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Chronic Disease and Labour Force Participation in Australia: an endogenous multivariate probit analysis of clinical prevalence data

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ABSTRACT

Reducing chronic disease has been identified as a priority for both health and labour force productivity improvement. The study estimated the influence of clinically diagnosed diabetes and cardiovascular disease on labour supply in men and women aged over 25 taking account of the observed and unobserved factors that influence both the risk of these chronic diseases and labour force participation. The results show that diabetes and cardiovascular disease together have a strong impact on labour market outcomes particularly for males, and that obesity, insufficient exercise, hypertension, lipid abnormality, smoking and parental diabetes all have a significant indirect effect on labour force participation.

Chronic disease and labour force participation in Australia: an endogenous multivariate probit analysis of clinical prevalence data

1. Introduction and background

In July 2006 the Council of Australian Governments (Council of Australian Governments 2006) agreed a framework for a human capital agenda to improve labour force participation and productivity in Australia. They identified reducing the incidence of preventable chronic disease among the working age population as a priority in order to both improve health outcomes and also to reduce the proportion of the working age population not participating and/or under-participating in paid employment due to illness, injury or disability (COAG 2006).

Health status is an important predictor of labour supply and chronic disease is a growing contributor to morbidity related labour market outcomes. Coronary heart disease is the largest single cause of death in Australia (19% of all deaths in 2004) with mortality in Indigenous Australians, 5 times that of other Australians and a significantly higher mortality rate in disadvantaged areas (Australian Institute of Health and Welfare 2006). Diabetes is also a major contributor to deaths in Australia (2.7% directly and associated with a further 6%) with mortality in Indigenous Australians 14 times that of other Australians. Each has a high morbidity cost with over 165,000 hospital separations from coronary heart disease and 66,700 hospital separations from diabetes in 2004. The major risk factors for diabetes and cardiovascular disease are well known – smoking, diet and a lack of physical activity along with genetic predisposition to high blood pressure, cholesterol levels and diabetes.

Commentators have expressed alarm at the rates of overweight and obesity in Australia, with a 2.5 fold increase from 1980 to 1995 before stabilizing for men but continuing to rise for women (Cameron, Welborn et al. 2003). Consequently obesity and physical inactivity have been promoted internationally as the primary focus for diabetes prevention (World Health Organisation, 2003). The risk of cardiovascular disease and diabetes are highly correlated not only because poor diet and inadequate physical activity are risk factors for both, but also because high blood pressure elevated blood fats and abdominal obesity that are common with diabetes are risk factors for heart disease. Diabetes is associated with a two to fourfold increase in the incidence of cardiovascular disease (CVD) and an elevated risk of premature death (Haffner, Lehto et al. 1998; Hu, Stampfer et al. 2001; Manuel and Schultz 2004).

The prevalence of major chronic illnesses including diabetes and cardiovascular disease has been on the rise in the past decade in developed countries. In 1997, 124 million people worldwide had diabetes. and by the year 2010 the total number of people with diabetes is projected to reach 221 million (Amos, McCarty et al. 1997). The number of Australian adults with diabetes has more than doubled since 1981 (Dunstan, Zimmet et al. 2002; Australian Institute of Health and Welfare 2006), and numbers are expected to continue to grow rapidly over the coming decades as the Australian population ages and becomes more overweight and less physically active. Many people go undiagnosed and even those who have been diagnosed often do not manage their diabetes. There have been significant improvements in how doctors manage patients with increasing rates of prescriptions for the treatment of hypertension, heart disease, diabetes and heart failure in recent years, but treatment gaps remain. For example many people stop taking cholesterol lowering drugs (statins) that are intended to be taken long term (Australian Institute of Health and Welfare 2007). Strategies of primary prevention such as improving diet and exercise combined with secondary prevention and treatment strategies to reduce the morbidity of those with disease offer opportunities to improve health and productivity of the workforce.

The aim of the current study is to determine the influence of the two major preventable chronic diseases in high income countries - diabetes and cardiovascular disease - on labour supply. The study uses an endogenous multivariate probit model with a recursive simultaneous structure and unit record data from a stratified random national survey and physical examination of 11,247 individuals in Australia. In Section II we describe some of the recent literature on the relationship between health status and labour market outcomes. In Section III we describe a theory and the empirical estimation of a joint model of labour supply and chronic disease. Section IV describes the AusDiab dataset: unit record data from a stratified random national survey with a physical examination of 11,247 individuals in Australia. In Section V we report the results of 3 separate univariate probit models for labour force participation, diabetes and cardiovascular disease and a 3 equation recursive simultaneous multivariate probit model. The latter allows for both unobserved heterogeneity and the simultaneous determination of diabetes and cardiovascular disease.

2. Recent literature

A large number of studies have estimated the relationship between health status and labour market outcomes. The vast majority of these studies have examined the relationship between a self reported general health status measure and labour outcomes. A small number of studies has looked at the effect of particular conditions such as obesity (Morris 2007), diabetes (Brown and Pagán Elena Bastida 2005), problem drinking (Feng, Zhou et al. 2001; MacDonald and Shields 2004) using either instrumental variable methods or recursive bivariate probit techniques.

The theoretical notion in all of these studies is that health like education can be considered an endowment of human capital that deteriorates over time but is capable of enhancement as a result of household production (Becker 1964; Becker, Zamagni et al. 1965; Lancaster 1966; Grossman 1972; Currie and Madrian 1999; Grossman 1999). This implies higher returns from work for healthy workers and that healthy people are more likely to work. Poor health may also impact directly on an individual’s preference for paid employment through the relative utility of work or leisure as well as reduce the total amount of time available to earn money. In addition, sickness in most Western countries gives an entitlement to income from welfare benefits conditional on not working (Grossman 1999; Cai and Kalb 2006; Disney, Emmerson et al. 2006). There are then a number of theoretical links between health status and work that suggest not only that better health improves labour outcomes but that that poorer health is likely to be associated with lower labour supply. This is not to deny that in some circumstances environmental factors at work may contribute to physical or mental ill health but in the case of chronic diseases studies here that kind of reverse causality is less likely.

Most studies in this literature rely on global self reported health as a proxy for latent individual health. Like many self reported measures, health status suffers from the potential for measurement error and endogeneity that could result in the overestimation of a health effect on labour market outcomes (Anderson and Burkhauser 1985; Stern 1989; Bound 1991; Bound and et al. 1999; Dwyer and Mitchell 1999; Campolieti 2002). The potential for endogeneity arises for at least 3 reasons. Poor health may be associated with unobserved household characteristics such as time or risk preference that also impact on labour market decisions. Social security eligibility conditions may encourage those surveyed individuals who do not participate in the labour force to overstate their ill health as a justification for their non participation, although the empirical literature has not found strong evidence of this effect so far (Stern 1989; Dwyer and Mitchell 1999; Cai and Kalb 2006). Poor health may also be a consequence of labour market outcomes raising the possibility of simultaneity bias.

An obvious alternative to measures of self reported health is to use more objective measures either from generic health status measures or clinical measures. Other researchers have examined the effects on labour market performance of specific chronic health conditions such as diabetes (Kahn 1998; Bastida and Pagan 2002; Brown and Pagán Elena Bastida 2005) or mental health problems (Waghorn and Chant 2005). Although specific health conditions may also be self-reported, relative to self-assessed global health status, they are much less likely to be subject to reporting/measurement errors. There are limitations in looking only at specific conditions in isolation. Many chronic diseases are interrelated through common risk factors and physiology. For example diabetes is associated with long-term conditions such as diseases of the circulatory system and eyes. In particular, people with diabetes are at an increased risk of developing coronary heart disease, stroke and peripheral vascular disease (Australian Institute of Health and Welfare 2006). In the 2004 national health survey 20% of persons reporting diabetes also reported heart, stroke or vascular disease; 18% of those aged 45-64 years, and 27% of those aged over 65 years, had one or more of these circulatory conditions (Australian Bureau of Statistics 2006). Among the studies on specific chronic health conditions and labour market performance, most have focused on one particular chronic illness and treated the incidences of other chronic illnesses as exogenous. However, incidences of chronic conditions such as diabetes and cardiovascular disease are likely to be in part the results of lifestyle behaviour and other unobservable individual characteristics that also influence labour market outcomes. Any degree of measurement errors due to the subjectivity of the self-reported medical conditions would also mean that the incidences of such reported chronic diseases are potentially endogenous. There are some exceptions in this literature such as (Brown and Pagán Elena Bastida 2005) who studied the impact of diabetes on employment, (MacDonald and Shields 2004) who looked at the impact of problem drinking on employment and (Morris 2007) who investigated the relationship between obesity and employment studied using a recursive bivariate probit model to account for endogeneity. In all cases however, only a single self-reported disease was used.

In contrast this paper uses clinically measured diagnoses of chronic diseases and risk factors to provide evidence on relationship between labour market participation and chronic disease and adopts a multivariate approach to estimation that account for multiple sources of endogeneity across two chronic diseases: diabetes and cardiovascular disease. The multivariate approach is similar to that in (Zhao and Harris 2004) for drugs, but with the addition of the simultaneous determination of two of the three dependent variables.

3. Model

The underlying theoretical model is one of a conventional household labour supply. The individual is assumed to make a trade off between labour and leisure subject to a constraint of full income. The decision to enter the labour force is the first part in a two part decision on hours supplied. The final outcome of hours worked will depend on both labour supply and the demand for that individuals labour. In this paper we do not model the second part of the decision but restrict the analysis to the participation part of the labour supply decision. This is done to simplify the model to allow the construction of a system of equations to estimate the relationship between chronic diseases and labour supply.

We focus on the participation decision rather than hours worked although we recognise that ill health associated with chronic disease is also likely to affect the number of hours worked. Labour force participation L is modelled as:

$$L=L(H, X, \theta) \tag{1}$$

Where H is the health status of the individual, X are exogenous observable household characteristics that affect productivity, and θ are unobserved household characteristics that affect labour outcomes.

Ill health will reduce the probability of employment for several reasons. As summarized in (Disney, Emmerson et al. 2006), first poorer health may raise the current disutility of work. Second poorer health reduces productivity, and through demand, the return from work and consequently wages. Third poor health may entitle the individual to non wage income such as disability benefits. Last poorer health may also lower life expectancy raising the present value of current wealth and induce earlier retirement. In this kind of structural model much attention has been paid in the literature to the issue of measuring the true underlying health of individuals. A common measure of health status is overall self reported health. However while at any point in time there may be a correlation between self reported health status and labour outcomes this may well be due to bias in measurement as individuals who report no employment misrepresent their health status. The most obvious solution to this would be to use a more objective measure of health. The problem however is to find adequate proxies for the health conditions that affect activity. If we restrict the issue to one disease such as diabetes we assume that other illnesses either do not affect the activity decision or are uncorrelated with diabetes. Moreover a single equation model of labour force participation and chronic diseases assumes that the diseases are exogenous determinants of labour outcomes. There are a number of reasons to believe that this might not be the case. For example there may be a number of unobserved common risk factors across diseases and the decision to supply labour for example associated with peer groups or family background. In this paper we construct a structural model of a number of chronic diseases and labour supply that reduces the potential for this source of endogeneity bias as well as that associated with potential simultaneous across diseases. The latter might arise for example in the case of diabetes and heart disease each of which might simultaneously influence labour force participation but where diabetes might independently be a risk factor for cardiovascular disease. An important potential advantage of this approach is that it allows us to estimate the indirect effect of a range of potential social and behavioural influences on employment that operate through chronic illness without making the assumption that chronic diseases are independent except for observed common risk factors and that each disease is an exogenous determinant of labour supply behaviour. For example we can examine the indirect effect of obesity and smoking behaviour on employment through the effect on the risk of each chronic disease.

Modelling individual health status

We estimate a joint model of labour supply and chronic disease. We begin by estimating 3 separate univariate probit models for labour force participation, diabetes and cardiovascular disease. To allow for the potential endogeneity associated with unobserved heterogeneity and the simultaneous determination of diabetes and cardiovascular disease we estimate a 3 equation recursive simultaneous multivariate probit model. The simultaneous equation model allows us to test for correlation between the residuals and ensures consistency of the estimated effects.

We define the unobserved latent variables for labour supply Y_1^* and for cardiovascular disease status Y_2^* and diabetes status Y_3^*

Y_1^*=x'$_1$β$_1$+Y_2^*+ Y_3^*+e$_1$	Y_1=1 if Y_1^*=>0, 0 otherwise	(1)
Y_2^*==x'$_2$β$_2$+a$_2$$Y_3^*$+ e$_3$	Y_2=1 ifY_2^*>0, 0 otherwise	(2)
Y_3^*==x'$_3$β$_3$+e$_3$	Y_3=1 if Y_3^*=>0, 0 otherwise	(3)

We begin by assuming that e_1, e_2, and e_3 are independent and estimate equations 1-3 using separate univariate probit equations. We then assume that e_1, e_2, and e_3 are joint normally distributed with means zero, and covariance matrix ∑. That is $[e_1,e_2,e_3]' \sim MVN(0, \sum)$ with the 3 variances assumed equal to 1. A univariate approach ignoring the potentially non zero off-diagonal elements in ∑ will produce inconsistent coefficient estimates where correlation across the error terms exists (Maddala 1983). Note that this is a recursive simultaneous equations model as the unobserved propensity to have diabetes (Y_3^*) is a regressor in the equation for cardiovascular disease (Y_2^*), and both are regressors in the determinants of labour force participation (Y_1^*). It has been shown that the endogenous variables on the right hand side of a bivariate recursive simultaneous equation binary model (and the FIML estimator of the simultaneous equation model) can be ignored (Greene 2003) (Maddala 1983)). The logic carries over to maximum likelihood estimation of this multivariate recursive simultaneous model. The recursive multivariate system of equations satisfies exclusion requirements. In addition the cardiovascular disease equation (2) includes the same right hand side variables as the labour force participation equation (1), but with the addition of smoking status, weight, exercise, and diabetes status. The diabetes equation (3) includes the same exogenous variables as equation 2 but also includes a variable that indicate whether the individual's mother or father had diabetes.

We use a simultaneous equation multivariate probit analysis estimated by simulated maximum likelihood implemented in STATA10.0 with the MVPROBIT routine. The variance-covariance matrix of the cross-equation error terms was estimated and the null hypothesis that $\rho_{12}=\rho_{13}=\rho_{23}=0$ was tested with a Wald test at the 10% level. If the null hypothesis cannot be rejected the model consists of independent probit equations that can be estimated separately.

We are primarily interested in inferences about the effect of differences in disease status on labour force participation. The estimation and interpretation of these conditional treatment effects, their standard errors, and the effect of regressors such as lifestyle and genetics is complicated both by the non continuous nature of the many of the variables and by the potential correlation of residuals across equations. For example the effect of being a smoker on labour force participation compared to the counterfactual of not smoking involves first an increase in the risk of each chronic disease, and then an indirect effect on labour force participation through the effect from diabetes and cardiovascular disease. In addition since diabetes is a risk factor for cardiovascular disease there is an additional indirect effect from smoking through the pathway of diabetes risk to cardiovascular disease prevalence and then to labour force participation. We estimate the marginal effect of all of the exogenous and endogenous variables on labour force participation and their confidence intervals separating out the direct and indirect treatment effects through these pathways of influence. The treatment effects were calculated from the difference in the predicted probabilities conditional on marginal changes for continuous regressors and zero and one for discrete variables in each equation. Standard errors were calculated using the Delta method taking account of the correlation in errors across equations. (Greene 2003) and tested at the 10% significance level.

The treatment effect of being diagnosed with cardiovascular disease is calculated as the difference in the predicted conditional probability of being in the labour force without cardiovascular disease less the predicted conditional probability of being in the labour force with cardiovascular disease after controlling for exogenous variables. The calculation of the treatment effect on labour force participation of diabetes and the exogenous variables is more complex involving as they do the indirect effect on labour supply through the risk of cardiovascular disease.

4. Data

The data come from the AusDiab survey, a population-based cross-sectional survey of national diabetes mellitus prevalence and associated risk factors in people aged ≥25 years, conducted between May 1999 and December 2000 in the six states and the Northern Territory of Australia (Dunstan, Zimmet et al. 2002). The study involved an initial household interview, followed by a biomedical examination that included an oral glucose tolerance test, standard anthropometric tests, blood pressure measurements and the administration of questionnaires. Of the 20 347 eligible people (aged ≥25 years and resident at the address for more than 6 months) who completed a household interview, 11 247 (55.3%) attended for the biomedical examination. To account for the clustering and stratification of the survey design, and to adjust for non-response, the data have been weighted to match the age and gender distribution of the 1998 estimated residential population of Australia aged ≥ 25 years.

The key advantages of the AusDiab survey from the point of view of this study is that it offers a large representative sample of the Australian population over the age of 25 with detailed information on individual self reported and health and clinically measured chronic disease status along with employment status. Importantly it includes clinically measured risk and treatment status for two major chronic diseases, diabetes and cardiovascular disease (blood pressure and cholesterol), self reported family risk information on diabetes, age, as well as lifestyle information on weight and exercise, smoking, and socio-economic information on education status, children and marital status. The richness of the data on chronic disease risk factors allows us to specify detailed structural equations that explain the prevalence of diabetes and cardiovascular disease independently of the participation decision. This allows us to adjust for the potential endogeneity of disease status associated with unobserved common factors that might explain the prevalence of cardiovascular disease, diabetes, and labour force participation.

The definition of those who are diabetic in the AusDiab survey is a combination of people on insulin or tablets who have been told they have diabetes plus those who say they have never been told they have diabetes but have a diabetic glucose value. A diabetic glucose value is based on measured venous plasma glucose concentration classifications that are outlined in the (WHO 1999). Cardiovascular disease is defined as a positive response to the questions “Have you ever been treated for or suffered from any of the conditions: heart disease e.g. heart attack, angina, or a stroke”. The definition of labour force participation from the AusDiab survey is taken to be those who are either working or not working but not retired. In the survey 5% of men and women in the working age groups were not working but not retired.

Explanatory variables for participation were chosen based on the empirical labour supply literature and include age, age squared, education level, marital status, diabetes and cardiovascular disease status. Explanatory variables for the two chronic disease equations -weight, exercise, hypertension and lipid levels, and family history of diabetes - were chosen on the basis of clinical literature on risk. A number of additional variables were initially considered e.g. past smoking, undiagnosed hypertension, untreated elevated lipid levels, overweight, and some exercise but jointly rejected on the theoretical basis that they were correlated with the included variables but less likely to have a direct impact on morbidity. The joint significance of these additional variables was rejected by an adjusted Wald test.

Descriptive statistics

Table 1 shows mean values for the main determinants of labour supply and the key risk factors for diabetes and cardiovascular disease in the sample. The average age was 47 years for men and 49 years for women. Forty-seven percent of men and 36.0% of women had a University degree. This is high compared to the general population of Australia and suggests some potential bias in so far as we might expect a somewhat greater attachment to the labour force in this sample than population as a whole. The survey illustrates the high prevalence of disease risk factors for chronic disease in the population. For example as measured by waist circumference 26.7% of men and 33.6% of women were obese. Waist circumference provides an measure of overweight that is reasonably well correlated with the more common body mass index (BMI) as weight in kilograms divided by height in metres squared (Lean, Han et al. 1995), but appears to be a better indicator of type 2 diabetes and cardiovascular disease (Haffner, Stern et al. 1987). Almost half of men (42.4%) and more than half of women (52.8%) did not get sufficient exercise to maintain their health, while smoking was more common in men (19.1% smoked) compared to women (13.7% smoked).

Table 1: Mean and standard errors for variables: males and females aged 25 and over

Variable	Item description in AusDiab	Male 25+		Female 25+	
		Population weighted sample mean	Standard error	Population weighted sample mean	Standar d error
In the labour force	Employed or not working but not retired	0.768	0.018	0.564	0.022
Diabetes	Confirmed diagnosis of diabetes	0.080	0.008	0.069	0.008
Cardiovascular disease	Told had stroke heart attack or angina	0.080	0.006	0.070	0.010
Education	High school completion	0.187	0.011	0.208	0.011
	University degree completed	0.474	0.022	0.360	0.022
Age	Age in years	47.5	0.718	49	0.096
Marital status	1=Married or de facto	0.777	0.016	0.697	0.016
Children	Number of dependent children	0.451	0.020	0.444	0.023
Obese	Waist size >101.9cm for men and >87.9cm for women	0.267	0.015	0.336	0.029
Sufficient	Over 150 mins phys. act. time	0.576	0.015	0.472	0.017
Smoker	Smokes daily	0.191	0.021	0.137	0.015
Mother or father diabetic	Diabetic	0.182	0.009	0.212	0.013
Treated Hypertensive	On hypertensive therapy	0.116	0.008	0.155	0.015
Treated cholesterol	On lipid therapy	0.077	0.008	0.074	0.008

Waist measures 3 times in cm and males and females are classified obese according to AusDiab criteria on waist measurement. (See WHO report: Obesity: Preventing and Managing the Global Epidemic; Report of a WHO Expert Committee, WHO 1998.)

The survey also reveals the high prevalence of underlying cardiovascular risk factors in the population with a prevalence of hypertension of 29.4% in men and 27.6% in women, while the prevalence of abnormal or treated cholesterol was 70.3% in men and 61.2% in women. The proportion on therapy for hypertension and abnormal cholesterol was 11.6% and 7.7% for men and 15.5% and 7.4% for women. This illustrates the potential to reduce the risk of diabetes and cardiovascular disease through prevention and treatment programs and by doing so both improve the health and the productivity of the population.

The prevalence of clinically confirmed diabetes and cardiovascular disease in males over 25 years of age is similar at 8.0 % but lower in females at 6.9% and 7.0%. Prevalence rises with age so that by age 55-64 years 16.6% of men and 9.5% of women have diabetes and 13.6 % of men and 5.3% of women have cardiovascular disease. Table 2 shows the percentage labour force participation by disease status. It suggests a low rate of labour force participation in persons with diabetes (22%) or cardiovascular disease (30%) or both (9%) compared to the average 66%. The data shown in Table 3 suggest that there is a considerable difference in the probability of being in the labour force between those with and without a chronic disease. The difference in proportions is particularly marked in men and women over 55 years when diabetes and cardiovascular disease prevalence and severity are highest.

Table 2: Observed proportions in labour force by disease status all persons aged 25 years and over

	Labour force participation	Cardiovascular disease	Diabetes
P(.)	0.66	0.08	0.07
P(.|CVD=1)	0.30	1	0.23
P(.|Diab=1)	0.22	0.23	1
P(.|CVD=1,Diab=1)	0.09	1	1

Table 3: Proportion in labour force by age and gender

Age group	Proportion with diabetes	Proportion without diabetes who are in labour force	se	Percent with diabetes who are in labour force	se	Proportion with CVD	Percent without CVD in labour force	se	Percent with CVD in labour force	se
Male										
35-44	0.026	0.956	0.015	0.859	0.077	0.019	0.956	0.015	0.871	0.104
45-54	0.066	0.926	0.019	0.879	0.063	0.047	0.935	0.015	0.678	0.072
55-64	0.166	0.683	0.031	0.392	0.097	0.136	0.676	0.024	0.360	0.056
65-74	0.207	0.186	0.026	0.076	0.027	0.246	0.185	0.027	0.098	0.030
All 25+	0.080	0.801	0.015	0.362	0.043	0.080	0.808	0.016	0.265	0.032
Female										
35-44	0.021	0.775	0.014	0.596	0.102	0.009	0.776	0.014	0.269	0.133
45-54	0.058	0.781	0.021	0.695	0.081	0.033	0.781	0.021	0.802	0.058
55-64	0.095	0.417	0.028	0.296	0.072	0.053	0.417	0.028	0.320	0.655
65-74	0.156	0.055	0.013	0.033	0.021	0.196	0.056	0.013	0.094	0.039
All 25+	0.068	0.584	0.020	0.238	0.033	0.070	0.592	0.020	0.171	0.034

Numbers are too small in the youngest and oldest groups to report reliable statistics

5. Results

Univariate regression results

Table 4 shows the marginal effects from univariate regressions of the two chronic diseases on labour force participation and the effect of risk factors on the prevalence of diabetes and cardiovascular disease for men and women aged over 25 years. Age and obesity stand out as significant factors associated with diabetes for men and women but obesity is a significant factor for cardiovascular disease only in men. Having a parent with diabetes increases the risk of diabetes. Smoking is significant for women in the prevalence of cardiovascular disease while lipid and hypertension treatment are associated with cardiovascular disease for both men and women. Diabetes is associated with cardiovascular disease (at least for women).

Multivariate system results

The system of multivariate probit equations for males and females was significant on a Wald test ($p \rightarrow 0$). The correlation between the labour force participation and diabetes equation residuals was moderate and significant for males and for women the correlation is moderate and statistically significant between the two disease equations (see lower part of Table 5). All other correlations were insignificant but a joint test rejects the null of no correlation across equations ($p \rightarrow 0$). This suggests that that there may be advantages in accuracy in using the multivariate system to estimate the effects of chronic disease prevalence and risk. Calculating the marginal effects from three separate univariate probit regressions will give misleading results.

Table 5 shows the results of the multivariate probit analyses of the probability of labour force participation for males and females over the age of 25. It shows the marginal effect of having diabetes, cardiovascular disease or both on labour force participation. For males the effect of cardiovascular disease is to reduce labour force participation by 0.106 and from diabetes by 0.058. For females the effect is 0.088 and 0.124 respectively. The effect from cardiovascular disease is insignificant for females and from diabetes insignificant for men. It is worth noting that for males the marginal effects of diabetes and cardiovascular disease on participation estimated in the system of equations are considerably lower than the estimates in the univariate regressions. For women cardiovascular disease is insignificant in both estimates, while diabetes has a larger effect in the system of equations than in the univariate regression (-0.124 compared to -0.109). Taking account of the endogeneity of chronic disease in part through the common risk factors does alter the estimate of the treatment effect of chronic disease, but it does so differently for men and women. This is plausible as there are well known differences in men and women in the prevalence of these diseases, their risk factors and their complications in addition to differences in labour supply behaviour.

Table 4. Marginal effect of risk factors on the probability of labour force participation, cardiovascular disease and diabetes: univariate regressions in males and females aged 25 and over

	Males 25+						Females 25+					
	Participation		CVD		Diabetes		Participation		CVD		Diabetes	
	Marginal effect	p	Marginal effect	p	Marginal effect	p	Marginal effect	p	Marginal effect	p	Marginal effect	p
CVD	-0.143	0.000					-0.029	0.726				
Diabetes	-0.122	0.003	0.011	0.177			-0.109	0.001	0.023	0.098		
High school	0.076	0.002					0.122	0.039				
University	0.085	0.002					0.224	0.000				
Age	0.344	0.000	0.027	0.000	0.035	0.000	0.924	0.000	0.024	0.000	0.021	0.000
Age^2	-0.05	0.000					-0.115	0.000				
Married	0.077	0.01					-0.067	0.058				
Children	0.035	0.237					-0.143	0.002				
Treated hypertension			0.024	0.020					0.025	0.019		
Lipid therapy			0.128	0.000					0.072	0.018		
Sufficient exercise			-0.001	0.878	-0.012	0.177			-0.014	0.146	-0.005	0.345
Obesity			0.01	0.059	0.059	0.000			0.007	0.301	0.06	0
Current smoking			0.007	0.334	0.024	0.098			0.008	0.397	-0.009	0.316
Parent diabetic					0.036	0.003					0.035	0.002
Prob.(LFP=1|CVD=1,Diab=1) - P(LFP=1|CVD=0,Diab=0)	0.289	0.000					-0.322	0.000				

CVD=Cardiovascular disease p is statistical significance (prob. t > critical value)

Table 5: Marginal effect of risk factors on labour force participation in males and females aged 25 and over: results from multivariate regressions

	Multivariate probit			
	Males n=4272		Females n=5251	
Variables	Marginal	p	Marginal effect	p
CVD	-0.106	0.060	-0.088	0.449
Diabetes	-0.058	0.319	-0.124	0.003
High school	0.047	0.071	0.119	0.089
University	0.059	0.010	0.211	0.054
Age	0.257	0.000	0.990	0.070
Age^2	-0.039	0.000	-0.124	0.031
Married	0.039	0.008	-0.046	0.336
Children	0.033	0.114	-0.163	0.055
Treated hypertension	-0.002	0.038	0.007	0.859
Lipid therapy	-0.007	0.010	0.018	0.860
Sufficient exercise	0.002	0.075	-0.002	0.958
Obesity	-0.010	0.000	-0.023	0.749
Current smoking	-0.006	0.102	0.008	0.362
Parent diabetic	-0.006	0.003	-0.015	0.763
Predicted prob. of participation	0.869	0.012	0.483	0.000
Prob.(LFP=1|CVD=1,Diab=1) - P(LFP=1|CVD=0,Diab=0)	-0.223	0.021	-0.476	0.620
	Correlation. Coefficient	p	Correlation. Coefficient	p
$\rho_{1,2}$	0.080	0.643	-0.281	0.366
$\rho_{1,3}$	0.364	0.050	0.157	0.359
$\rho_{2,3}$	0.117	0.463	-0.647	0.000
$\rho_{1,2}= \rho_{1,3}= \rho_{2,3}=0$		0.000		0.000

1=Participation; 2= Cardiovascular disease(CVD); 3= Diabetes; p value for t-test on marginal effects and Chi^2 for correlations

Table 5 also shows the marginal indirect effect of the disease risk factors on labour force participation. For example the effect on males of being obese is to increase the risk of diabetes and cardiovascular disease and thereby indirectly reduce the probability of being in the labour force by 0.01. Similarly smoking, insufficient exercise, hypertension, and abnormal cholesterol each have a small but significant effect on labour force participation for both men and women through their effect on the risk of chronic disease.

In addition to the effect on labour force participation it is likely that diabetes and cardiovascular disease have an effect on the labour productivity of those in employment. The AusDiab survey does not have information on wages or hours worked to allow us to test this. It is also likely that the severity of disease has an impact on labour force participation. Including self reported general morbidity in a system of equations would considerably increase the complexity of the estimation in the multivariate system. Instead we explored this issue by including a dichotomous variable for self reported poor health and two interaction terms for self reported poor health and each disease in the univariate participation equations.

Table 6 shows the effect of poor health on labour force participation for those with diabetes or cardiovascular disease. The reduction in the probability of being in the labour force associated with having diabetes and being sick compared to having diabetes but not reporting being in poor health, was significant for men (0.17; 95%CI 0.07, 0.26) but not significant for women (0.08; 95%CI -0.06, 0.21). The reduction in the probability of labour force participation associated with having cardiovascular disease and being sick compared to having cardiovascular disease but not reporting being sick was high and significant for men (0.35; 95%CI 0.21, 0.48) but small and insignificant for women (0.03; 95%CI -0.23, 0.29). It seems clear that the morbidity associated with cardiovascular disease or diabetes has a strong effect on labour force participation at least for men. While some men may retire following a cardiac event or on being diagnosed with diabetes for most it is the complications associated with the disease that leads to a change in behaviour. The implication is that primary prevention of cardiovascular disease and diabetes will improve labour market outcomes but secondary prevention and treatment if it can reduce the complications of the disease could have a very significant impact on labour supply.

Table 6. Effect of chronic disease and poor health on predicted participation rate by gender

		CVD=1, Sick=0	CVD=1, Sick =1	Diabetes=1, Sick =0	Diabetes=1, Sick =1
Males	Participation rate	0.800	0.453	0.778	0.613
	Difference	-0.346 (-0.213; -0.480)		-0.165 (-0.073, -0.257)	
Females	Participation rate	0.507	0.478	0.405	0.327
	Difference	-0.029 (0.233, -0.290)		-0.077 (0.059, -0.214)	

CVD=Cardiovascular disease

6. Conclusion

In the context of concerns about the size of the labour force into the future the potential for improved labour outcomes from chronic disease prevention and treatment are significant. For example a report to the Government of Victoria estimated that the negative impact of population ageing in the next 40 years would lead to a decline in labour force participation in Victoria from around 64.7 per cent in 2005 to 55.6 per cent by 2035 (Victoria's Workforce Participation Taskforce 2005). To maintain the size of the workforce they estimate that participation rates in 2035 would have to be 15 per cent higher across all age groups than they were in 2005. The present study confirms that the prevalence of risk factors for cardiovascular and diabetes in the Australian population over the age of 25 years has a significant impact on labour market outcomes. The combined size of the effect of these two chronic diseases on reduced labour force participation was 0.22 for men and at least 0.124 for women from diabetes alone. We found that, particularly for men with cardiovascular disease or diabetes, being sick had a large effect on labour force participation. This means that eliminating the risk of disease at the population level could increase the effective labour force by into the future by more than 1.2% for men and 0.08% for women. Reducing the morbidity associated with the complications of these chronic diseases, through secondary prevention and effective treatment, would have an effect not only labour force participation but also on labour productivity. It may not be feasible to eliminate these chronic diseases especially in the short term, although reducing some of the risk factors for diabetes and cardiovascular disease may also be important for other serious chronic disease such as cancer, arthritis and mental illness that affect labour market outcomes.

There is a number of promising approaches to the primary and secondary prevention of diabetes and cardiovascular including lifestyle (smoking reduction, weight reduction and physical activity increasing) as well as pharmacological interventions. Some of these have been shown to be successful in experimental studies and to offer value for money at least in simulations. For example it has been suggested that making pharmaceuticals that are widely regarded as effective such as antihypertensive and lipid-lowering pharmacologic therapy available to a wider group of patients for the primary prevention of cardiovascular disease would be a cost effective way of reducing cardiovascular disease (Kostis 2007). Strong, consistent evidence from large, well-designed trials has definitively shown that maintenance of modest weight loss through diet and physical activity prevents the progression from early diabetes (Pan, Li et al. 1997; Tuomilehto J 2001; Diabetes Prevention Program Research Group 2002; Eddy, Schlessinger et al. 2005) and can reduce the incidence of type 2 diabetes in high-risk persons by about 40-60% over 3 to 4 years (Centers for Disease Control and Prevention Primary Prevention Working 2004). While studies such as these that focus on multiple risk factors using individual health practitioner based counselling and educational methods are useful, there has been a recognition that interventions based on lifetime risk are more likely to be effective. In particular the importance of early life factors (*in utero* and early childhood) in creating predispositions to chronic disease in adulthood has been recognised. What this implies are broader strategies that involve a wider range of agents (e.g. transport, education, tax system, market regulation) to change social norms, in the case of obesity for example to a norm of more active living and healthy life habits.

The current study does not provide any new evidence on the cost effectiveness of measures to reduce the prevalence of chronic disease, but it does illustrate that the effective implementation of chronic disease prevention programs could have a significant effect on the stock of human capital particularly for those aged 55 years and over where the risk of chronic disease and the potential loss of human capital is highest. The last decade has seen tremendous advances in the treatment of heart disease and cardiovascular disease risk factors. There is now an large body of evidence supporting the use of ACE inhibitors, antihypertensive medications, and lipid lowering agents for both primary and secondary prevention of cardiovascular disease events in high-risk populations, including those with diabetes (UKPDS 1998; HOPE 2000; MRC/BHF 2002). The AusDiab survey data here shows that only 11.5% of those with elevated lipids were on medication. Only 50% of those with elevated blood pressure were on medication, and only 50% of either group got sufficient exercise. There has been a substantial rise in the use of cardio protective drugs in Australia in the last few years, but there is still likely to be a substantial number of people who would benefit from medication.

It has to be recognised that our ability to forecast just how effective a lever on labour force participation these interventions might be is limited by the cross sectional nature of the data used here and the robustness of the translation of the evidence on the effectiveness of interventions into practice in Australia. The analysis suggests a potentially significant effect of chronic disease prevention and treatment on labour market outcomes, but the current data do not allow us to take account of the history of respondents in terms of risk and treatment or the dynamics of treatment effects. The 1999-2000 AusDiab survey is the first wave of a panel and future research can take advantage of the follow up data to confirm these results and shed light on the labour market outcomes of changes in disease status over time.

7. References

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