CENTRE of POLICY STUDIES and the IMPACT PROJECT

Eleventh Floor, Menzies Building
Monash University, Wellington Road
CLAYTON Vic 3800 AUSTRALIA

Telephone: (03) 9905 2398, (03) 9905 5112 — from overseas: 61 3 9905 2398 or 61 3 9905 5112

Fax: (03) 9905 2426 — 61 3 9905 2426

e-mail: impact@buseco.monash.edu.au

Internet home page: http//www.monash.edu.au/policy/

The Impact of Changes in Health Status: An Economywide Analysis for Australia

by

GEORGE VERIKIOS
PETER B. DIXON
MAUREEN T. RIMMER
Centre of Policy Studies
Monash University

and

ANTHONY H. HARRIS
Centre for Health Economics
Monash University

General Paper No. G-231 February 2013

ISSN 1 031 9034 ISBN 978 1 921654 39 8

The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to economy-wide modelling of economic policy issues.

The Impact of Changes in Health Status: An Economywide Analysis for Australia

George Verikios, Peter B. Dixon, Maureen T. Rimmer
Centre of Policy Studies, Monash University

and

Anthony H. Harris
Centre for Health Economics, Monash University

Abstract

We construct a dynamic, computable general equilibrium model of the Australian economy that incorporates a detailed representation of demographic and health trends of the labour force. We project the economywide effects of changes in the health status of the workforce associated with a change in chronic disease prevalence. Our results show that reductions in chronic disease and the associated rate of health decline of older workers have a much greater effect than similar reductions for younger workers. Traded sectors benefit much more than nontraded sectors, with a consequent improvement in the trade balance and a real depreciation of the exchange rate. The increase in workforce participation also decreases the capital-labour ratio and raises the returns to capital relative to labour.

JEL codes:	C68, I15, J11
Keywords:	chronic disease, computable general equilibrium, health status, labour supply

Acknowledgements

This work was partly funded by the National Health and Medical Research Council. The views expressed here are the authors' and do not necessarily represent those of the financing institution or their affiliates. Thanks are due to Xueyan Zhao for advice on the Household, Income and Labour Dynamics in Australia Survey and David Johnson for helpful comments on this paper.

Table of contents

Tables

Figures

1. Introduction

Chronic diseases, such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes, are by far the leading cause of mortality in the world, representing 63% of all deaths. Out of the 36 million people who died from chronic disease in 2008, nine million were under 60 and 90% of these premature deaths occurred in low- and middle-income countries (WHO, 2011). Chronic illness reduces individual welfare, increases direct health care costs and causes indirect costs in other parts of the economy (Sachs and Malaney, 2002). In this work we develop a disaggregated dynamic general equilibrium model of the macroeconomic impact of chronic disease.

At macroeconomic level, the mortality and morbidity associated with chronic diseases place a heavy burden on the economies of low- and middle-income countries and, where they affect the principal income earner, they can have major impacts on household income. In a World Bank qualitative survey of 60,000 poor women and men in 60 countries, sickness and injury was the most frequent trigger for downward mobility (Narayan, 2000). Chronic diseases, including cardiovascular disease and diabetes, are estimated to reduce GDP by up to 6.8% in low- and middle-income countries experiencing rapid economic growth, as many people die prematurely (WHO, 2011).

In high-income countries chronic diseases are not only the leading cause of death but also of disability, and are associated with high morbidity and the use of health services. In this work, we illustrate the effect of chronic illness on the wider economy by focussing on the impact of changes in ill health associated with chronic disease on the macroeconomy of a high-income country. We use the example of Australia, where the main causes of death in 25-64 year olds in 2007-08 were coronary heart disease for males (14% of deaths) and breast cancer for females (12%). Over a third of Australians with hypertension or cardiovascular disease (36%) report having fair or poor health, while 42% of those with diabetes and 58% of those with angina have fair or poor health compared with only 4% of those with no long-term condition (ABS, 2010). Programs that can prevent chronic disease have the potential to have a major impact on those with poor health status, particularly in older age groups. For example, in the 2007-08 Australian National Health Survey, of the 17% of individuals over the age of 18 years who report being in fair or poor health, 21% have hypertensive disease (high blood pressure) as a current long-term condition, and 43% report having one or more of the broader group of conditions relating to the cardiovascular system (ABS, 2010).

The labour market is the major conduit through which the indirect costs of disease manifest via reduced labour productivity and workforce participation (Gershberg et al., 2000).

Thus, the analysis of the wider effects of chronic disease and ill health requires an economywide model that links health and labour supply. We develop an economywide model that analyses the macroeconomic effects of permanent reductions in the rate of health decline of workers that are comparable to reductions in the population prevalence of chronic disease. Our findings indicate that health improvements for 10% of the unhealthiest older workers can have strong macroeconomic effects.

Most of the empirical literature on the effects of chronic disease on labour market outcomes is based on the canonical model of Grossman (1972). Within this literature, studies of how adverse labour market outcomes, due to chronic disease or ill health, affect the general economy fall into two main categories. One category is macroeconomic growth models that treat health either as a production input in its own right, or as labour-augmenting: Agénor (2008) is a recent example. These studies tend to be applied-theoretic in nature and represent the economy with two or three sectors at most. Such studies can only provide qualitative results, usually via closed-form solutions, and give scant detail on sectoral effects. A second category of studies apply computable general equilibrium (CGE) models that indirectly incorporate a proxy for health via the effects of given disease (or diseases) or health issue. One recent example is Smith et al. (2005), which examines the impact on the UK of antimicrobial disease resistance. Another recent example is Bosello et al. (2006), which studies the regional impacts of climate-change-induced change in human health. These two examples are typical of this category of studies in that they are based on economywide models that are calibrated on national accounts and input-output data. Thus, they contain policy-relevant sectoral detail and provide quantitative estimates of economic impacts.

Until recently, of the category of studies that apply CGE models to analyse health issues, none directly incorporated labour productivity or labour supply as an endogenous function of population-wide health (or health proxy). As far as we are aware, Rutten and Reed (2009) is the first study that develops such a link. They apply a comparative-static CGE model for the UK that makes health a function of health care provision. Health then determines effective labour supply. Rutten and Reed (2009) show that an increase in the national health budget will increase health and, thus, effective labour supply, which in turn raises national welfare via higher incomes and well-being. Like Rutten and Reed (2009), we apply a CGE model to simulate the effect of a change in health on effective labour supply and macroeconomic outcomes; but unlike Rutten and Reed we focus on the health status-labour supply nexus exclusively, and use a more disaggregated multisectoral dynamic CGE model that allows for inertia and lags in market responses. In our framework, population health follows existing trends and is a function of non-health care factors, e.g., lifestyle, demographic trends. Our labour market specification identifies age- and health-specific participation rates for labour market participants and allows us to evaluate the macroeconomic effects of disease prevention and health promotion programs that target particular sub-groups of the population, e.g., older people, people with cardiovascular disease. The model also allows us to calculate effects by industry and employment type. We take a dynamic approach and represent movements across health states through time based on empirical transitions taken from longitudinal survey data. The labour market theory we apply was initially developed in Dixon and Rimmer (2003) and was first applied to a specific disease (AIDS/HIV) in Roos (2012).

We embed our labour market specification within a dynamic, multisectoral CGE model of the Australian economy with a detailed representation of the health sector. We analyse the economywide effects of permanent reductions in the rate of health decline of younger and older workers. Our approach demonstrates the importance of representing the age and health characteristics of labour market participants in order to properly evaluate disease prevention and health promotion programs of different population sub-groups

2. Health and human capital: the empirical literature

Intuition and casual observation suggest that health affects labour market outcomes (participation, employment, hours, productivity and wages). The literature shows that there is a positive relationship between health and labour market outcomes including both labour supply and productivity. Deterioration in health results in lower hours worked in the short term, a reduction in employment in the longer term. There are a number of reasons why we may observe a correlation between health, wages and offers of employment:

- an increase in health leads directly to an increase in productivity that would lead to an increase offers of employment and in the wage rate offered;
- an employer may perceive health to be correlated with unobservable attributes such as capacity to work which affect productivity and hence be more likely to make an offer of employment and higher wage offer to a healthier individual;
- an individual may be discriminated against because they are unhealthy, irrespective of their productivity and may receive less offers of employment and lower wage offers (Contoyannis and Rice, 2001).

In general, the econometric literature has found a positive relationship between health, wage rates and hours of employment (Luft, 1975; Grossman and Benham, 1973; Bartel and Taubman, 1979; Contoyannis and Rice, 2001). Some of the literature takes a more dynamic approach and uses lagged health as a determinant of current labour supply. In an early example of this, Haveman et al. (1994) estimated a simultaneous equations model for working hours, wages, and health with longitudinal data on 613 white males observed over 8 years from the US Panel Study of Income Dynamics. They found lagged ill-health (measured by a dichotomous indicator of health related work-limitations) reduces wages of men by 54% compared to no limitations. In a joint discrete intertemporal model of health and employment risks, Haan and Myck (2009) use lagged variables, i.e., current employment is dependent on last period health but not current health that is explained in part by past employment, to simulate the employment experience of a 29 year old employed German man. Between the ages of 30 and 50 the initial health status only marginally affects the employment risk. But in the last 10 years the risk of not being employed increases for those with initial poor health. At the age of 55 the difference in the median employment rate by health status amounts to 7 percentage points and increases to nearly 20 percentage points at the age of 59. Pelkowski and Berger (2004), using the longitudinal US Health and Retirement Study and accounting for the nonrandom selection of those in employment, found a reduction in total earnings associated with a permanent health condition for a random worker is 52% and 52.4% for males and females. By far, the largest portion of this total effect is on the probability of working, with much smaller effects on wages. In other words, permanent health conditions reduce wages and hours worked, but have far greater effects on the likelihood that an individual works in the first place. This literature is consistent with the approach we take here and with other evidence that better health increases the probability that an individual will be employed and the number of hours worked (Cai and Kalb, 2006; Lechner and Vazquez-Alvarez, 2004), and that poor health increases the likelihood of early retirement.

Another strand of this literature, and one that is consistent with the approach we take here, uses changes in past health (health shocks) to identify the health work relationship. In Germany, for example, Riphahn (1999) finds that a drop in a self-reported measure of health satisfaction has significant effects on employment. Using waves of the U.S. Health and Retirement Study, Bound et al. (1999) find that both changes in health and the long-term level of health influence labour supply decisions, and that the rate of retirement of men by age 62 was five times as great for those in poor health than for those in average health (Bound et al., 2010). Disney et al. (2006) apply the method to the first eight waves of British Household Panel Survey (BHPS), 1991 to 1998. They find that health shocks are an important determinant of retirement behaviour in the UK. These results are confirmed by Roberts et al. (2006), Roberts et al. (2008) and Garcia-Gomez et al. (2008) using the BHPS, by Hagan et al. (2006) using the European Community Household Panel, and by Zucchelli et al. (2010) using Australian HILDA data.

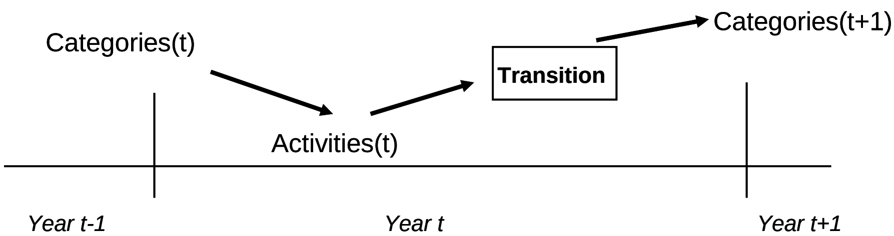
3. Age- and health-specific labour supply

In our approach the supply side of the labour market is represented by decisions that reflect age and health status. We identify 5 age groups (the set AGE), 5 health statuses (the set HEALTH), 8 occupations (the set WORK) and 3 non-employment categories (short-run unemployed, long-run unemployed and new entrants: the set NWORK).[1]

There are six key ingredients in our approach; the first three ingredients are presented in Figure 1. The six ingredients are:

- the specification of *categories by age, health status and work status*, determined at the *start* of each year;
- the identification of *activities*, what people do *during* the year;
- the determination of labour supply from each category to each activity;
- the determination of labour demand in employment activities;
- the specification of wage adjustment processes reflecting demand and supply;
- the determination of everyone's activity, who gets the jobs and what happens to those who do not.

Figure 1. Representing labour supply by categories, activities and their transitions



3.1 Categories and activities

The workforce is divided into *categories*: people are allocated to categories according to their age, health status and recent workforce *activity*. The number of people in each category at the start of year *t* is linked to the number of people in each activity in year *t*-1 according to

$$\mathrm{CAT}_t(a,h,c) = \sum_{b \in \mathrm{AGE}} \sum_{i \in \mathrm{HEALTH}} \mathrm{ACT}_{t-1}(b,i,c) * \mathrm{T}(b,i,c,a,h)\,,$$

$$a \in \mathrm{AGE}, h \in \mathrm{HEALTH}, c \in \mathrm{WF} = \mathrm{WORK} \cup \mathrm{NWORK}\,. \qquad (1)$$

[1] Short-run unemployed is defined as being unemployed in year *t*-1 but employed or not in the labour force in year *t*-2. Long-run unemployed is defined as being unemployed in years *t*-1 and *t*-2.

In equation (1), $\mathrm{CAT_t(a,h,c)}$ is the number of people at the start of year *t* who are in age group *a*, have health status *h* and who performed workforce function *c* in year *t*-1. Workforce functions include employed states (WORK) and unemployed states (NWORK). $\mathrm{CAT_t(a,h,c)}$, *c* = new entrants (i.e., those who were not in the labour force in year *t*-1), is set exogenously and reflects demographic factors. $\mathrm{ACT_{t-1}(b,i,c)}$ is the number of people in activity $\mathrm{(b,i,c)}$ in year *t*-1, i.e., the number of people who in year *t*-1 belonged to age group *b*, had health status *i* and workforce function *c*. $\mathrm{T(b,i,c,a,h)}$ is the proportion of people in activity $\mathrm{(b,i,c)}$ in year *t*-1 who are allocated to category $\mathrm{(a,h,c)}$ at the start of year *t*, i.e., it is the transition matrix.

The transition matrix $\mathrm{T(b,i,c,a,h)}$ is an important ingredient of our approach. In estimating it we use the relationship:

$$\mathrm{T(b,i,c,a,h) = P_1(a|b,i) * P_2(h|b,i,c)}\,. \qquad (2)$$

In equation (2), $\mathrm{P_1(a|b,i)}$ is the probability of a person who was in age group *b* with health status *i* in year *t*-1 joining age group *a* in year *t*.[2] To a large extent, these probabilities can be set mechanically, e.g., where *b* is the 10-year age group 29 to 38 (denoted A29-38) our first approximation to P_1 is

$$\mathrm{P_1(A29{-}38|\,A29-38, i)} = 0.9,\ \forall \mathrm{i}, \text{ and}$$

$$\mathrm{P_1(A39{-}48|\,A29-38, i)} = 0.1,\ \forall \mathrm{i};$$

where A39-48 is the 10-year age group 39 to 48.

In our second approximation we allow for death and permanent discouragement from seeking work (D), which gives

$$\mathrm{P_1(A29{-}38|\,A29-38, i)} = 0.9*[1\text{-}D(A29\text{-}38, i)], \text{ and}$$

$$\mathrm{P_1(A39{-}48|\,A29-38, i)} = 0.1*[1\text{-}D(A29\text{-}38, i)].$$

Further refinements can be made to allow for non-uniformity in the distribution of people within each age group.

In equation (2), $\mathrm{P_2(h|b,i,c)}$ is the probability of a person who, in year *t*-1, was in age group *b*, had health status *i* and workforce function *c*, who moves to health status *h* in year *t*. We estimate these probabilities from the Household, Income and Labour Dynamics in Australia

[2] Thus, $\mathrm{T(b,i,c,a,h)}$ is a first-order Markov model since all probabilities of being in state (*a*, *h*) in year *t* are only a function of state (*b*, *i*) in year *t*-1.

(HILDA) survey (Summerfield et al., 2011).[3] Table 1 contains an example of this work. It sets out a P_2 matrix for a classification system involving:

- 5 health statuses (H1, excellent; H2, very good; H3, good; H4, fair; H5, poor);
- 5 age groups (A15-28, ages 15 to 28; etc);
- 2 workforce functions: working and non-working.

The numbers indicate, for example, that 52% of people who, in year *t*-1, belonged to the age group 15-28, had health status H1, were working and survived to year *t* then experienced health status H1 in year *t*. Similarly, 39% of people who, in year *t*-1, belonged to the age group 61+, had health status H5, were non-working and survived to year *t* then experienced health status H4 in year *t*.

In calculating the values in Table 1, we used the first five available HILDA waves, i.e., surveys for the years 2002 to 2006. We looked at the self-reported health statuses for individuals that appeared in the surveys for years *t*-1 and *t*. Then we computed Table 1 by making averages of all of the available transitions. Table 1 indicates that the HILDA survey implies for all age groups except A15-28, people who worked in year *t*-1 are less likely to assess themselves as experiencing declining health in year *t* than people who did not work in year *t*-1. For example, 49% of working people aged 39-48 with H1 health in year *t*-1 experience declining health in year *t* whereas the corresponding percentage for non-working people was 67%. The exception is young people. Non-working young people in excellent health, a group most likely dominated by students, are less likely to experience health decline than their working counterparts (44% cf. 48%).

3.2 Labour supply from each category to each activity

We develop equations that describe the supply of labour from each category to each activity. These equations have the form:

$$\mathrm{LS_t(a,h,w,c) = CAT_t(a,h,w) * F_{a,h,w,c}\left(\frac{W_t(c)}{AW_t(a,h,w)}\right)},$$

$$\mathrm{a \in AGE, h \in HEALTH, w, c \in WF}\,; \tag{3}$$

where $\mathrm{LS_t(a,h,w,c)}$ is the supply in year *t* to labour force function *x* from people in category

[3] HILDA is a large, nationally-representative household panel study conducted annually in Australia since 2001.

Table 1. Probabilities of changes in health status

From\To	Working: Health status[a] H1	H2	H3	H4	H5	Total	Health decline	Non-working: Health status[a] H1	H2	H3	H4	H5	Total	Health decline
				A15-28[b]							A15-28[b]			
H1	0.52	0.38	0.08	0.01	0.00	1.00	0.48	0.56	0.34	0.10	0.01	0.00	1.00	0.44
H2	0.14	0.59	0.24	0.02	0.00	1.00	0.27	0.17	0.54	0.25	0.04	0.00	1.00	0.29
H3	0.03	0.32	0.54	0.10	0.01	1.00	0.11	0.03	0.29	0.55	0.12	0.01	1.00	0.13
H4	0.02	0.10	0.47	0.35	0.05	1.00	0.05	0.00	0.11	0.41	0.40	0.07	1.00	0.07
H5	0.00	0.08	0.29	0.43	0.20	1.00		0.00	0.03	0.28	0.31	0.39	1.00	
				A29-38[b]							A29-38[b]			
H1	0.52	0.39	0.08	0.01	0.00	1.00	0.48	0.46	0.42	0.11	0.01	0.00	1.00	0.54
H2	0.11	0.63	0.24	0.02	0.00	1.00	0.27	0.10	0.61	0.26	0.02	0.00	1.00	0.29
H3	0.02	0.28	0.59	0.10	0.01	1.00	0.11	0.02	0.23	0.57	0.17	0.02	1.00	0.18
H4	0.01	0.10	0.39	0.46	0.05	1.00	0.05	0.00	0.07	0.34	0.52	0.06	1.00	0.06
H5	0.00	0.04	0.27	0.45	0.24	1.00		0.02	0.02	0.07	0.28	0.62	1.00	
				A39-48[b]							A39-48[b]			
H1	0.51	0.40	0.08	0.01	0.00	1.00	0.49	0.33	0.51	0.12	0.02	0.01	1.00	0.67
H2	0.10	0.63	0.26	0.02	0.00	1.00	0.27	0.06	0.62	0.28	0.03	0.01	1.00	0.31
H3	0.01	0.23	0.64	0.11	0.01	1.00	0.11	0.02	0.19	0.58	0.20	0.02	1.00	0.22
H4	0.00	0.05	0.37	0.53	0.06	1.00	0.06	0.00	0.02	0.26	0.56	0.16	1.00	0.16
H5	0.02	0.04	0.24	0.33	0.38	1.00		0.00	0.01	0.08	0.31	0.60	1.00	
				A49-60[b]							A49-60[b]			
H1	0.49	0.44	0.06	0.01	0.00	1.00	0.51	0.48	0.44	0.07	0.02	0.00	1.00	0.52
H2	0.09	0.63	0.26	0.02	0.00	1.00	0.29	0.08	0.57	0.31	0.04	0.00	1.00	0.35
H3	0.01	0.22	0.65	0.12	0.01	1.00	0.12	0.01	0.17	0.63	0.18	0.01	1.00	0.19
H4	0.00	0.06	0.35	0.52	0.07	1.00	0.07	0.00	0.01	0.23	0.62	0.14	1.00	0.14
H5	0.00	0.02	0.02	0.43	0.54	1.00		0.00	0.01	0.02	0.34	0.64	1.00	
				A61+[b]							A61+[b]			
H1	0.43	0.52	0.05	0.00	0.00	1.00	0.57	0.43	0.47	0.09	0.02	0.00	1.00	0.57
H2	0.07	0.64	0.26	0.02	0.00	1.00	0.29	0.06	0.57	0.33	0.03	0.00	1.00	0.37
H3	0.01	0.23	0.64	0.12	0.01	1.00	0.12	0.01	0.14	0.64	0.19	0.01	1.00	0.20
H4	0.00	0.01	0.31	0.61	0.07	1.00	0.07	0.00	0.02	0.21	0.67	0.09	1.00	0.09
H5	0.00	0.00	0.09	0.64	0.27	1.00		0.00	0.00	0.05	0.39	0.55	1.00	

[a] H1: excellent. H2: very good. H3: good. H4: fair. H5: poor. [b] Age groups: A15-28, ages 15 to 28; A29-38, ages 29 to 38; A39-48, ages 39 to 48; A49-60, ages 49 to 60; A61+ ages 61 and over.

$\mathrm{CAT}_t(a,h,w)$, $W_t(c)$ is the wage or benefit in year *t* for workforce function *x*, and $\mathrm{AW}_t(a,h,w)$ is the average wage or benefit over all workforce functions available in year *t* to people in $\mathrm{CAT}_t(a,h,w)$.

We introduce several important features of labour supply via the specification of the functions $F_{a,h,w,c}$ including:

(1) people who worked in occupation *o* in year *t*-1 supply labour strongly to occupation *o* in year *t* (e.g., most economists want to continue being economists);

(2) people supply labour only to occupations compatible with their skills (e.g., economists do not try to become medical doctors);

(3) unemployed people supply relatively weakly to work activities (i.e., discouraged worker effect); and

(4) supply to work activities from a category depends on the category's age and health characteristics.

Evidence for (4) is given in Figure 2, derived from HILDA.

Figure 2. Employment fractions for groups classified by age and health status

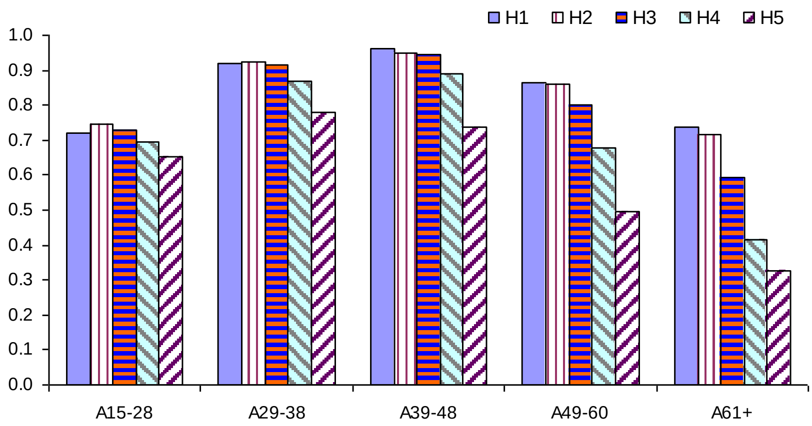


Figure 2 shows employment fractions for each age group. Within each age group it shows employment fractions by each health status. We see that employment fractions decline sharply as we move to low health statuses (H4 and H5). Employment fractions also drop off sharply in the higher age groups. These patterns are supported by data from cross-sectional surveys for Australia (Schofield, 2007) and the US (Bound et al., 1999).[4]

3.3 Demand for labour, wage adjustment and who gets the jobs

Demand for labour is specified along conventional CGE lines. Each industry's demand for labour of occupation *o* is a function of: the industry's output level; technology variables; the industry's capital stock; and the wage rate of occupation *o* relative to the wage rate of other occupations. At this stage we have assumed that industries do not distinguish labour inputs by age and health status. We plan to relax this assumption in future work.

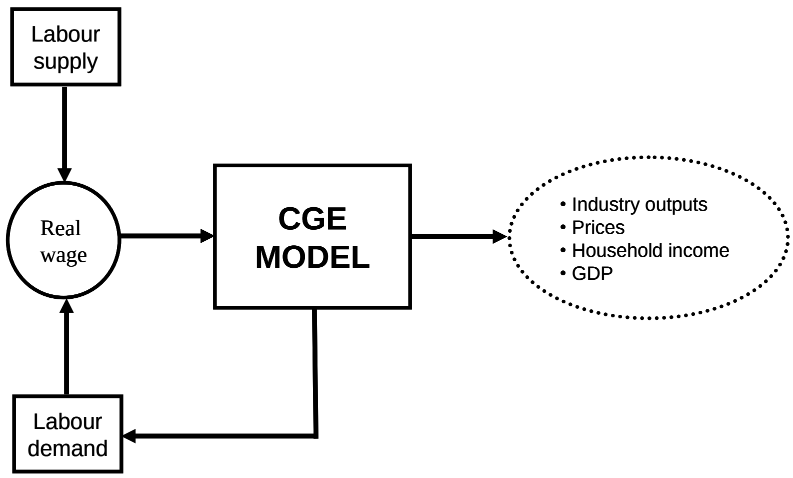
Figure 3 presents a stylised representation of the interaction between labour demand, labour supply and the core of the CGE model. Together, labour demand and supply for occupation *o* determine wage adjustment via:

[4] These patterns are also supported by econometric studies analysing the relationship between health and labour force participation using HILDA (e.g., Cai and Kalb, 2006).

$$\mathrm{RW_t(o) = RW_{t-1}(o) + \alpha\left[LD_t(o) - LS_t(o)\right]} \tag{4}$$

where $\mathrm{RW_t(o)}$ $\left(\mathrm{RW_{t-1}(o)}\right)$ is the real after-tax wage rate received by occupation *o* in year *t* (*t*-1), $\mathrm{LD_t(o)}$ is demand for occupation *o* (aggregated across industries), $\mathrm{LS_t(o)}$ is supply of occupation *o* (aggregated across age, health and workforce categories), and α is a positive parameter. Under (4) and α=0.5, wages adjust sluggishly, leaving gaps between demand and supply. We normally assume that supply exceeds demand. Thus, we need a rationing system to decide who gets the jobs and what happens to those whose offers to work are not accepted. We assume that incumbents have a strong advantage and that job openings beyond those filled by incumbents are shared between non-incumbents in proportion to the strength of their supplies.

Figure 3. Interaction between labour supply, labour demand and CGE model



4. The economywide model: MONASH-Health

The representation of the labour supply described above is embedded within MONASH-Health: a dynamic, CGE model of the Australian economy. Its theoretical structure is similar to the MONASH model of Australia (Dixon and Rimmer, 2002). Below we describe those elements of MONASH-Health that are important to the analysis undertaken here.

4.1 Overview

MONASH-Health contains a detailed representation of the health sector: this represents a new development for CGE models. Previous CGE analysis of health issues usually depicts the health sector by subsuming it within a broader sector in either a multi-sector model (e.g., McKibbin and Sidorenko, 2006) or a single-sector model (e.g., Keogh-Brown et al., 2010). Smith et al. (2005) are an exception in specifying three health sector industries.

4.1.1 The health sector

In representing the health sector, j (=1,...,18) health treatments (e.g., cardiovascular disease) are distinguished from c (=1,...,6) health commodities (e.g., pharmaceuticals) and services (e.g., hospitals); see Table 2. The health treatment activities are based on the International Classification of Diseases–10th Revision and their absolute and relative sizes in the model data are determined using statistics from AIHW (2004). The health (commodities and) services facilitate the provision of treatment activities and are health services that are typically recognisable in detailed national accounts data.

Table 2. Health treatments and health services in MONASH-Health

Health treatments		Health commodities and services
1. Cardiovascular disease	2. Genitourinary	1. Human pharmaceuticals
3. Nervous system	4. Endocrine, nutritional and metabolic	2. Hospitals, nursing homes
5. Musculoskeletal	6. Skin diseases	3. Medical services
7. Injuries	8. Maternal conditions	4. Dental services
9. Respiratory system diseases	10. Infectious and parasitic diseases	5. Optometry
11. Oral health	12. Diabetes mellitus	6. Ambulance services
13. Mental disorders	14. Neonatal causes	
15. Digestive system	16. Congenital anomalies	
17. Neoplasms	18. Signs, symptoms, ill-defined conditions and other contact with the health system	

Each health treatment industry uses a unique combination of health services; this information is also sourced from AIHW (2004). Some treatment activities are pharmaceutical intensive (e.g., respiratory system diseases; diabetes mellitus); others are hospital intensive (e.g., injuries; neonatal). The health treatment activities (or industries) do not directly demand primary factors (land, labour and capital) but are linked to other sectors of the economy via their demands for health services as intermediate inputs. Thus, their demand for primary factors is indirect via the demand for primary factors by the industries that produce their intermediate inputs: health services (Table 3(a), column 1). The outputs of the health treatment industries are purchased by the representative household as consumption (Table 3(b)): these purchases are made at subsidised prices (65%) financed by government revenue.

The health services sectors use primary factors and intermediate inputs in production. Regardless, health service industries mainly use primary factors as inputs and this is dominated by labour inputs (Table 3(a), column 2). Their outputs are almost exclusively sold to the health treatment industries (Table 3(a), column 1). A small amount of health services is sold to the representative household (Table 3(b), column 1); like the sales of health treatments, these sales are also made at prices that receive a 65% subsidy.

4.1.2 The non-health sectors

MONASH-Health also contains d (=1,...,24) non-health sectors; Table 3 presents data on these sectors as broad aggregates. The non-health sectors use their own outputs as inputs as well as primary factors; primary industries also use land as a factor of production. In contrast to the health services sectors, non-health firms' outputs can be sold to other firms, capital creators (for investment), the representative household, the government, or exported (Table 3(b)).

Table 3. Sales structure in MONASH-Health (2010 $A billion)

	(1)	(2)	(3)	(4)	(5)	
			(a) Sales to industries			
	Health treatments	Health services	Primary industries	Secondary industries	Tertiary industries	**Total[a]**
Health treatments	0	1	0	1	1	**3**
Health services	49	1	0	1	1	**53**
Primary products	0	0	23	74	17	**114**
Manufacturing	0	4	19	92	183	**298**
Services	0	8	17	54	569	**648**
Primary factors	0	40	96	110	804	**1050**
Total[a]	*49*	*54*	*155*	*331*	*1575*	***2166***
			(b) Sales to final demand			
	Consumption	Investment	Government	Other[b]	Exports	**Total[a]**
Health treatments	45	0	0	0	2	**47**
Health services	4	0	0	0	0	**4**
Primary products	13	8	1	4	71	**98**
Manufacturing	71	17	0	1	90	**179**
Services	357	185	174	196	51	**963**
Total[a]	*491*	*210*	*175*	*200*	*214*	***1291***

[a] Totals may not sum due to rounding. [b] Sum of (i) change in stocks and (ii) margins sales.

4.2 Model theory

The model can be represented as

$$F_m(\mathbf{Y_t}) = \mathbf{0}, \tag{5}$$

where $\mathbf{Y_t}$ is the vector of p model variables at time t, $\mathbf{0}$ is the $p \times 1$ null vector and F_m are m differentiable and continuous functions. Behavioural relationships (e.g., production and utility functions), equilibrium conditions (e.g., market clearing and zero pure profits) and definitional relationships are imposed via (5). The p variables are divided into two mutually exclusive lists, e (exogenous) and $(p-e)$ (endogenous). The values of all endogenous variables in (5) are equilibrium values; any perturbation of the exogenous variables will lead to new equilibrium values for all endogenous variables. The values of all model variables are calibrated using the data described in Sections 4.1.1 and 4.1.2. We can calculate the change in the equilibrium values of the endogenous variables due to a change in any of the exogenous variables by totally differentiating each equation in (5) giving a system of linear homogeneous equations, i.e.,

$$\nabla F_m\left(dY_t\left(\mathbf{X}\right), dY_t\left(\mathbf{N}\right)\right) = \mathbf{0}, \tag{6}$$

where ∇F_m is a vector of first-order partial derivatives of F_m, $dX_t\left(\mathbf{X}\right)$ is the vector of changes in the exogenous variables, and $dY_t\left(\mathbf{N}\right)$ is the vector of changes in the endogenous variables. Thus, (6) is an example of displacement analysis (see Dixon et al. 1980, pp. 21–23). (6) can be compactly written in matrix form as

$$A\boldsymbol{v} = \mathbf{0}, \tag{7}$$

where A is an $m \times p$ matrix of coefficients, and $\boldsymbol{v}$ is a vector of $p \times 1$ changes (or percentage changes) in model variables. Many of the functions underlying (7) (i.e., equations (5)) are highly nonlinear. Writing the equation system like (7) allows us to avoid finding the explicit forms for the nonlinear functions. It also minimises computational burdens as (7) is a derivative form of the underlying nonlinear functions of the model. Solving the model in derivative form follows the method pioneered by Johansen (1960). Although (7) is of linear form, accurate solutions are generated by applying multistep solution procedures.[5] Our presentation below of the model equation system follows (7) by being in percentage-change form.

4.2.1 Production structure

All industries are treated in a fashion that is typical of CGE models (e.g., Francois and Reinert 1997). There is a representative firm for each sector and it employs constant-returns-to-scale (CRTS) technology, and it takes the prices of all inputs as given in minimising costs. Each firm potentially uses primary factors and intermediate inputs in production in three nested production functions; the actual usage of inputs by industries is as described in Sections 4.1.1 and 4.1.2 and represented in Table 3(a).

At level 1, the *i* (=1,…,48) industries decide on the (percentage change in) their use of the *k* (=1,…,48) intermediate inputs q_{ki}^I using Leontief production technology:

$$q_{ki}^I = q_i + a_{ki}^I; \tag{8}$$

[5] See Dixon and Rimmer (2002), pp. 113–18, for more details. The model is solved using the multistep algorithms available in the GEMPACK economic modelling software (Harrison and Pearson, 1996).

where q_i is (the percentage change in) the *i*-th industry's activity level, and a_{ki}^I is technical change augmenting the *k*-th intermediate input. At this level, firms also decide on their demand for the primary factor composite q_i^F (i.e., an aggregate of land, labour and capital) using Leontief production technology:

$$q_i^F = q_i + a_i^F ; \tag{9}$$

where a_i^F is technical change augmenting the use of all primary factors. Representing each industry's demand for intermediate inputs and the primary factor composite using Leontief technology fixes these demands as a share of the industry's activity level, unless there is a change in the underlying production technology.

At level 2, firms decide on their use of the *k* intermediate inputs by source *r* (= domestic, foreign) q_{kir}^I using CES (constant elasticity of substitution) production technology:

$$q_{kir}^I = q_{ki}^I - \sigma_k \left(p_{kir}^I - p_{ki}^I \right); \tag{10}$$

where σ_k is the CES between intermediate inputs from different sources, and $p_{kir}^I \left(p_{ki}^I \right)$ is the price of individual (average) intermediate inputs from source *r* (all sources). The values for σ_k are zero for all intermediate inputs except human pharmaceuticals, for which it is set at 2.[6] At this level, firms also decide on their demand for the *b* (= land, labour, capital) primary factors of production q_{bi}^F using CES production technology:

$$q_{bi}^F = q_i^F - \tau \left(p_{bi}^F - p_i^F \right); \tag{11}$$

where $\tau \left(= 0.5\right)$ is the CES between any pair of primary factors, and $p_{bi}^F \left(p_i^F \right)$ is the individual (average) price of primary factors. Representing industry demands for intermediate inputs (by source) and individual primary factors using CES technology fixes these demands as a share of composite demands for intermediate inputs and primary factors, unless there is a change in relative prices.

At level 3, firms decide on their use of the *n* (=8) labour types (occupations) q_{ni}^L using CES production technology:

$$q_{ni}^L = q_{bi}^F - \upsilon \left(p_{ni}^L - p_{bi}^F \right),\ b = \text{labour}, \tag{12}$$

where $\upsilon \left(= 0.35\right)$ is the CES between any pair of labour types, and $p_{ni}^L \left(p_{bi}^L \right)$ is the individual (average) wage rate paid by producers.

[6] Unless otherwise specified, all parameter values are taken from the MONASH model (Dixon and Rimmer, 2002).

4.2.2 Consumer demand

In general, (the percentage change in) household demand for the *i* (= *j*+*c*+*d* =48) goods q_i^H is represented by

$$q_i^H - w = \varepsilon_i \left(v^H - b\right) + \sum_{g=1}^{48} \eta_{ig} p_g^H + a_i^H - a^H \; ; \tag{13}$$

where w is the number of households, v^H is aggregate household expenditure, ε_j is the expenditure elasticity of demand for *i*-th good, η_{ig} is the price elasticity of demand for good *i* with respect to good *g* (=1,...,48), a_i^H represents household tastes for good *i*, and a^H is an average of a_i^H weighted by budget shares. We assume household preferences are described by a Klein-Rubin utility function and thus we set the elasticities in (13) accordingly. This gives expenditure elasticities that range between 0 and 1.35, and own-price elasticities that range between -0.84 and -0.27. Representing household demand as in (13) means that household demand for good *i* is mainly driven by expenditure and substitution effects, but also by changes in household tastes.

For a subset of the *i* goods, i.e., the *c* health services and *d* non-health goods, household tastes a_{c+d}^H are set as exogenous and consumer demand q_{c+d}^H is a function of expenditure and substitution effects. For the subset of *j* health treatments, we recognise that some of these are likely to have zero demand even at a zero price if people are not ill. But, generally, this is not true as people also demand health treatments for preventions (e.g., health check ups, preventative drug use, and screening for risk factors). To handle this behaviour, we set household tastes in (13) as endogenous and consumer demand is set as exogenous and follows forecasts that have been developed from Australian Institute of Health and Welfare data outlining expected future demand for individual treatments (Begg et al., 2007). These demands are then assumed to be met by suppliers via market-clearing conditions. In reality, demands for health treatments are usually rationed (usually via queuing), either due to funding restrictions or capacity constraints, leading to lower utility for households due to time costs and the disutility of delayed treatments. With this representation, unmet (or excess) demand for a given health treatment will raise its price. A higher price will reduce utility via lower real income, *ceteris paribus*. Thus, while this representation reflects some of the utility effects in actual health care markets further work is required to improve it. Regardless, we do not feel this representation affects the applicability of the model to assessing the wider effects of health status changes associated with disease prevention.

Like representative firms, the representative household allocates its demand for non-health treatments $\left(q^{H}_{c+d}\right)$ across domestically-produced and imported goods via a CES function.

4.3 Dynamic mechanisms

MONASH-Health includes three types of dynamic mechanisms: capital accumulation; liability accumulation; and lagged adjustment processes. Capital accumulation is specified separately for each industry. An industry's capital stock at the start of year *t*+1 is its capital at the start of year *t* plus its investment during year *t* minus depreciation. Investment during year *t* is determined as a positive function of the expected rate of return on the industry's capital. Liability accumulation is specified for the public sector and foreign accounts. Public sector liability at the start of year *t*+1 is public sector liability at the start of year *t* plus the public sector deficit incurred during year *t*. Net foreign liabilities at the start of year *t*+1 are net foreign liabilities at the start of year *t* plus the current account deficit in year *t* plus the effects of revaluations of assets and liabilities caused by changes in price levels and the exchange rate. Lagged adjustment processes include those already described for wage adjustment (Section 3.3) and the gradual elimination of differences in rates of return across industries.

4.4 Model solution

In a MONASH-Health simulation, we run the model twice to create the 'baseline' and 'policy' runs. The baseline is intended to be a plausible (or business-as-usual) forecast while the policy run generates deviations away from the baseline. For the non-health treatment sectors, the baseline incorporates trends in industry technologies, household preferences, trade and demographic variables.[7] Exogenous variables in the baseline include the consumer price index, population and world prices (i.e., ex-duty prices of imports). Their paths are set in accordance with forecasts made by expert forecasting groups.[8] Exports are endogenous and respond to domestic prices in foreign currency terms. Thus, the terms of trade are endogenous and the economy is treated as 'almost small'. Aggregate household expenditure moves with household disposable income and household wealth. Aggregate real government expenditure moves with real GDP. Aggregate labour supply is a function of population, the real wage and real household wealth.

---

[7] See Dixon and Rimmer (2002), p.38, for further details.

[8] The Reserve Bank of Australia, the Australian Bureau of Statistics, and the International Monetary Fund.

In the policy simulation, all exogenous variables have the values they had in the baseline with the exception of the variables of interest. Comparison of results from the policy and baseline simulations then gives the effects of moving the variables of interest away from their baseline values. For the present study, the baseline and policy runs differ with regard to the values given to exogenous variables representing changes in transition across health statuses of the workforce. We interpret the differences between the results in the baseline and the policy runs as the effects of changes in health status transitions.

5. An illustrative application of MONASH-Health

Here we explore the effects of improving the average health status of the Australian workforce and how this might affect the labour market, the macroeconomy and sectoral outputs. We conduct two simulations.

Simulation 1: reducing the rate of health decline for older workers, A49-60

In the first simulation, we compute the effects of an improvement in the health status of people in age group A49-60. We assume that 10% of all A49-60 people with low health statuses (H4 and H5) experience a one status improvement in their health transition.
This means that:

- 10% of (A49-60, H4) people who were destined to become H5 in the next period instead become H4;
- 10% of (A49-60, H4) people who were destined to become H4 in the next period instead become H3;
- 10% of (A49-60, H4) people who were destined to become H3 in the next period instead become H2;
- 10% of (A49-60, H4) people who were destined to become H2 in the next period instead become H1;

and

- 10% of (A49-60, H5) people who were destined to become H5 in the next period instead become H4;
- 10% of the (A49-60, H5) people who were destined to become H4 in the next period instead become H3;
- 10% of the (A49-60, H5) people who were destined to become H3 in the next period instead become H2;

- 10% of (A49-60, H5) people who were destined to become H2 in the next period instead become H1.

The changes in health transition are applied by shocking $T(b,i,c,a,h)$ in equation (1). We assume that this change is permanent and occurs in 2011.

Simulation 2: reducing the rate of health decline for younger workers, A29-38

In the second simulation, we compute the effects of an improvement in the health status of people in the age group A29-38. We assume that 10% of all A29-38 people with low health statuses (H4 and H5) experience a one status improvement in their health transition in the same way as that described for A49-60 people in simulation 1. We also assume that this change is permanent and occurs in 2011.

The choice of an improvement in health status for 10% of those in fair or poor health is illustrative only and does not correspond to any particular health improvement or illness prevention strategy. However, our choice it realistic insofar as there are significant numbers of people with poor or fair health who have preventable chronic diseases. For example, in the 2007-08 Australian National Health Survey 17% of individuals over the age of 18 years report being in fair or poor health (ABS, 2010). Of those with fair or poor health, 21% have hypertensive disease (high blood pressure) as a current long term condition, and 43% report having one or more of the broader group of conditions relating to the cardiovascular system. It is also worth noting that over a third of people with hypertension or cardiovascular disease (36%) report having fair or poor health, while 58% of those with angina have fair or poor health. Clearly, programs to address the prevention of cardiovascular disease have the potential to have a major impact on health status, particularly in the older age groups. Thus, the kind of intervention modelled here, that reduces the rate of health decline of 10% of those in fair or poor health, is substantial and would be equivalent to improving the health of around 17% of those who currently have chronic hypertension or 10% of those with cardiovascular disease.

5.1 The effect on categories of workers at the start of 2011

The number of people in each category at the start of 2011, $CAT_{2011}(a,h,c)$ in equation (1), is a function of $T(b,i,c,a,h)$ and $ACT_{2010}(b,i,c)$. Table 4(a) presents the movements in A49-60 workers across health statuses in simulation 1; this is the change in $CAT_t(a,h,c)$, a = A49-60, from 2010 to 2011. We see that about 19,000 A49-60 workers move from H4-H5 to H1-H3, of which about 63% are employed. Table 4(b) presents the movements in A29-38 workers across health statuses in simulation 2. About 12,000 A29-38 workers move from H4-H5 to H1-H3; in contrast to simulation 1, a larger majority of A29-38 workers who move are employed (about 86% cf. 63%) reflecting relatively higher employment rates of A29-38 workers who are H4-H5. Although A29-38 workers represent about 20% of the workforce compared with 16% for A49-60 workers, many more A49-60 workers hold health statuses H4-H5 (19%) than do A29-38 workers (11%). Thus, the ratio of A29-38 to A49-60 workers who move from H4-H5 to H1-H3 is only 0.62 (=12,074/19,323).

Table 4. Effects on categories of workers by health status at the beginning of 2011

Workforce status	H1	H2	H3	*Subtotal (H1-H3)*	H4	H5	*Subtotal (H4-H5)*	Total
				(a) Simulation 1: A49-60 workers (persons)				
Employed	1212	6177	4751	*12140*	-9126	-3014	*-12140*	0
Unemployed	129	2170	4884	*7183*	-3504	-3680	*-7183*	0
Total	1341	8347	9635	*19323*	-12629	-6694	*-19323*	0
				(b) Simulation 2: A29-38 workers (persons)				
Employed	2140	6348	1961	*10449*	-8960	-1490	*-10450*	0
Unemployed	217	773	633	*1625*	-1083	-541	*-1624*	0
Total	2358	7121	2595	*12074*	-10043	-2031	*-12074*	0
				(c) Simulation 1: A49-60 workers (percentage change)				
Employed	0.91	0.98	0.66	*0.82*	-3.85	-7.64	*-4.39*	
Unemployed	0.62	2.11	2.75	*2.38*	-3.09	-9.16	*-4.68*	
Total	0.87	1.14	1.07	*1.08*	-3.60	-8.41	*-4.49*	0.00
				(d) Simulation 2: A29-38 workers (percentage change)				
Employed	0.67	0.57	0.21	*0.44*	-3.83	-5.38	*-4.00*	
Unemployed	0.77	0.84	0.72	*0.78*	-3.04	-6.73	*-3.72*	
Total	0.68	0.59	0.25	*0.47*	-3.73	-5.68	*-3.96*	0.00

Source: MONASH-Health simulation.

Although the total size of the workforce does not change initially, the distribution of the workforce is altered towards health statuses H1-H3 for A49-60 and A29-38 workers. With less A49-60 workers in H1-H3 compared to A29-38 workers in H1-H3 (81% cf. 89%) in 2010, the simulated movements lead to bigger proportional increases in A49-60 workers in H1-H3 (1.08%) compared to A29-38 workers (0.47%): see Table 4(c) and (d). The increase is particularly strong for unemployed A49-60 workers in H1-H3, reflecting the high unemployment rates for A49-60 workers in H4-H5.

5.2 The effect on worker activities in 2011: labour supply

The increases in A49-60 and A29-38 workers in categories H1-H3 at the start of 2011 will lead to increases in offers to work (i.e., labour supply) for all occupations via equation (3). Nevertheless, as the increases in H1-H3 categories are bigger for A49-60 workers than for A29-

38 workers, A49-60 workers increase their offers to work by more for all occupations (Table 5, columns 1 and 4). For example, A49-60/H1-H3 workers increase their labour supply by about 1% for all occupations, whereas A29-38/H1-H3 workers increase their labour supply by about 0.45%.

The decreases in A49-60 and A29-38 workers in categories H4-H5 at the start of 2011 will also lead to decreases in labour supply for all occupations via equation (3); these decreases average around 4%. Considering the increases (H1-H3) and decreases (H4-H5) in labour supply for A49-60 and A29-38 workers, overall labour supply from A49-60 workers rises by about 0.1% but by only 0.01% for A29-38 workers.

Table 5. Effects on labour supply in 2011 (percentage change)

Occupation[a]	Simulation 1: A49-60 workers			Simulation 2: A29-38 workers		
	(1)	(2)	(3)	(4)	(5)	(6)
	H1-H3	H4-H5	Total	H1-H3	H4-H5	Total
1. Managers	0.97	-4.33	0.11	0.46	-3.99	0.01
2. Professionals	0.99	-4.42	0.11	0.47	-4.07	0.01
3. Associate Profess	0.99	-4.40	0.11	0.47	-4.05	0.01
4. Tradespersons	0.95	-4.17	0.11	0.45	-3.88	0.01
5. Advanced Clerical	0.99	-4.42	0.11	0.47	-4.11	0.01
6. Intermed Clerical	0.97	-4.32	0.11	0.46	-4.00	0.01
7. Intermed Production	0.91	-3.99	0.11	0.43	-3.73	0.01
8. Elementary Clerical	0.97	-4.20	0.12	0.45	-3.88	0.01
9. Labourers	0.95	-4.17	0.12	0.45	-3.88	0.01

Source: MONASH-Health simulation.

[a] 1. Managers and Administrators; 2. Professionals; 3. Associate Professionals; 4. Tradespersons and related workers; 5. Advanced clerical and service workers; 6. Intermediate clerical, sales and service workers; 7. Intermediate production and transport workers; 8. Elementary clerical, sales and service workers; 9. Labourers and related workers.

5.3 The effect on real wage rates and labour demand in 2011

The effects on labour supply for all workers in 2011 are shown in Table 6. In simulation 1, labour supply increases by about 0.16% for all occupations; in simulation 2, labour supply increases by about 0.002%. These differences in labour supply response reflect the relative changes in offers to work by A49-60 workers (for simulation 1) and A29-38 workers (for simulation 2) explained earlier; workers in other age groups do not respond in 2011. At initial real wage rates, the increases in labour supply lead to an excess supply of labour. As real wage rates are assumed to adjust sluggishly to disequilibrium in the labour market via (4), the excess supply of labour will drive down real wage rates but not enough to clear the labour market. Lower wage rates induce firms to expand their labour demand. In simulation 1, labour demand expands by about 0.006% for all occupations. In simulation 2, labour demand expands by

0.001% reflecting the much smaller labour supply response: 0.002% for all occupations. Hence, real wage rates also fall by much less in simulation 2.

Table 6. Labour market effects in 2011 (percentage change)

Occupation[a]	Simulation 1			Simulation 2		
	Labour supply	Real wage rate	Labour demand	Labour supply	Real wage rate	Labour demand
1. Managers	0.016	-0.006	0.005	0.002	-0.001	0.001
2. Professionals	0.016	-0.006	0.004	0.002	-0.001	0.001
3. Associate Profess	0.016	-0.006	0.004	0.002	-0.001	0.001
4. Tradespersons	0.016	-0.006	0.005	0.002	-0.001	0.001
5. Advanced Clerical	0.015	-0.005	0.004	0.002	-0.001	0.001
6. Intermed Clerical	0.016	-0.006	0.004	0.002	-0.001	0.001
7. Intermed Production	0.017	-0.006	0.006	0.002	-0.001	0.001
8. Elementary Clerical	0.015	-0.006	0.004	0.002	-0.001	0.001
9. Labourers	0.016	-0.005	0.005	0.002	-0.001	0.001

Source: MONASH-Health simulation.

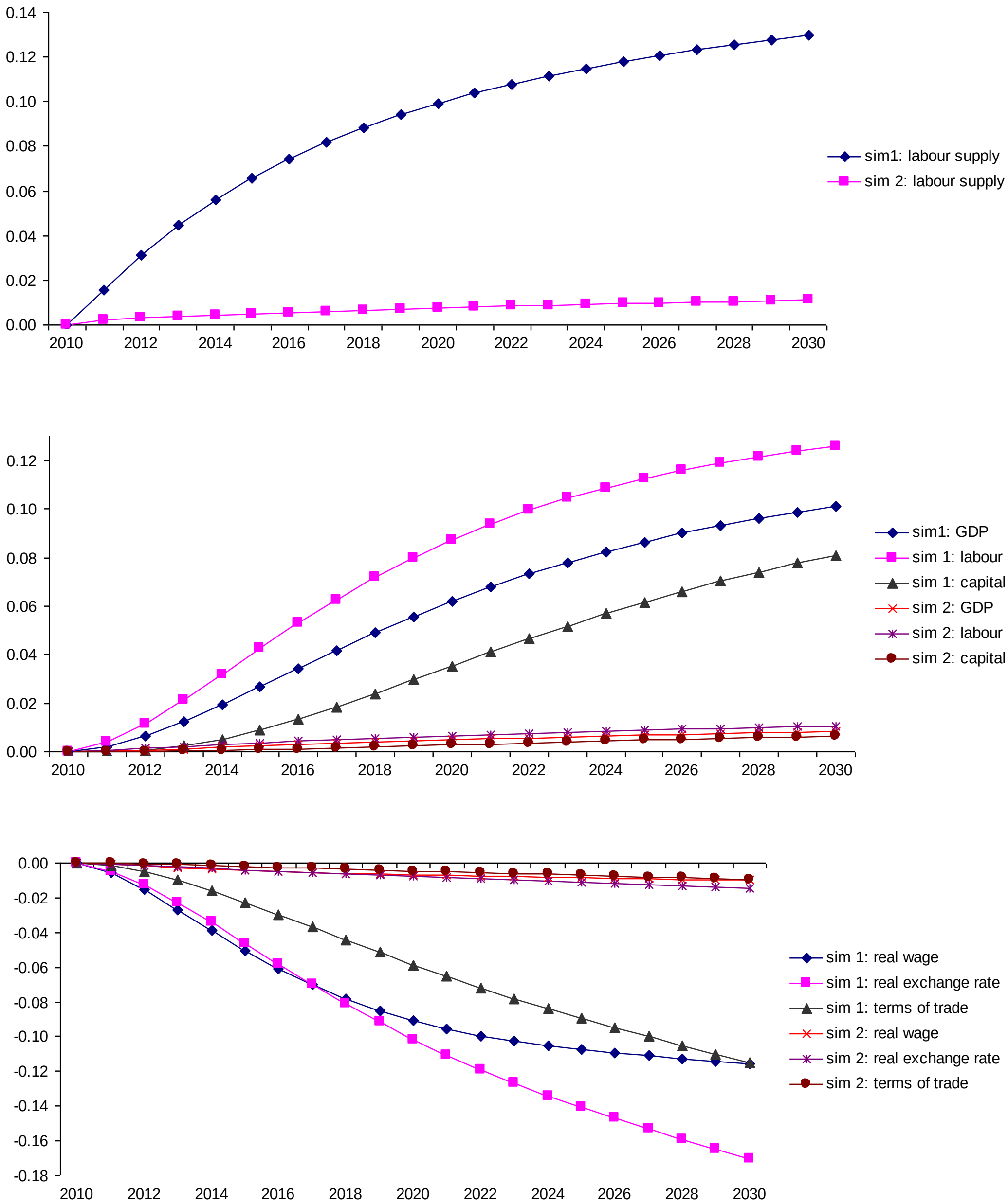
[a] 1. Managers and Administrators; 2. Professionals; 3. Associate Professionals; 4. Tradespersons and related workers; 5. Advanced clerical and service workers; 6. Intermediate clerical, sales and service workers; 7. Intermediate production and transport workers; 8. Elementary clerical, sales and service workers; 9. Labourers and related workers.

5.4 The macroeconomic effects to 2030

Figure 4 shows the labour supply responses for the two simulations to 2030. Simulation 1 shows an increase of 0.13% and simulation 2 an increase of 0.01%; these differences reflect the short-run effects explained above for 2011 but the absolute magnitudes are much larger. This reflects the permanent nature of the increased transitions to higher health statuses in each simulation. The higher transitions to health statuses H1-H3 lead to increased workforce participation well beyond 2011. For simulation 1, the increase in long-run labour supply is much greater than in simulation 2, as in simulation 1 there is a steep increase in work participation rates by A49-60 workers as they move from health statuses H4-H5 into health statuses H1-H3 (see Figure 2); this is less true for A29-38 workers. That is, work force participation of A49-60 people is highly sensitive to health status compared to A29-38 people.

Figure 4 also shows labour supply increasing by a decreasing rate beyond 2011 for both simulations. This partly reflects the life-stage of workers whose health transitions are improved in each simulation: both A49-60 and A29-38 workers who are moved from H4-H5 to H1-H3 are young enough that they will continue to have positive effects, but of differing magnitudes, on labour supply as they age and move to higher age categories. Nevertheless, as these workers age they eventually leave the workforce or die. Hence, their effect on labour supply will decrease over the very long-run.

Figure 4. Macroeconomic effects (%)



The long-run increase in labour supply approximates the long-run increase in labour demand in each simulation: 0.13% in simulation 1 and 0.01% in simulation 2 (Figure 4). The increase in labour usage also leads to increased capital usage but the increase in capital usage is smaller than the increase in labour usage: 0.08% in simulation 1 and 0.006% in simulation 2. Thus, real GDP expands by less than labour usage: 0.1% in simulation 1 and 0.008% in simulation 2. Further, as labour usage increases by more than capital usage in both simulations, the capital-labour ratio falls and, via the factor-price frontier,[9] raises the return to capital relative to labour.

The fall in the real wage induced by the expansion in labour supply reduces the cost of domestic production and, hence, domestic price levels. Lower domestic prices increase demand for exports and import-competing domestic goods at the initial real exchange rate. As the consumer price index is the numeraire, it cannot fall to reflect the fall in domestic prices. Instead, the nominal exchange rate depreciates to accommodate the fall in domestic prices; thus, the price of domestic goods falls relative to the price of imported goods in domestic currency terms and this is represented in Figure 4 as a real exchange rate depreciation. The depreciation in the real exchange rate in each simulation is proportional to the increased labour supply and lower real wage: 0.17% in simulation 1 and 0.014% in simulation 2. With the price of imported goods rising strongly in domestic currency terms (0.14% in simulation 1; 0.012% in simulation 2), the terms of trade fall in both simulations. Although not presented, the effects on the government budget are positive (i.e., the budget deficit falls relative to GDP) but negligible.

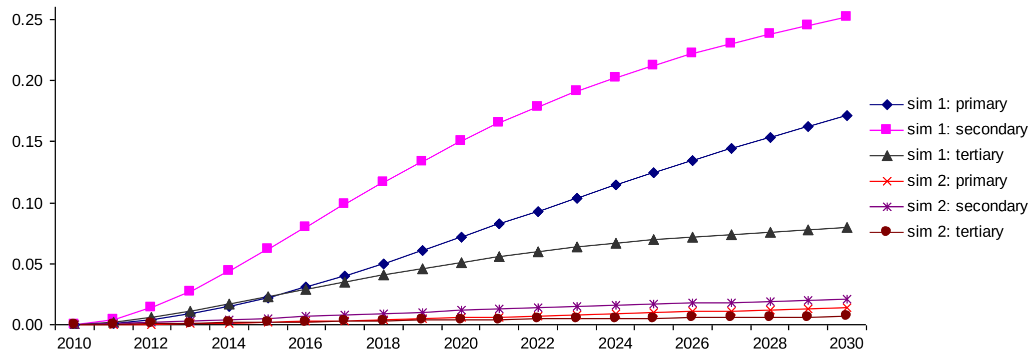
5.5 The microeconomic effects to 2030

In both simulations, the real exchange rate depreciation benefits all sectors but traded goods sectors (primary, secondary) benefit much more than the nontraded sectors (tertiary). For simulation 1, Figure 5 shows secondary sectors (i.e., manufacturing) expand by 0.25% and primary sectors (i.e., agriculture, mining) expand by 0.17% to 2030, whereas tertiary sectors (i.e., services) expand by only 0.08% to 2030. The relative changes for sectoral output are similar in simulation 2 but the absolute magnitudes are much smaller. The stronger expansion in traded sectors reflects the more elastic demand curves they face in world markets when the cost of domestic production falls. Of the traded sectors, secondary industries benefit more from the increased labour supply as they are more reliant on labour inputs relative to primary industries. So as labour supply expands and real wage rates fall, production costs for secondary industries fall by more than production costs for primary industries.

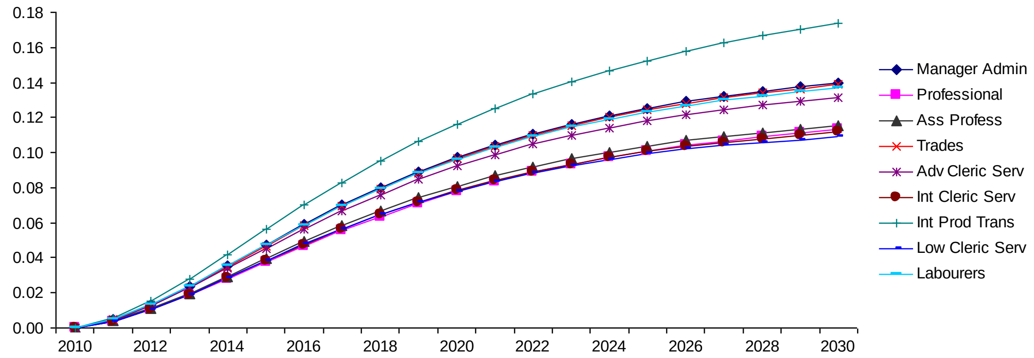
[9] See Samuelson (1962).

Figure 5. Microeconomic effects (%)

(a) Industry value added



(b) Occupational demands: simulation 1



(c) Occupational demands: simulation 2

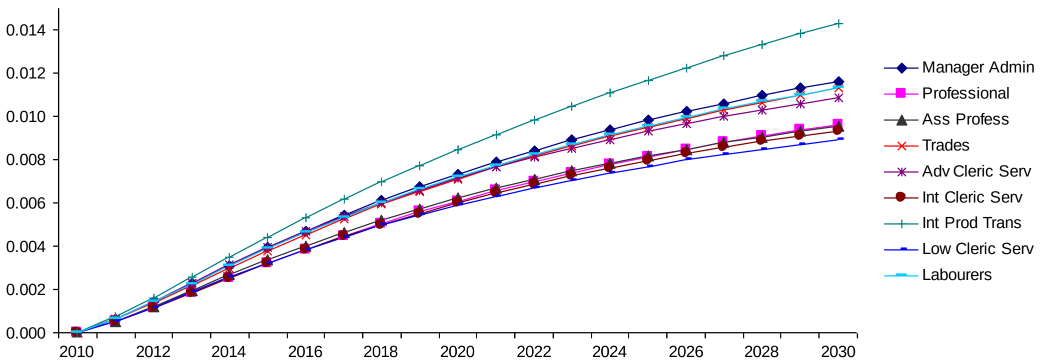


Figure 5 also shows the effects on occupational demands in each simulation. In both simulations, demand for the *Intermediate production and transport workers* grows by more than for other occupations. Smaller increases in demand are observed for *Managers and administrators*, *Tradespersons and related workers*, and *Labourers and related workers*. The smallest increases in demand are observed for *Professionals*, *Associate professionals*, and *Clerical, sales and service workers*. The relative growth in occupational demands reflects the relative output growth for the primary, secondary and tertiary sectors. Thus, *Intermediate production and transport workers* are chiefly employed by the secondary industries, whereas

Professionals and *Clerical, sales and service workers* are chiefly employed by the tertiary sectors. It should be noted that the differences in effects on labour demands across occupations are not very large. For example, in simulation 1 the highest growth is observed for *Intermediate production and transport workers* (0.07%) whereas the lowest growth is observed for *Elementary clerical, sales and service workers* (0.04%).

The improvements in health statuses for the age groups A49-60 and A29-38 do not favour the supply of labour from any particular occupation. This reflects our assumption that health transitions only vary between working and non-working people, they do not vary by occupation. It also reflects the assumption that industries do not distinguish labour inputs by age and health status. Thus, when labour supply increases, relative wage rates across occupations largely move together in each simulation and so labour demands do not vary dramatically across occupations.

6. Conclusion

We develop an economywide model that links health and workforce participation, or labour supply, in order to analyse the wider effects of chronic disease (or ill health), with reference to evaluating programs that reduce or prevent chronic disease, or health promotion (i.e., lifestyle) programs. In our model the link between health and labour supply is represented by a labour market specification that identifies age- and health-specific participation rates for labour market participants. Our approach is dynamic and represents movements across health states through time based on empirical transitions taken from longitudinal survey data. The labour market specification is embedded within a dynamic, multisectoral computable general equilibrium model of the Australian economy that includes a detailed representation of the health sector.

We apply the model to analyse the economywide effects of permanent reductions in the rate of health decline for younger (29-38 years) and older (49-60 years) workers; these changes mimic permanently lower prevalence of chronic diseases within these population sub-groups. Our findings indicate that health improvements for 10% of the unhealthiest older workers can have strong macroeconomic effects; we estimate that employment can rise by 0.13% and real GDP by 0.1% over the period 2011-2030. Similar improvements in health status for younger workers lead to much smaller effects: we estimate that employment can rise by 0.01% and real GDP by 0.008%. The different magnitudes in the macroeconomic effects reflect the relative labour supply responses for each group of workers. For older workers, the increase in long-run labour supply is much greater than for younger workers as there is a steep increase in workforce participation rates by older workers as they transition from poorer health to better health over time; this is much less true for younger workers. That is, workforce participation of older workers is highly sensitive to health status compared to younger workers. At the sectoral level, traded sectors benefit much more from the increase in labour supply than nontraded sectors, with a consequent improvement in the trade balance and a real depreciation of the exchange rate.

Our results are consistent with the only other study, that we are aware of, that directly incorporates labour productivity or labour supply as an endogenous function of population-wide health within an economywide framework for the UK: Rutten and Reed (2009). They find that a roughly 10% improvement in health status leads to increase in labour supply of between 0.5% and 0.8%; Rutten and Reed (2009) do not report GDP effects.

The key model assumptions on the relationship between health status and employment are also broadly consistent with the literature. For example, the results in Cai (2010, Table 5) suggest that a change in self-assessed health from poor or fair to good health would increase labour force participation by 2-4 percentage points. So, as in our simulations, if 10% of low health status people transition to a higher health status we might predict about a 0.2-0.4 percentage point improvement in labour force participation. Our predicted 0.1% increase for those aged 49-60 suggests that the employment status transition probabilities associated with self-reported health are conservative compared to those predicted by a simultaneous equation econometric model that uses the same Australian HILDA data (Cai, 2010).

Our approach demonstrates the importance of representing the age and health characteristics of labour market participants in order to properly evaluate wider effects of chronic disease. Thus, our results are of interest to health policy makers when deciding on the allocation of budgets across disease prevention or health promotion programs. Our results are also of interest to workforce planners by indicating the relative economywide benefits of improving workforce participation of different sub-groups of the population. Nevertheless, we feel there are two fertile areas of development for the framework presented here. One is to allow industries to distinguish labour inputs by age and health status. This would mean that wage rates would vary by age and health status: this would give a direct mechanism between changes in age- and health-specific labour supply and industry output. Another possible area of development is to link health status and demands for health treatments. Currently, health treatments are exogenous to any changes in health status and the model understates the economic gains from improved health; a wider model would also allow us to consider the full impact of treatment programs alongside disease prevention.

References

Agénor, P-R. (2008), ‘Health and infrastructure in a model of endogenous growth’, *Journal of Macroeconomics*, vol. 30, pp. 1407–22.

ABS (Australian Bureau of Statistics) (2010), *National Health Survey - Confidentialised Unit Record Files, 2007-08*, Cat. No. 4324.0, ABS, Canberra, 27 August.

—— (2011), *Health Expenditure Australia 2009-10*, Health and Welfare Expenditure Series No. 46., Cat. No. HWE 55, AIHW, Canberra.

AIHW (Australian Institute of Health and Welfare) (2004), *Australia's Health 2004*, AIHW, Canberra.

—— (2011), *Health Expenditure Australia 2009-10*, Health and Welfare Expenditure Series No. 46., Cat. No. HWE 55, AIHW, Canberra.

Arndt, C. and Lewis, J.D. (2001), ‘The HIV/AIDS pandemic in South Africa: sectoral impacts and unemployment’, *Journal of International Development*, vol. 13, pp. 427–49.

Bartel, A. and Taubman, P. (1979), ‘Health and labour market success: the role of various diseases’, *Review of Economics and Statistics*, vol. 56, 2–8.

Begg, S. Vos, T., Barker, B., Stevenson, C., Stanley, L. and Lopez, A.D. (2007), *The Burden of Disease and Injury in Australia 2003*, AIHW, Canberra.

Bloom, D.E. and Canning, D. (2000), ‘The health and wealth of nations’, *Science* vol. 287, pp. 1207–09.

Bosello, F., Roson, R. and Tol, R.S.J. (2006), ‘Economy-wide estimates of the implications of climate change: human health’, *Ecological Economics*, vol. 58, 579–91.

Bound, J., Schoenbaum, M., Stinebrickner, T.R. and Waidmann, T. (1999), ‘The dynamic effects of health on the labour force transitions of older workers’, *Labour Economics*, vol. 6, pp. 179–202.

Cai, L. (2010), ‘The relationship between health and labour force participation: evidence from a panel data simultaneous equation model’, *Labour Economics*, vol. 17, 77–90.

Cai, L. and Kalb, G. (2006), ‘Health status and labour force participation: evidence from Australia’, *Health Economics*, vol. 15, pp. 241–61.

Contoyannis, P. and Rice, N. (2001), ‘The impact of health on wages: evidence from the British Household Panel Survey’, *Empirical Economics*, vol. 26, no. 4, pp. 599–622.

Currie, J. and Madrian, B. (1999), ‘Health, health insurance and the labor market’, in Card, D. and Ashenfelter, O. (eds.), *Handbook of Labor Economics*, North Holland, Amsterdam.

Disney, R., Emmerson, C. and Wakefield, M. (2006), ‘Ill health and retirement in Britain: a panel data-based analysis’, *Journal of Health Economics*, vol. 25, no. 4, pp. 621–49.

Dixon, P.B., Bowles, S. and Kendrick, D. (1980), *Notes and Problems in Microeconomic Theory*, North-Holland, Amsterdam.

Dixon, P.B. and Rimmer, M.T. (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: A Practical Guide and Documentation of MONASH*, Contributions to Economic Analysis 256, North-Holland Publishing, Amsterdam.

Dixon, P.B. and Rimmer, M.T., (2003), ‘A new specification of labour supply in the MONASH model with an illustrative application’, *The Australian Economic Review*, vol. 36, no. 1, pp. 22–40.

Francois, J.F. and Reinert, K.A. (1997), *Applied Methods for Trade Policy Analysis: A Handbook*, Cambridge University Press, New York.

Garcia-Gomez, P., Jones, A.M. and Rice, N. (2008), ‘Health effects on labour market exits and entries’, *Health, Econometrics and Data Group Working Paper No. 08/03*, Department of Economics, University of York.

Gershberg, A.I., Grossman, M. and Goldman, F. (2000), ‘Health care capital financing agencies: the intergovernmental roles of quasi-government authorities and the impact on the cost of capital’, *Public Budgeting and Finance*, vol. 20, no. 1, pp. 1–23.

Grossman, M. (1972), ‘On the concept of health capital and the demand for health’, *Journal of Political Economy*, vol. 80, pp. 223–55.

Grossman, M. and Benham, L. (1973), ‘Health, hours and wages’, in Perlman, M. (ed.), *The Economics of Health and Medical Care*, Wiley, New York.

Haan, P. and Myck, M. (2009), ‘Dynamics of health and labor market risks’, *Journal of Health Economics*, vol. 28, no. 6, 1116–125.

Hagan, R., Jones, A.M., and Rice, N. (2006), ‘Health and retirement in Europe’, *Health, Econometrics and Data Group Working Paper No. 06/10,* Department of Economics, University of York.

Haveman, R.H., Wolfe, B., Kreider, B. and Stone, M. (1994), ‘Market work, wages, and men's health’, *Journal of Health Economics*, vol. 13, no. 2, 163–82.

Harrison, W.J. and Pearson, K.R. (1996), ‘Computing solutions for large general equilibrium models using GEMPACK’, *Computational Economics*, vol. 9, no. 2, pp. 83–127.

Johansen, L. (1960), *A Multisectoral Study of Economic Growth*, Contributions to Economic Analysis 21, North-Holland, Amsterdam.

Keogh-Brown, M.R., Wren-Lewis, S., Edmunds, W.J., Beutels, P. and Smith, R.D. (2010), ‘The possible macroeconomic impact on the UK of an influenza pandemic’, *Health Economics,* vol 19, iss. 11, pp. 1345–60.

Lechner, M. and Vazquez-Alvarez, R. (2004), ‘The effect of disability on labour market outcomes in Germany: evidence from matching’, *Centre for Economic Policy Research,* Discussion Paper 4223, London.

Luft, H. (1975), ‘The impact of poor health on earnings’, *Review of Economics and Statistics*, vol. 57, pp. 43–57.

McKibbin, W.J. and Sidorenko, A.A. (2006), *Global Macroeconomic Consequences of Pandemic Influenza,* Lowy Institute for International Policy, February.

Narayan, D., Chambers, R., Shah, M.K. and Petesch, P. (2000), *Voices of the Poor: Crying Out for Change,* Oxford University Press, New York.

Pelkowski, J.M. and Berger, M.C. (2004), ‘The impact of health on employment, wages, and hours worked over the life cycle’, *Quarterly Review of Economics and Finance,* vol. 44, pp. 102–21.

Riphahn, R.T. (1999), ‘Income and employment effects of health shocks: a test case for the German welfare state’, *Journal of Population Economics,* vol. 12, no. 3, pp. 363–89.

Roberts, J., Rice, N. and Jones, A.M. (2006), ‘Sick of work or too sick to work? Evidence on health shocks and early retirement from the BHPS’, *Health, Econometrics and Data Group Working Paper No. 06/13,* Department of Economics, University of York.

Roberts, J., Rice, N. and Jones, A.M. (2008), ‘Early retirement and inequality in Britain and Germany: How important is health?’, *Health, Econometrics and Data Group Working Paper No. 08/27,* Department of Economics, University of York.

Roos, E.L. (2012), *HIV/AIDS and the South African Labour Market: A CGE Analysis*, PhD thesis, Monash University, September.

Rutten, M. and Reed, G. (2009), ‘A comparative analysis of some policy options to reduce rationing in the UK’s NHS: lessons from a general equilibrium model incorporating positive health effects’, *Journal of Health Economics*, vol. 28, pp. 221–33.

Sachs, J. and Malaney, P. (2002), ‘The economic and social burden of malaria’, *Nature,* vol. 415, pp. 680–5.

Samuelson, P.A. (1962), ‘Parable and realism in capital theory: the surrogate production function’, *Review of Economic Studies*, vo. 29, no. 3, pp. 193-206.

Schofield, D.J., Passey, M.E., Earnest, A., Gloor, I.C. and Shrestha, R. (2007), ‘Are we getting healthier as we grow older? Implications for babyboomer labor force participation’, *Annals Of The New York Academy Of Sciences*, vol. 1114, pp. 230–40.

Smith, R.D., Yago, M., Millar, M. and Coast, J. (2005), ‘Assessing the macroeconomic impact of a healthcare problem: the application of computable general equilibrium analysis to antimicrobial disease resistance’, *Journal of Health Economics*, vol. 24, iss. 6, pp. 1055–75.

Summerfield, M., Dunn, R., Freidin, S., Hahn, M., Ittak, P., Kecmanovic, M., Li, N., Macalalad, N., Watson, N., Wilkins, R. and Wooden, M. (2011), *HILDA User Manual – Release 10*, Melbourne Institute of Applied Economic and Social Research, University of Melbourne.

WHO (World Health Organization) (2011), *Global Status Report on Noncommunicable Diseases 2010*, WHO, Geneva.

Zucchelli, E., Harris, A., Jones, A.M. and Rice, N.T. (2010), 'The effects of health shocks on labour market exits: evidence from the HILDA survey', *Australian Journal of Labour Economics*, vol. 13, no. 2, pp. 191-218.