reported at least once in the six biennial waves over the period 1992-2002 that they were often troubled by pain.

The starting point for this paper is that individuals' reports of pain exhibit considerable variation over time. For more than half of the individuals who reported pain at least once, pain was no longer reported in a subsequent wave. We will document in this paper that onsets of and exits from pain are a central reason for onsets and exits from reported work disability. In turn these pain induced onsets of work disability are an important cause of exits from the labor force. Since in a large number of cases pain appears to be transitory, just considering cross sectional relations between pain and work would be misleading if permanent pain has a much stronger effect on work force exit than transitory pain. Thus to understand the relation between pain, work disability, and employment, one has to account fully for the dynamic interrelationships between them.

Our empirical framework builds on a dynamic binary choice panel data equation for employment, allowing for unobserved heterogeneity and state dependence, in the spirit of Heckman (1981). In this work equation, work disability and pain prevalence are included as explanatory variables. To account for common factors driving unobserved heterogeneity in the employment equation as well as in the work disability and pain equations, the dynamic equation for employment is estimated jointly with dynamic equations for pain prevalence and work disability prevalence.

Our results demonstrate that dynamic models of pain and work disability and pain and employment lead to new and different insights compared to cross-sectional models. First, there is strong evidence of substantial correlated unobserved heterogeneity between all three outcomes, something that cross-sectional models inherently ignore. Second, just as a cross-sectional labor supply equation cannot distinguish between the transitory and long run effect of wages on labor supply, such cross-section models cannot separate out the short and long run impacts of pain on disability and employment. Our estimates imply that these effects are quite distinct with long-run effects of pain on disability and employment being much larger than the short run effects. However, transitory episodes of pain are also important as they turn out to be a crucial factor influencing transitory episodes of work disability and, through their influence on work disability, transitory patterns of employment.

The remainder of the paper is organized as follows. The next section describes the data that will be used while section 2 summarizes the principal patterns in the dynamics of work disability, pain, and work amongst those in their pre-retirement years. The econometric models that we employ are outlined in the third section. Section four discusses our main empirical results for predicting the interrelated dynamics of pain, work disability, and labor force participation. These parameter estimates are then used to ascertain whether simulations based on our model can successfully mimic the observed patterns of the relation between pain and labor force participation. These simulations are presented in section 5 while the final section highlights our conclusions.

1. Data

For this research, we rely on data obtained from the original cohorts of the Health and Retirement Study (HRS). The original HRS-cohort is a national sample of about 7,600 households (12,654 individuals) with at least one person in the birth cohorts of 1931 through 1941 (about 51-61 years old at the wave 1 interview in 1992). The principal objective of HRS is to monitor economic transitions in work, income, and wealth, as well as changes in many dimensions of health status. HRS includes questions on demographics, income and wealth, and employment. Questions are also asked in each wave about self-reports of general health status, the prevalence and incidence of many chronic conditions and functional status and disability. Follow-ups take place at approximately two-year intervals.

HRS has several advantages for the topic of this paper. First, it provides a relatively large sample of individuals during those ages where work disability rates are large and rising. Second, HRS currently has six waves from the original set of panel respondents allowing an examination of the dynamics of pain, work disability, and labor force participation for a decade.

There are three concepts central to this research that warrant a bit more elaboration- work disability, pain, and labor force participation. The HRS work disability question, which is asked each round, is

"Do you have any impairment or health problem that limits the kind or amount of paid work you can do?"

Respondents can answer *yes* or *no*.

While the form of this HRS disability question differs from that used in the Current Population Survey (CPS), overall rates of reported work disability do not seem sensitive to the specific wording of the question.[1]

The second key concept concerns the question on pain, which also is asked every survey round. The HRS pain question is

"Are you often troubled with pain?"

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[1] The CPS asked respondents "Does anyone in the household have a health problem or disability which prevents them from working or which limits the kind or amount or work they can do? [If so,] who is that? (Anyone else?)") Banks et al (2005) used a sample of HRS respondents who agreed to participate in an Internet survey, and randomly assigned the CPS or HRS work disability question. They found no significant differences in rates of self-reported work disability with these two variants of the work disability question. For an excellent discussion of the different work disability questions in different surveys, see Burkhauser et al (2002).

Once again respondents can answer *yes* or *no*. There is no question in the HRS about either the location or the severity of the pain.

Pain clearly has subjective and objective aspects.[2] Objectively, in a reaction to a variety of stimuli, pain is started when energy is converted into electrical energy (nerve impulses) by sensory receptors called nociceptors. These neural signals are then transmitted to the spinal cord and brain, which perceives them as pain. Even without medication, individuals may differ in how they assess, interpret, and tolerate pain.

The form of the HRS question implies that people are being queried about pain that is both recurrent and not completely relieved by medication. Some evidence that this is so comes from the Dutch CentERpanel survey of about 2,000 respondents 25 and older who were asked both the HRS pain question as well as a question about whether they had experienced any pain in the last thirty days. The prevalence for the HRS 'often troubled by pain' question was 27% compared to 59% prevalence for the question on 'any pain in the last thirty days' (Banks et al, 2005).

The final key question refers to labor force activity and is the most straightforward. Each wave HRS respondents are asked,

"Are you working now, temporarily laid off, unemployed and looking for work, disabled and unable to work, retired, a homemaker, or what?"

Individuals who respond that they are working now are recorded as workers and all other responses are treated as not working.

For this paper, we use a balanced panel of respondents who participated in each wave, have no missing values on the explanatory variables, and gave valid responses to the questions on pain, work disability, and labor force status in each wave. The main

[2] See Osterweis, Kleinman and Mechanic (1987) for a discussion of pain and its relation to work disability and social security.

reason for focusing on the balanced panel is that much of our analysis is based on summary statistics like the percentage of respondents that is work disabled in all waves, the percentage with at least one transition from not working to working, etc. Such statistics can only be interpreted in the balanced panel with respondents who participated in all six waves.

Table 1.
Descriptive Statistics

Balanced Panel HRS 1992-2002; 6371 observations

wave	1	2	3	4	5	6	explanation
pain	.223	.259	.244	.260	.275	.287	dummy reports pain
worklim	.171	.209	.232	.239	.255	.271	dummy work limitation
work	.730	.673	.602	.541	.471	.391	dummy paid work
married	.751	.762	.741	.732	.712	.703	dummy married
age	55.9	57.3	59.7	61.6	63.0	65.2	age in years
age < 55	.376	.257	.001	0	0	0	dummy younger than 55
age 55-59	.448	.446	.501	.326	.203	.017	dummy age 55-59
age 60-64	.177	.295	.420	.424	.436	.427	dummy age 60-64
age 65	0	.003	.079	.249	.362	.555	dummy older than 64
dummy variables prevalence of health conditions							
hbp	.335	.366	.399	.434	.476	.529	high blood pressure
diabetes	.074	.087	.105	.122	.142	.174	diabetes
cancer	.046	.054	.068	.083	.104	.127	cancer
lung	.052	.063	.069	.082	.093	.110	lung disease
heart	.098	.118	.141	.159	.186	.223	heart condition
stroke	.015	.019	.025	.031	.038	.049	stroke
mental	.080	.097	.114	.132	.145	.161	depression etc.
arthritis	.360	.416	.479	.527	.565	.613	arthritis
Time invariant characteristics							
hispanic	.048						dummy hispanic
nonwhite	.112						dummy non-white
female	.539						dummy female
education							
edlow	.214						dummy <12 yrs educ.
ed12	.371						dummy 12 yrs educ.
ed1315	.200						dummy 13-15 yrs educ.
edhig	.215						dummy >15 yrs educ.

Note: All weighted with respondent level sampling weights provided by HRS.

Table 1 presents some descriptive statistics of the balanced panel for all six waves. Race, ethnicity, and gender distributions mimic their population averages while the fraction of married respondents falls, mainly due to the increased likelihood of widowhood. Education has been coded by four dummies, such that a fairly even distribution across categories results. Since the balanced panel is part of the original HRS cohort of individuals born between 1931 and 1941 and their spouses, respondents are typically aged between 50 and 61 in the first wave and between 60 and 71 in the final wave. This initial sampling focus on the pre-retirement years explains the sharp fall in the fraction of the sample who work. Similarly, the prevalence of pain, work related health problems, and other health conditions all rise with age. Across these six waves of the HRS, there is a 10 percentage point increase in the fraction of respondents who report that they have a work disability and a 6.4 percentage point increase in the fraction who say that they are often troubled by pain.

2. Describing the Dynamics of Pain, Work Disability, and Employment

Aggregate reports of disability prevalence may be similar across waves, but specific individuals may change their responses over time even when the question wording is identical. Table 2 provides an initial perspective on this issue by dividing HRS respondents present in the six survey waves into four groups. The first group, representing about 55% of the sample, consists of those who never reported having a work disability in any of the six waves. The final group—constituting only 7.4% of respondents, is the mirror opposite—those who reported a work disability in all six waves. They could be thought of as the permanently disabled at least within this ten-year window. This would imply that over this time frame the permanent disability rate is only about one-third of the average yearly disability rate reported in Table 1. Disability exhibits very sharp gradients with respect to education in the first and final row of Table 2. Reported work disability rates decline sharply with years of schooling, but the fraction of the disabled who are ‘permanently work disabled’ also falls rapidly across schooling classes. For example, among those with 0-11 years of schooling, those always reporting disability are about half as numerous as those irregularly reporting disability. The comparable fraction for those who graduated from college is about one-in-five.

Table 2
Report of Disability by Years of Education in Six Waves of HRS

Years of education	0-11	12	13-15	16 plus	All
Never reported disability	38.8	53.3	60.0	69.9	55.1
Consistent report of new onset	19.2	16.2	15.5	11.4	15.7
Irregular report of disability	28.2	23.1	19.3	15.8	21.8
Always reported disability	13.8	7.5	5.2	2.9	7.4

All respondents who are present in the six waves. Data are weighted. Numbers of observations: 0-11 years of education: 1573; 12 years of education: 2288; 13-15 years of education: 1193; more than 15 years of education: 1232.

Given the ages of HRS respondents, disability rates should be expected to increase across the waves, and they do. Between the first and sixth HRS wave the percentage who claimed that they had a work disability increased from 17.1% to 27.1% (see Table 1) - an increase by more than 60%. These new onsets do not necessarily represent a new permanent work disability. See the second row of Table 2, which includes HRS respondents who reported a new disability onset between the HRS waves and who did not negate that report in a subsequent wave. About 16% of the respondents are in this group, in which the less educated are somewhat overrepresented.

The most interesting group for our purposes is in the third row of Table 2: those who reported having a work disability in one wave but subsequently said that they had no work disability. This group represents a significant fraction of all respondents—more than one in every five. They are an even larger fraction of those who ever reported a work disability over this time frame - almost half of all respondents who ever reported a work disability subsequently said that they are not work disabled. Some types of work disability clearly are temporary and even for more severe problems actual recovery is possible.

HRS allows us to explore the dynamic relationship between pain and work disability. Table 3 accomplishes that by separating reports of pain and work disability into four groups- those who never reported pain, those who reported an onset of pain which was not followed by any subsequent recovery from pain, those who reported pain but had at least one subsequent pain recovery, and those who reported pain in all six waves. A similar division is used for the report of work disability across the six waves.

Fifty-three percent of this sample experienced pain at least once over the ten-year period. Even though short-term and minor experiences of pain have been most likely eliminated by the form of the HRS pain question, the irregular (on and then off) reporting of pain is still quite common. Only 7% of the sample reported in all six waves that they experienced pain. Of the 53% of individuals who reported pain at least once, 58% did not report that pain in at least one subsequent wave. Similarly, amongst the half of respondents reporting work disability in at least one wave, half of them subsequently reported that they did not have a work disability.

Table 3
Marginals of Disability by Reports of Pain in First Six Waves of HRS—Ages 51-61 in 1992; Balanced Panel 1992-2002

	never work disabled	consistent new onset	Irregular disabled	always disabled	All
Never reported pain	78.1	7.8	13.1	1.1	46.6
Consistent report of new pain onset	36.1	32.7	25.7	5.4	15.2
Irregular report of pain	41.4	18.2	32.4	8.0	30.9
Always reported pain	5.5	19.8	24.8	49.9	7.2
All	55.1	15.7	21.8	7.4	

All respondents who are present in the first six waves of HRS. Data are weighted.

Table 3 also illustrates the strong relationship between the presence of pain and work disability. Among those who never reported pain, eighty percent never claimed that they had a work disability. On the other end of the pain scale, amongst those who always reported pain, only about 5% never reported being work disabled and almost 50% said that they were work disabled in every wave. These data thus suggest that pain is strongly associated with higher rates of reported work disability.

They also indicate that the irregular reports of pain and irregular reports of work disability are closely linked. Table 3 shows that irregular reports of pain are far more likely to lead to irregular reports of work disability than to a consistent new onset of work disability. Similarly, a consistent new onset of pain that is also reported in all subsequent survey waves is more likely to result in a consistent (permanent) new onset of work disability.

If pain affects work disability and work disability in turn affects the ability to work, it would not be surprising that the dynamics of experiencing pain may also be associated with the exit and entry of individuals from employment. Using the same format as in Table 3, Table 4 illustrates the association of the observed patterns of pain with the corresponding patterns of employment. The final row listing the marginals for work reflects the pre-retirement life-cycle stage on which this analysis focuses. A little less than one fifth of the sample did not work in any wave while almost forty percent exited employment not to return within this sample window. About one of every seven respondents reenter employment after exiting.

Table 4

Marginals of Work by Reports of Pain in First Six Waves of HRS—Ages 50-61 in 1992; Balanced Panel 1992-2002

	Never Worked	Consistent New Exit	Irregular Work	Always Worked	All
Never reported pain	14.3	39.1	14.4	32.1	46.6
Consistent report of new pain onset	17.4	42.2	15.9	24.5	15.2
Irregular report of pain	21.6	35.6	14.7	28.1	30.9
Always reported pain	46.0	31.5	11.8	10.6	7.2
All	19.3	38.0	14.5	28.2	

All respondents who are present in the first six waves of HRS. Data are weighted.

The association between pain and work appears to be strong. For example, among those respondents who never experienced pain, one third of them always were workers. In contrast, the corresponding fraction of those who always worked among those who always reported pain was only about 10 percent. Similarly almost half of the respondents who always reported pain in each of the six HRS waves did not work in any of the waves. Moreover, an onset of pain that persists into subsequent waves appears to be strongly associated with a labor force withdrawal that is also permanent

3. Dynamic Model

In this section, we outline our model for estimating the interrelated dynamics of pain, work related health, and labor force status (work versus no work). The model consists of three dynamic probit equations. The equation for pain of respondent i in time period t is specified as:

$$P_{it}^{*} = X_{it}^{'}\beta^{P} + \gamma_{P}^{P} P_{i,t-1} + \alpha_{i}^{P} + \varepsilon_{it}^{P};$$
$$P_{it} = 1[P_{it}^{*} > 0] \qquad (1)$$

Here P_{it} is the binary indicator of whether a respondent reports that he or she is often troubled by pain $(P_{it} = 1)$ or not $(P_{it} = 0)$. The lagged dependent variable $P_{i,t-1}$ reflects one form of the persistence of health problems leading to pain. The other type of pain persistence, represented by the unobserved heterogeneity term α_{i}^{P}, is treated as a random individual effect, normally distributed and independent of the error term and the exogenous variables X_{it}. The error terms ε_{it}^{P} are assumed to follow a standard normal distribution, independent of individual effects and exogenous variables and independent of each other.[3]

The second probit equation models the answer to the work disability question, "Do you have an impairment or health problem that limits the amount or type of work you can do." This is another yes/no question, giving an indicator variable $D_{it} = 1$ if the answer is "yes" and $D_{it} = 0$ if the answer is no. The probit equation for this variable is specified as follows:

$$D_{it}^{*} = X_{it}^{'}\beta^{D} + \gamma_{P}^{D} P_{i,t-1} + \gamma_{D}^{D} D_{i,t-1} + \delta_{P}^{D} P_{i,t} + \alpha_{i}^{D} + \varepsilon_{it}^{D};$$
$$D_{it} = 1[D_{it}^{*} > 0] \qquad (2)$$

[3] In this equation we do not allow for an effect of work on pain. Although in specific occupations, the nature of the work definitely may be such that the risk of a pain related injury increases this seems in general much less important than the reverse effect – the effect of pain on the probability to work – and we therefore focus on the latter. See, for example, Scherzer, Rugulis and Krause (2005).

Here we allow for an immediate effect of pain on work disability, as well as a lagged effect. We also allow for persistence in work disability through other channels than pain (the term $\gamma_D^D D_{i,t-1}$). Assumptions about individual effects α_i^D and error terms ε_{it}^D are similar to the assumptions in the pain equation. The unobserved heterogeneity terms in the two equations are allowed to be correlated.[4]

The third equation explains whether respondents do paid work or not. As explained above, this can be self-employment or salaried employment, full-time or part-time, based upon self-reported occupational status. Labor force status is denoted by an indicator variable $W_{it} = 1$ if the respondent works and $W_{it} = 0$ otherwise. The probit work equation is specified as follows:

$$\begin{aligned} &W_{it}^* = X_{it}^{'}\beta^W + \gamma_P^W P_{i,t-1} + \gamma_D^W D_{i,t-1} + \gamma_W^W W_{i,t-1} + \delta_P^W P_{i,t} + \delta_D^W D_{i,t} + \alpha_i^W + \varepsilon_{it}^W; \\ &W_{it} = 1[W_{it}^* > 0] \end{aligned} \quad (3)$$

Thus we allow for an immediate effect of work disability on labor force status. Pain can have an immediate indirect effect through work disability, but we also allow for the possibility of an immediate direct effect keeping work disability constant (the term $\delta_P^W P_{i,t}$). An argument for this is the finding that the relation between disability and work may be different for pain than for other injuries or health problems, due to the partly subjective nature of pain (see, for example, Johnson, Baldwin and Butler, 1998).

The assumptions about individual effects and error terms are the same as before. We do not allow for correlation between the error terms in the three equations, but we do

[4] On the other hand, we assume error terms in the work disability equation are independent of those in the pain equation. Unexpected shocks affecting pain have an effect on work disability through the pain variable in the systematic part of the equation. They are assumed to be unrelated to other shocks on work disability that do not work through pain or other explanatory variables

allow for correlated individual effects, not imposing any restrictions on the covariance matrix of the unobserved heterogeneity terms in the three equations.

To account for the initial conditions problem, we follow Heckman (1981), Hyslop (1999) and Vella and Verbeek (1998) and specify separate equations for wave 1. These equations have the same exogenous regressors and contemporaneous dependent variables on the right hand side as the dynamic equations presented above, but do not include the lagged dependent variables. No restrictions are imposed on the coefficients or their relation to the coefficients in the dynamic equations. These coefficients are estimated jointly with the parameters in the dynamic equations and can be seen as nuisance parameters.[5]

For estimation, we use a balanced panel of HRS respondents 1992-2002 with no missing values on dependent or independent variables and whose age is between 50 and 71 in all waves. This yields a data set of 6,286 respondents, all of them observed six times (37,716 observations). As exogenous explanatory variables, we include basic demographics (age, education, gender, race, marital status) and health conditions (i.e., onsets of chronic diseases). All explanatory variables (and dependent variables) are dummies. For age we use dummy variables with benchmark category younger than 55; for education we use categorical dummies based upon years of education, with benchmark category exactly 12 years. The definitions of the other variables are presented in Table 1.

[5] In the initial condition equations, we include arbitrary linear combinations of the individual effects in the three dynamic equations. This is the same as including an arbitrary linear combination of the three entries in u_i. The estimated coefficients of these linear combinations can be seen as nuisance parameters.

4. Results

Estimation results for the three dynamic equations for pain, work disability, and employment respectively are presented in Tables 5-7. Table 8 lists the estimated parameters for unobserved heterogeneity in the three equations.[6] The effects of exogenous variables do not vary substantively from what one would get from cross-section probits and contain no surprises. We therefore focus more on the effects of lagged and current dependent variables and on the role of unobserved heterogeneity.

Table 5
Results Obtained for Pain Equation (1); Waves 2-6

	Par.	S.e.	t-val.
constant	-1.590	0.061	-25.99
female	0.047	0.031	1.53
hispanic	0.114	0.059	1.95
nonwhite	-0.090	0.041	-2.19
educ < 12y	0.185	0.038	4.82
educ 13-15	-0.107	0.044	-2.40
educ > 15y	-0.168	0.041	-4.08
age 55-59	-0.107	0.044	-2.42
age 60-64	-0.227	0.045	-5.00
age >64	-0.396	0.050	-7.94
married	0.029	0.032	0.92
hypertension	0.135	0.027	4.91
diabetes	0.173	0.038	4.60
cancer	0.151	0.043	3.52
lung disease	0.372	0.047	7.97
heart problem	0.242	0.035	6.99
mental ill	0.566	0.038	14.70
arthritis	0.836	0.028	29.78
stroke	0.175	0.067	2.62
lagged pain	0.465	0.029	16.08

Note: Data are from a balanced panel of 6,286 HRS respondents in all waves between 1992-2002.

In the pain equation presented in Table 5, pain decreases with education and age and is positively associated with all of the health conditions included in the model. Not surprisingly, the prevalence of pain is particularly likely for respondents with

[6] Tables A1, A2 and A3 in the appendix present the estimates of the static equations explaining the initial values of the dependent variables; these are estimates of nuisance parameters that will not be discussed.

arthritis. We find that both state dependence and unobserved heterogeneity play a large role. Reporting pain in a given wave substantially increases the probability that pain is reported in the next wave, but the probabilty of lagged pain persisting is well below one. The marginal effect of lagged pain at the mean varies from 12.5%-points in wave 2 to 13.5%-points in wave 6 (not reported in Table 5). Unobserved heterogeneity in pain is also quite significant, though somewhat less important than the idiosyncratic shocks (the individual effects have estimated standard deviation 0.88; the idiosyncratic shocks have standard deviation 1).

The results obtained for the work disability equation are listed in Table 6. Reported rates of work disability also decline with education, but appear to be unrelated to age at least in this narrow age span. Women and married individuals are less likely to report a work disability while African-Americans are more likely to do so. All forms of health problems have a statistically highly significant effect on the likelihood that one reports to be work disabled.

Most importantly, pain has a strong and significant immediate effect on work disability. The average *ceteris paribus* difference between the probabilities of reporting a work disability of someone often troubled by pain and someone not often troubled by pain is almost 13%-points in the first wave and about 16.8%-points in the final wave. Similarly, state dependence in work disability plays a substantial role, and it seems even more important here than it was in the pain equation.

On average, the probability of reporting a work disability by someone who was work disabled in the previous wave is about 21%-points higher than for a respondent who was not work disabled in the previous wave but was similar in other respects. The effect of lagged pain on the probability of reporting a current work disability is smaller than of lagged disability or of current pain, but still statistically significant. This may suggest that lagged pain is an indicator that current pain is more serious, something not fully captured in the observed pain dummy.

The implied standard deviation of the individual effect in the work disability equation is 0.852 (not reported in the tables), of a similar order of magnitude as the individual effect in the pain equation. We find a strongly significant positive correlation

Table 6
Results Obtained for Work Disability Equation (2): Waves 2-6

	Par.	S.e.	t-val.
constant	-1.915	0.072	-26.51
female	-0.069	0.032	-2.13
hispanic	0.020	0.061	0.33
nonwhite	0.105	0.041	2.56
educ < 12y	0.264	0.040	6.64
educ 13-15	-0.162	0.046	-3.52
educ > 15y	-0.313	0.044	-7.13
age 55-59	0.049	0.056	0.87
age 60-64	0.038	0.057	0.66
age > 64	-0.053	0.060	-0.88
married	-0.159	0.032	-4.95
hypertension	0.167	0.029	5.70
diabetes	0.317	0.039	8.22
cancer	0.249	0.043	5.80
lung disease	0.522	0.045	11.69
heart problem	0.533	0.035	15.31
mental illness	0.491	0.040	12.39
arthritis	0.443	0.031	14.07
stroke	0.745	0.059	12.67
lagged pain	0.126	0.033	3.85
lagged work disability	0.735	0.032	22.90
pain	0.505	0.030	16.58

Note: Data are from a balanced panel of 6,286 HRS respondents in all waves between 1992-2002.

between these two individual effects of 0.574, showing that permanent unobserved characteristics that make it likely that people suffer from pain largely overlap with unobserved characteristics that lead to work disability. This is another channel through which a positive correlation between pain and work disability is introduced, in addition to the causal effect of pain in the work disability equation. The positive correlation between the individual effects makes pain endogenous in the work disability equation – it correlates with the total unobservable term (random effect plus error term). This is taken into account in our estimation procedure, but implies that a simple cross-section probit not accounting for endogeneity of pain would give biased estimates.

Table 7 lists our results for the probit predicting the dynamics of labor force participation. The results for our exogenous explanatory variables are once again as expected. Women are less likely to work than men are, participation falls with age as retirement approaches, and the probability of not working is higher for the less educated and the less healthy.

As expected, Table 7 confirms that work disability reduces the chances to be at work. The effect is statistically significant and substantial. In the first wave, the average *ceteris paribus* difference between employment probabilities of people with and without a work disability is about 25%-points. In the last wave, it has increased to 38%-points. Together with the causal effect of pain on work disability found in Table 6, this also implies a strong effect of pain on the probability to be at work. However, there is no evidence of a direct immediate effect of pain on the chance to be at work in addition to the indirect effect through work disability (i.e., pain is insignificant in the work equation).

As expected, state dependence in labor force status plays an important role. It is much stronger still than the state dependence effect in the other equations. The effect of lagged work disability and lagged pain, keeping lagged work status (and other variables) constant, is quite small. Lagged work disability is statistically significant, lagged pain is not. Thus neither current pain nor lagged pain have a direct effect on labor force status indicating that the effects of pain on work purely work through work disability.

The unobserved heterogeneity term in the work equation has an estimated standard deviation of 0.509.[7] It is smaller than in the other equations but strongly significant, explaining about 20% of the unsystematic variation in the equation. This

Table 7
Results Obtained for Work Equation (3):Waves 2-6

	Par.	S.e.	t-val.
constant	0.158	0.071	2.24
female	-0.314	0.026	-12.14
hispanic	-0.100	0.050	-1.98
nonwhite	-0.004	0.033	-0.12
educ < 12y	-0.103	0.032	-3.25
educ 13-15	0.084	0.034	2.50
educ > 15y	0.100	0.032	3.15
age 55-59	-0.130	0.048	-2.72
age 60-64	-0.615	0.049	-12.55
age >64	-0.958	0.055	-17.45
married	-0.142	0.026	-5.42
hypertension	-0.058	0.023	-2.47
diabetes	-0.071	0.036	-2.01
cancer	-0.079	0.040	-1.99
lung disease	-0.103	0.043	-2.41
heart problem	-0.071	0.032	-2.26
mental illness	-0.121	0.036	-3.37
arthritis	-0.044	0.025	-1.76
stroke	-0.259	0.064	-4.06
lagged pain	-0.056	0.034	-1.63
lagged work disability	0.090	0.036	2.49
lagged work	1.643	0.029	56.59
pain	-0.044	0.035	-1.28
work disability	-0.754	0.035	-21.72

Note: Data are from a balanced panel of 6,286 HRS respondents in all waves between 1992-2002.

individual effect is not significantly correlated with the individual effect in the pain equation, but it is significantly negatively correlated with the individual effect in the work disability equation (the correlation coefficient is about –0.42). Thus unobserved characteristics that lead to work disability overlap with unobserved characteristics that keep people from working. This is a second source of the negative correlation between

[7] This is computed from the estimates in Table 8 as $\sqrt{(0.028^2 + 0.277^2 + 0.426^2)}$

work disability and work, in addition to the causal effects. Similar to the previous equation, it means that work disability is endogenous in the work equation, something taken into account in our estimation strategy.

Table 8
Parameter Estimates Unobserved Heterogeneity
Waves 2-6[8]

	Par.	S.e.	t-val.
Pain in pain	0.879	0.026	33.31
Pain in work disability	0.489	0.029	17.09
Work dis. in work dis.	0.698	0.028	24.84
Pain in work	0.028	0.024	1.16
Work disability in work	-0.277	0.028	-9.84
Work in work	0.426	0.033	13.03

5. Model Simulations of Dynamics

Based on these models, we simulated the cross-wave patterns of pain and work to assess the extent to which time series variation in pain is related to time series variation in labor force participation. We took the observed values of the exogenous variables in the sample and drew values of the error terms and individual effects. These were used to recursively generate new values of the dependent variables, including those in the first wave (relying on the parameter estimates in the appendix). Our main results are summarized in Tables 9 and 10, which examine the implied relation of patterns of pain to

[8]The parameterization of the individual effects is as follows. Let $u_i = (u_i^P, u_i^D, u_i^W) \sim N_3(0, I)$. Then the vector of individual effects $\alpha_i = (\alpha_i^P, \alpha_i^D, \alpha_i^W)$ is specified as $\alpha = \Lambda u,$ with $\Lambda = \begin{pmatrix} \lambda_P^P & 0 & 0 \\ \lambda_P^D & \lambda_D^D & 0 \\ \lambda_P^W & \lambda_D^W & \lambda_W^W \end{pmatrix}$,
a lower triangular matrix. The parameter estimates are estimates of the entries in Λ.

work disability and whether or not one is working. These tables can be compared to Tables 3 and 4 above to investigate how well our model estimates track the actual data.

The model simulation dynamics of the relationship between patterns of pain and work disability over time are reasonably close to the pattern found in the data (cf. Table 3). First, the simulations mimic the strong association between the persistent components of pain. Among those who never reported pain, we predict that 74% of them would never be disabled- the observed frequency is 78%. We under-predict the amount of permanent disability associated with permanent pain- almost 50% in the data compared to 33%, but the overall prevalence of permanent pain is rather low.

Table 9

Marginals of Disability by Reports of Pain in First Six Waves of HRS- ages 51-61
Simulated Data

	Never Disabled	Consistent New Onset	Irregular Disabled	Always Disabled	All
Never reported pain	74.1	9.0	16.0	0.9	44.6
Consistent report of new pain onset	29.9	32.1	32.1	5.8	15.2
Irregular report of pain	39.1	20.1	34.8	6.0	34.7
Always reported pain	6.4	36.5	23.8	33.2	5.4
All	51.5	17.9	25.4	5.2	

All respondents who are present in the first six waves of HRS. Data are weighted.

Most importantly and central to the goal of this paper, we appear to do a good job of matching the irregular patterns of pain and work disability. The simulated row for patterns of work disability associated with irregular occurrence of pain is almost identical to the observed data in Table 3. In particular based on our estimated model, we predict that among those who experienced irregular episodes of pain, 35% of them also exhibit irregular patterns of work disability. The observed frequency from Table 3 is 32%.

Seeing this relationship from the perspective of irregular reports of work disability is also informative. Half of the respondents with some reported work disability have irregular patterns of disability. Our model predicts that the most common association with irregular work disability is irregular reports of pain. We predict that half of those with irregular reports of work disability have irregular reports of pain.

Consider next the observed dynamics of the relation of pain to labor force participation and how they correspond to the observed frequencies in Table 4. Our empirical estimates imply that pain affects work only through work disability – we found no direct effect of pain or lagged pain on work. The first and next to last row of Table 10 confirm the strong relation of persistent pain to the permanent component of work. According to the simulations, among those who were in pain for all six waves, 30% would never work over this period and only one in eight would work all six waves. In contrast, only one in eight would never work among those respondents who never reported pain in any wave.

Table 10

Marginals of Work by Reports of Pain in First Six Waves of HRS- ages 51-61
Simulated Data

	never worked	consistent new exit	Irregular work	always worked	All
Never reported pain	12.7	36.9	18.4	32.0	44.6
Consistent report of new pain onset	20.0	41.7	15.8	22.6	15.2
Irregular report of pain	20.8	37.1	18.0	24.2	34.7
Always reported pain	30.1	44.0	13.5	12.4	5.5
All	17.5	38.1	17.6	26.8	

All respondents who are present in the first six waves of HRS. Data are weighted.

Our model-simulated patterns mimic the data for those who never or always reported pain reasonably closely. For example, the observed and simulated rows are very similar for those who never reported pain in any of the waves. While there is a strong relation between permanent pain and work, we under predict the fraction of respondents who never worked amongst those who were always in pain. It is important to keep in mind here, however, that those always in pain represent only 7 percent of the sample.

Keeping in mind the general trend to leave the labor force during this period, onsets of pain or recovery from pain both have the expected effects. The largest transitional exits from the labor force are associated with the onset of pain (second row of the pain transitions) while the recovery from pain is also associated with the largest hazard rate for returning to work. Irregular patterns of work characterize 17.6 percent of our respondents over this time period. One third of these respondents with irregular patterns of work are predicted by our models to have irregular patterns of pain. The probability and ease of reentry into the labor force at older ages appears to be very much affected by the absence of prior pain. This critical relationship that episodic pain plays in labor force dynamics at older ages has not been adequately documented in the existing health and labor force literature.

6. Conclusions

We have examined the relation between the dynamics of reporting pain with the dynamics of reporting work disability, and the impact of both on the observed patterns of exit and entry into employment in a sample of pre-retirement individuals over a ten-year time span. To do so, we estimated a recursive dynamic model, where pain is explained by demographics and a set of health conditions, allowing for state dependence. Similarly, work disability is explained by pain (both current and lagged) and the same set of demographics and health conditions, again allowing for state dependence. Finally whether one works or not is then explained by work disability and pain (both current and lagged), the same set of demographics and health conditions, and by state dependence in employment. In all three equations, we allow for random individual effects which can be correlated across equations.

We find considerable individual variation in reports of work disability over time, and that this variation in reported work disability can be explained by similar within person variation from wave to wave in reports of pain. Our estimates also imply that wave to wave variation in reports of pain have a significant impact on observed patterns of reported employment, but that this effect is completely mediated through self-reports of work disability. The sharp and significant dynamics inherent in the experience of pain are an important and neglected contributor to the dynamics in whether individuals report that they have a work related disability and therefore in the dynamics of labor market employment at older ages.

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Appendix: Estimates of Auxiliary Parameters

Table A1. Results Pain Equation Wave 1

	Par.	S.e.	t-val.
constant	-1.908	0.099	-19.24
female	0.077	0.055	1.40
hispanic	0.290	0.098	2.94
nonwhite	0.059	0.072	0.82
educ < 12y	0.282	0.067	4.18
educ 13-15	-0.017	0.079	-0.21
educ > 15y	-0.327	0.077	-4.24
age 55-59	-0.047	0.054	-0.87
age 60-64	-0.269	0.075	-3.56
age >64	0		
married	0.190	0.063	3.01
hypertens	0.115	0.055	2.07
diabetes	0.146	0.088	1.66
cancer	0.207	0.107	1.93
lung disea	0.465	0.109	4.25
heart prob	0.298	0.084	3.55
mental ill	0.948	0.089	10.71
arthritis	1.021	0.054	19.08
stroke	0.344	0.203	1.69

Table A2. Results Equation for Work Disability Wave 1

	Par.	S.e.	t-val.
constant	-2.131	0.115	-18.53
female	-0.197	0.063	-3.13
hispanic	0.173	0.107	1.61
nonwhite	0.089	0.085	1.06
educ < 12y	0.269	0.076	3.55
educ 13-15	-0.258	0.093	-2.78
educ > 15y	-0.327	0.090	-3.63
age 55-59	0.167	0.063	2.63
age 60-64	0.065	0.084	0.77
age >64	0		
married	-0.148	0.070	-2.11
hypertens	0.167	0.062	2.71
diabetes	0.288	0.092	3.13
cancer	0.378	0.118	3.20
lung disea	0.552	0.118	4.68
heart prob	0.887	0.086	10.32
mental ill	0.813	0.092	8.79
arthritis	0.576	0.063	9.09
stroke	1.305	0.196	6.64
pain	0.780	0.086	9.09

Table A3. Results Equation for Working Waves 1

	Par.	S.e.	t-val.
constant	2.113	0.099	21.37
female	-0.860	0.055	-15.58
hispanic	-0.264	0.095	-2.79
nonwhite	-0.013	0.066	-0.19
educ < 12y	-0.311	0.062	-4.99
educ 13-15	0.131	0.071	1.85
educ > 15y	0.299	0.070	4.26
age 55-59	-0.278	0.053	-5.20
age 60-64	-0.609	0.067	-9.14
age >64	0		
married	-0.273	0.060	-4.57
hypertens	-0.054	0.051	-1.06
diabetes	-0.182	0.090	-2.03
cancer	-0.010	0.110	-0.09
lung disea	-0.157	0.110	-1.43
heart prob	-0.008	0.088	-0.09
mental ill	-0.489	0.091	-5.35
arthritis	0.037	0.056	0.66
stroke	0		
pain	-0.242	0.090	-2.70
worklim	-0.991	0.095	-10.41

Table A4. Parameter Estimates Unobserved Heterogeneity Wave 1

	Par.	S.e.	t-val.
Ω_{11}	1.010	0.050	20.36
Ω_{12}	-0.012	0.039	-0.31
Ω_{13}	-0.057	0.051	-1.11
Ω_{21}	0.557	0.052	10.67
Ω_{22}	0.871	0.060	14.60
Ω_{23}	-0.112	0.057	-1.97
Ω_{31}	-0.027	0.041	-0.65
Ω_{32}	-0.458	0.049	-9.35
Ω_{33}	-0.700	0.060	-11.65

The individual effects in the initial conditions equations are specified as Ωu_i, where u_i is the vector defined in the main text (end of Section 3). Thus the individual effect in the equation explaining pain in wave 1 is $\Omega_{11}u_{i1}+\Omega_{12}u_{i2}+\Omega_{13}u_{i3}$, the individual effect in the equation explaining work disability in wave 1 is $\Omega_{21}u_{i1}+\Omega_{22}u_{i2}+\Omega_{23}u_{i3}$, and the individual effect in the equation explaining whether someone works in wave 1 is $\Omega_{31}u_{i1}+\Omega_{32}u_{i2}+\Omega_{33}u_{i3}$. In addition, the initial conditions equations also contain idiosyncratic error terms assumed to be standard normal, independent of each other and everything else.